A heuristic method to distinguish horse rider mounts using a single wrist mounted inertial sensor

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Table of Contents

List of figures

List of Tables

List of Illustrations

Attestation of Authorship

I hereby declare that this submission is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person (except where explicitly defined in the acknowledgements), nor material which to a substantial extent has been submitted for the award of any other degree or diploma of a university or other institution of higher learning.

Intellectual Property Rights

Ethics approval

Ethics application 08/47 was approved for a period of three years until 15 May 2011 on 15th May 2008 by the Auckland University of Technology Ethics Committee (AUTEC).

The ethics forms used within this project are included as appendix 8.

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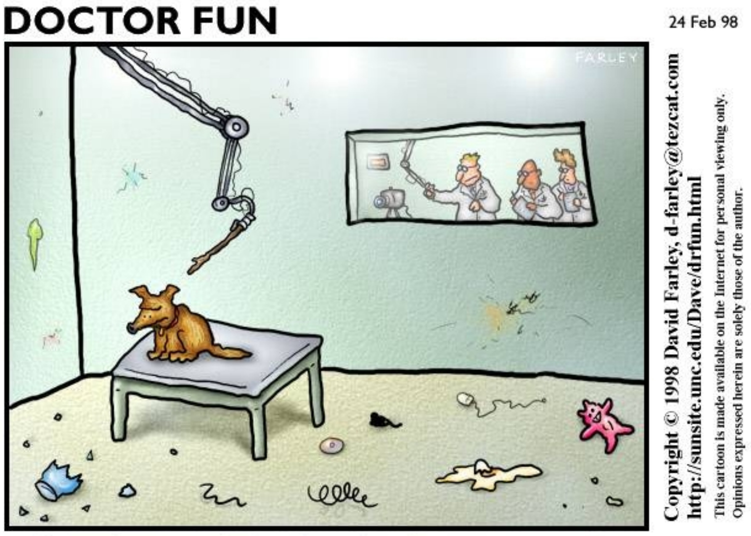
Abstract

A Design Science methodology was used to create a context recognition method for data from a single, wearable inertial sensor. The sensor was worn on riders right wrists. The data was associated with a rider mounting their horse within the traditional European riding style. Data was collected from 20 participants, 2 laboratory and 55 real-life data collection sessions. A manual human pattern matching search method was applied to 2 laboratory and 7 real life datasets during recognition training and two features, one within the accelerometer data and the other within the gyroscope data were identified. The method was evaluated by searching for these two features within 15 alternate datasets. The method was successful in recognising features that could be associated with mounting where riders used a hand-on-cantle mounting technique. The method did not consistently recognise features that could be associated with mounting when riders used a hand-on-front of saddle mounting technique. The researcher concluded that manual heuristic human pattern search and matching methods could be used to distinguish mounting in 11 out of 12 cases where the domain was restricted to hand-on-cantle mounting techniques and that such methods may possibly be generalised to include other mounting techniques and other contexts. The researcher also concluded that a single compound sensor can, in some instances, provide enough information within a restricted domain to enable successful context recognition.



Research continues late into the night at the secret government poke-it-with-a-stick laboratory.

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Chapter 1 – Introduction and Background

Introduction

This chapter discusses the main research objective, shows that this area has not previously been covered in other research, justifies the relevance of this research objective, discusses the basic methodology and explains the background, overview, constraints and main definitions associated with this objective. This is designed to provide an overview that introduces the main ideas and concepts that are expanded upon in the rest of this document.

This research project and thesis are designed to answer the question “Is it possible to distinguish in real life when a horse rider mounts a horse using inertial data captured from a single electronic sensor module worn on the rider's wrist”?

This project forms part of a wider, on-going investigation into the possible utility of electronic sensors as coaching aids for horse riders whilst riding. The project will attempt to create a manual method that is capable of recognising some aspect of the “mount” activity associated with horse riding. The mount activity is a string of actions that are performed by a horse rider as they get on a horse and that forms the starting boundary around riding activities. The terminal boundary for riding activities occurs when the rider dismounts from the horse.

The intention within this research is to attempt to create a manual method for recognising mount activity so that follow-on research can use this as a marker to possibly derive an algorithm from that manual method. The development of a possible algorithmic recognition method is outside of this project and thesis. Any such algorithm that is later instantiated, if at all, will be used to improve the workability of wearable, electronic horse riding training aids and so it is important that both the manual method from this thesis and any future algorithmic method is grounded in data taken from real riding situations. Basing the methods on real data will assist in ensuring that such training aids are workable in real training situations (Foerster, Smeja and Fahrenberg (1999), Bao and Intille (2004) and Ravi, Dandekar, Mysore and Littman (2005)).

Within this project it is sufficient to find a mark or series of marks within the sensor data stream that are both regular enough in shape and occurrence and that occur during the mount phase such that it is possible to conclude that they usually co-occur with mounting and can be assumed to signal that the rider has mounted the horse.

Recognising dismounting is also excluded from this project due to time constraints even though it is also important as the terminal marker of being on a horse.

The goal of producing a useful artefact (the manual method) that will operate upon real or realistic data leads to the choice of Design Science as the research methodology for this project.

Electronic inertial sensors were chosen to capture the data for this project because such sensors are relatively cheap to build, are reasonably accurate at measuring human movement and posture, are small in size with low power requirements and can be interfaced to small, low powered processors that can then be worn on the body of horse riders (and others) without interfering unduly with their riding activities (Benbasat (2000)).

The device is to be wrist mounted because the human wrist is highly expressive of complex human movement, especially movement that involves using our hands. Most forms of mounting a horse would use the hands to assist in mounting. The human wrist also provides a useful mounting area for the device, providing a reasonable sized area for the device to be located in, without compromising most movements that a horse rider would normally undertake while riding or preparing to ride. In addition, the researcher has previously developed a wrist mounted training aid for horse riders and so the successful development of a method for recognising the mount activity could be ported to such a device once the derived algorithm was successfully developed.

While it would be possible to recognise the mount activity more simply and/or reliably by using a sensor mounted on the rider's seat, the saddle or the rider's waist, the ultimate goal is to provide singular, stand-alone training devices that do not need to communicate with other sensors or devices for context data and so the compound sensor that gathers the the context recognition signal for mounting must also act as the sensor that gathers information about rider posture.

Likely sites for usefully monitoring rider posture are: wrists, head, lower back, front thorax, lower leg, foot and seat. This excludes sensor placement on the saddle (not on the rider's body) and the rider's waist. Lower back, front thorax and rider seat are all possible alternative sites to the rider's wrist for mounting a mount-recognition sensor however all these sites have a much more subtle (although highly important) affect on riding and so although they may represent easier sites to recognise mount activity they represent a far harder challenge for posture management. In addition, all these sites, including the wrist, if taken singularly need to be able to recognise mount activity. Lastly, the researcher has both a background in and a special interest in wrist posture for horse riders and so the wrist was chosen as the site for mount-activity recognition within this project.

Being able to recognise complex human movement with a single sensor has utility. A single compound device that is capable of monitoring and recognising complex human movement would allow simpler and cheaper stand-alone devices to be built that assist horse riders, (and by implication) other sports-people and the wider community to train more effectively with appropriate feedback from the devices. In addition, prior research has suggested that a minimum of two or more sensors situated at two or more different sites on the body are required to accurately monitor complex movement in real situations (Kern, Schiele and Schmidt (2003)) and so to do such recognition with a single sensor would be novel.

Prior activity context sensing research utilizing realistic situations has been applied across diverse domains and activities but not, according to research as at February 2007, to the domain of horse riding and so the application of this technology in this area is also novel. Most of the prior research into context sensing within realistic situations has set out to cover a range of situations and activities that might typically be encountered during a person's “normal” day (walking, running, sitting, standing, climbing stairs) and so has not used the person's domain context to provide clues to the activity context. By and large, this prior research has concluded that multiple inertial sensors are needed to reliably recognise activity context in realistic situations.

By restricting the overall domain to that of horse rider training then prior knowledge of the domain can be used to narrow the range of activities that need to be searched across to only those activities normally encountered during horse rider training and by doing this it will simplify the recognition of the mount activity, such that it may be possible to recognise mounting using a single inertial sensor operating on the raw inertial data or some simple derivative of the raw data. This is simpler than either using multiple sensors or using the output from the sensors to develop a model of movements.

Any marker that is found to distinguish “mounting” may well also occur within different domains of human activity. For example a marker may be found that also commonly occurs when climbing ladders or doing “horse” activities during Gymnastics or a number of other areas. However, any such out-of-domain duplication is not an issue and does not reduce the value of any marker found within this research because the intention is to confine the use any marker that is found in this research to devices that are solely applicable within the domain of horse rider training.

It would, however, create reliability issues if any marker found also occurs within other activities normally associated with horse rider training. With this in mind, inertial sensor data will be collected during full rider training sessions during this project, rather than only collecting data during the mount activity. However, the search for duplicate markers within this extended data is proposed to be done during follow on research projects and so is specifically excluded from the scope of this research project.

The researcher has not encountered this explicit use of intended domain to assist in activity context recognition within the research literature although some recent research within realistic situations has targeted particular domains, such as motor vehicle assembly and may have implicitly used domain knowledge to assist in activity recognition.

Being able to recognise the mount activity using a single, on-body sensor will make it possible to simplify the user interface of future wearable, electronic horse riding training aids and that will likely make them easier to use within that domain.

The research question can be described using additional questions that help to further explain why it is useful and relevant to pursue this research and these additional questions help to categorise the prior literature. The following additional questions are answered and expanded on in the Literature Review chapter:

- Why choose a horse rider mounting a horse?
- Why distinguish something? - Context/Activity Sensing
- Why choose to distinguish context in real life?
- Why use inertial data to try to distinguish context?
- Why is the device wrist mounted?
- Why restrict the research to only one device?

Background

Personal Background

The researcher has a background of twelve years of experience assisting his daughters and their horses in equestrian competitions, taking care of his family's horses, learning from some of the best NZ and international riding coaches, coaching riders and undertaking volunteer management of equestrian organisations. Professionally the researcher has a background in technical and management areas within the Information Technology industries in New Zealand, Australia and the United Kingdom.

Within equestrian sport the researcher became particularly involved in managing and mentoring his oldest daughter as she strived for and gained recognition at a national (NZ) level in Young Rider Dressage, culminating in the winning of two national high points awards in 2002 and subsequent selection for the Dressage NZ Young Rider Development Squad in 2003. During this period the researcher had the opportunity to observe his daughter while she trained under noted NZ and international coaches.

Out of these observations came a conviction that the use of some relatively simple wearable electronic sensors and associated feedback mechanisms could substantially assist riders in learning more effectively and quickly, while supporting coaches in achieving their coaching goals. From this idea and subsequent implementations of it came the interest for research into this project.

The Domain of Horse Riding

In the following Definitions section a definition of “ride” is presented that clearly articulates that in order to ride a horse, one must first be mounted on the horse. It is also know from general observation that the vast majority of people, even the vast majority of horse riders do not normally go about their lives, mounted on a horse. It follows then, for most people who are not living their lives already mounted on a horse, that if they wish to ride then they must first mount the horse. Mounting then is a necessary transitory state between being un-mounted and being mounted on the horse.

Generally, but not always, once a rider is mounted they will then proceed to ride the horse and when they are finished, will dismount (another necessary transitory state) and are once again un-mounted. These two transitory states (mounting and dismounting) form boundary conditions around the state called Mounted.

It has been shown that being Mounted is a necessary prerequisite to riding. In a simplified form, mounting and dismounting then also form boundaries around riding. This last statement is not always true but never-the-less it is true often enough that it has some value that will be seen when looked at in more detail later on.

In the same way that most of us do not live our lives already mounted on a horse, horses do not live their lives standing around, saddled up, waiting for people to come along and mount them so that they can ride. In general they spend most of their lives, unsaddled and feeding, usually in a field or in a stable. This means that preparation is usually required before mounting (although not always) and there are post-dismount actions that are usually required as well.

These pre-mounting and post-dismounting actions relate to both the horse and the rider. Leaving the horse aside and concentrating on the rider, then (from personal observation) most riders who train while riding (as opposed to other reasons for riding) will prepare themselves by putting on riding specific clothing such as riding breeches, riding boots, riding gloves and often a riding helmet. Also when finished riding they will take these riding specific clothes off again.

This can summarised as a list of five phases of activity, namely: unmounted preparation, mounting, mounted, dismounting and unmounted-post-mount. These five states will form, for the purposes of this project, the domain of horse riding. References to the Domain of Horse Riding at other points within this document assume that it is these five phases of activities that are being talked about.

Within these five phases, the only phase where a horse rider can actually be riding is the middle, Mounted phase (see later definition of ride in this chapter). It can not be inferred that a rider is riding when they are in the Mounted phase because they may be doing other activities such as speaking on a mobile phone or any of a number of things that riders do when they are mounted on a horse that is not riding. However, it can be reasonably inferred that they aren't riding when in any of the other four phases and there is a reasonable expectation that they will ride (at some stage) while mounted. This point, that a rider can only be riding after they have mounted, is fundamental to the research question. This is depicted in diagrammatic form in the following simple diagram.

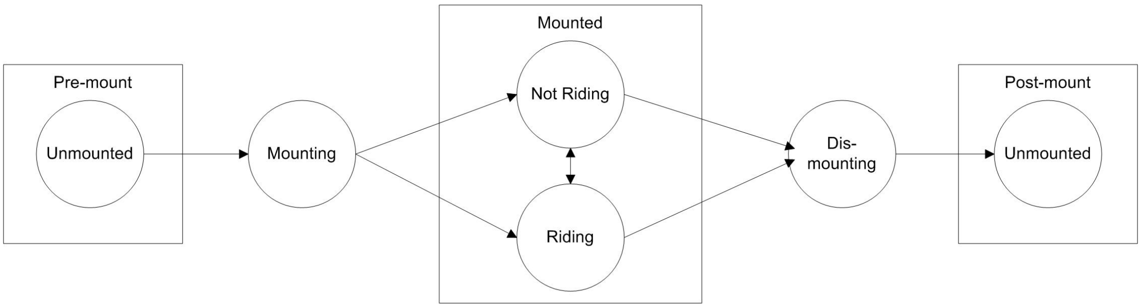


Figure 1: A simple diagram showing the relationship of riding phases

For clarity the simple diagram in figure 1 is NOT a State Transition Diagram. A State Transition Diagram might well be built from this starting point but would contain more information about all the possible state transitions than the diagram shows. For example it is possible to start mounting but not complete this phase and so return to pre-mount (unmounted) without progressing through being mounted. Other transitions are also possible.

Of course there are many other activities associated with keeping and riding horses such as caring for them, buying feed and other products for them, buying equipment, books and a number of other things that could logically be included in the Domain of Horse Riding but these additional activities will be ignored for the purposes of this project.

The importance of the (perhaps seemingly obvious) point that a rider can only ride when mounted is that if a wearable electronic rider coaching aid that is capable of recognising mounting is then introduced into the situation, then that aid can restrict itself to providing feedback to the rider only when the rider is mounted. The benefit of this is that the user interface can become simpler, especially for a rider who may well want to put their attention into riding rather than manipulating a coaching device.

In addition, as a result of the common habit amongst riders of putting on riding specific clothing before mounting and riding and then replacing that clothing after finishing riding and dismounting, it becomes feasible to have riders put on the wearable electronic riding coach when putting on other riding specific clothes and to similarly take the riding coaching aid off again when the other riding specific clothes are taken off after dismounting. This means that the wearable rider coaching aid only needs to search within the activities normally encountered within the Domain of Horse Riding, as defined within this document.

By restricting the range of activities that need to be searched, in this way, it may perhaps become substantially simpler to detect some common marker within the activities associated with mounting. This may allow for recognition of context or sub-context using the data from a single sensor rather than from multiple sensors.

If it is possible to detect the activities of mounting then it may also be possible to detect other activities such as when a rider is actually riding and even possibly detect what specific riding activity they are doing at a particular time while riding. There would thus be additional useful information about the rider's activities or context within the Domain of Horse Riding.

In order to infer that the rider is actually riding rather than doing some other non-riding activity while mounted additional contextual information such as “is the horse moving or standing still?” and “is the rider in a body position that is consistent with riding?” is needed. However, even without these additional contextual triggers, if it is possible to detect mounting and dismounting then it is possible to separate out from the rest of the rider's life the times when she is on a horse from the times when she is not.

A human riding coach knows when the pupil is mounted or not and this is trivial but essential information for the coach. While some riding coaching can be done while the pupil is dismounted, for example via video examples, this is inevitably followed up when the pupil is mounted on the horse. An electronic coach however has no simple way of ascertaining if the pupil is mounted or not unless it:

- always assumes that the pupil is mounted,

- is told specifically by a person involved (perhaps via a switch or menu selection), or

- can somehow work out for itself that the pupil is mounted.

While options one and two are practical alternatives they both have drawbacks associated with them. For example, during earlier unpublished research it was established that a device that always assumed that the person using it was mounted, was effective but inconvenient to use and was considered to be dumb by users when used outside of actual riding situations such as when preparing their horse. Test subjects using this device while they were not riding commented that they thought the device annoying at times because it couldn't tell when it was appropriate to provide feedback to them (when mounted) and when it wasn't (when not mounted). Earlier, unpublished usability research also established that a device that needed to be explicitly told that a rider was mounted was sometimes not turned on simply because the rider didn't turn it on while getting ready to ride but then forgot to turn it on when they were on the horse.

This lead to a premise that a device that could be turned on but that could then work out for itself when the person wearing it was mounted would perhaps have more utility and would usually be considered smart (provided that its predictions were reasonably accurate and its subsequent actions were appropriate), would perhaps be considered more usable and therefore it would be used more and be more effective.

Having a device that can attempt to sense context and then tying that ability into an adaptive user interface doesn't always result in something that is useful or easier to use and so some caution is required here. The Literature Review looks at some prior research in this area but resolving this dilemma is outside the scope of this project. Finding a reliable method for electronically sensing the context *mounted* via recognition of the assumed boundary condition *mounting* would have possible utility and is a non-trivial exercise. This then is a knowledge additive objective of this research.

Overview

This project sets out to capture inertial sensor readings taken from a single unit worn on the wrist of a selection of riders as they go about their normal rider training activities, both unmounted and mounted. In addition to the inertial sensor, the riders are also videoed in such a way that the sensor data can be time synchronised with the video.

The data is then subsequently analysed to see if there are attributes within the sensor data that are common across riders that would enable recognition of when a rider wearing one of these sensors mounts a horse. The area within the sensor data where mounting occurs is established by reference to the video.

Data is collected from as realistic situations as possible within the constraints of the project. This is done because a number of prior researchers that based their recognition methods on data captured during highly structured or artificial laboratory tests discovered that these methods were much less reliable when run against data from real life situations (Foerster, Smeja and Fahrenberg (1999), Bao and Intille (2004) and Ravi, et al. (2005)). Collecting and analysing real world sensor data is likely to result in more robust recognition methods and algorithms, possibly at the expense of not finding common, recognisable factors across the different riders.

Data was collected from a larger number of subjects (20) than many of the earlier researchers in this field and the plan was to collect data from riders from different riding disciplines and with differing ranges of riding skills and experience so as to get a cross-section of real world data. A useful cross-section of rider disciplines and skills was obtained, however, the number of riders and riding sessions were ultimately constrained by the time available to complete the project and by the ability to recruit riders.

Rider instructions were minimised so that the riders acted as they normally would during the data capture process (to retain realism) and flexibility was maintained in terms of where, when and how the data recording sessions were conducted. This need to keep structure to a minimum was one of the factors that pointed towards Design Science as a methodology rather than towards a more highly structured methodology that required more structured data capture.

The field work of building the sensors required for data capture and the resulting data capture sessions were done in Sweden while generously hosted by Professor Mark Smith of the Wireless@KTH research laboratory at KTH university's Kista campus. Professor Smith has extensive teaching and research experience in the area of Context Sensing and offered his services, experience and the resources of his laboratory to assist in building the sensors that were needed for the project together with other key resources such as the video camera, iPaq PDA (used for data logging), computing resources (to render the video), video tapes and other equipment that was used along with important contacts within the Swedish equestrian community. It would not have been possible to complete this project without this assistance.

The data capture sessions generally took place around the greater environs of Stockholm with nine sessions covering three riders also being recorded in Örebro. The possible variety of riders was somewhat restricted by the researcher's lack of local Swedish contacts within the equestrian community and while the overall number of riders was within the expected bounds for the project, selection was limited to those riders who were open enough to volunteer to participate. The researcher is indebted to those riders who did volunteer, for their generosity of time and in many cases their friendship.

Project constraints

This section lists some explicit constraints that apply to this project. Where relevant, these constraints are further expanded in the rest of this document.

Non Technical Constraints

Time: This project is required to be completed within 10.5 months across a 12 months period. The initial plan was to spend 2 months preparing to travel to Sweden, while researching and writing up the literature review and methodology sections; 5 months in Sweden building the sensor, recruiting riders, doing data capture and initial analysis of the sensor and video data; followed by 3.5 months back in New Zealand completing the analysis, drawing conclusions and completing the write up of the thesis.

The plan did not take into account that almost all participants were unavailable for 6 weeks during the Swedish summer holiday break. The sensor build also took longer than anticipated. This resulted in the Swedish visit being extended for an additional month to allow sufficient data to be collected. The data collection phase became shortened and was busier than anticipated. This lead to some errors during data capture. Many Swedish riding establishments were closed during August and a number of potential participants were excluded because they were unavailable during this time.

As a result of the time constraints some areas of research have been excluded even though they were attractive and could have added substantive content to the research.

Experience: The researcher is an “emerging researcher” and so is inexperienced in many aspects of academic research. As a result of this inexperience, a number of things were done in ways that could have been done more effectively and as a result sometimes steps had to be repeated or re-done. On other occasions data was lost. This inexperience further compounded the time constraints.

Resources: The initial total budget for this project was NZ$2,500. This budget was substantially exceeded mostly as a result of the costs of travelling to and living in Sweden for six months. As a result the project was financially constrained and used free or donated resources whenever possible.

The financial constraints added considerable time to any activity that required funding as there was a need to look for free or cheap alternatives before proceeding.

Technical Constraints

Riding style: The research was constrained to include what may be called "traditional European riding". This riding style in New Zealand would be termed English riding and is defined by Wikipedia as a term used within North America, Australia and New Zealand to describe a form of horse back riding seen throughout the world with a number of style variations but that "*all feature a flat English saddle without a deep seat, high cantle or saddle horn .... and is the basic style of riding seen in the various events at the Olympics*" (*English Riding* [Wikipedia], 2009). Within Europe this riding style is simply called "riding" as there is no perceived need to differentiate it from the less popular riding styles. Excluded from this research are Western Riding, Vaulting, Mounted Games and every other riding style except traditional European riding.

This constraint simplifies subject recruitment and data capture. Some riding styles use different shaped saddles (Western Riding) and saddle shape may be a factor in how riders mount. Other riding styles such as Vaulting and Mounted Games have ways of mounting (vaulting directly on to the horse) that are not seen in other riding styles.

In addition, riding is an old sport with strong traditions, including strong traditions about how to mount a horse (see the Literature Review Chapter for a more in-depth discussion). As a result, riding style influences how a rider mounts and strong traditions associated with mounting are expected to produce a higher level of "natural" conformity than may be present in other activities. This should be noted when considering the applicability of the results of this research in other domains of activity.

Riders always mount saddled horses: Data capture is constrained to situations where riders mount a horse that is wearing a saddle. Mounting a horse with a saddle is substantively different from mounting a horse without a saddle.

Most traditional European style riders who are training usually ride a horse wearing a saddle because most competition within the traditional European riding style requires that the competing horse be wearing a saddle. While many riders regardless of riding style also ride without a saddle (bareback) from time to time for a number of reasons, riding tacked up (with a saddle) is more common. This constraint was imposed to simplify data capture and analysis.

This constraint was not explicitly communicated to subjects in any of the preparatory literature because of the desire not to influence riders riding choices. Despite this non-communication, no rider rode without a saddle during any of the data capture sessions. This informally supports our own personal experience and contention that traditional European riders ride with a saddle more commonly than without.

No disabled riders: No disabled riders or riders who always need substantive assistance to mount volunteered to be subjects. Riders who require substantive assistance have different mounting techniques from riders who do not.

However, the data does include riders who used mounting steps, mounting blocks and who had assistance via a “leg up” to mount. These are commonly occurring alternatives for riders especially for riders where there is a substantive difference between the rider height and the horse height, where horses do not stand still while mounting and where riders are older and less athletic and so find it difficult to mount from the ground. This constraint was imposed to simplify data capture and analysis.

Left hand mounts only: This was a formal constraint but was not communicated to participants as a constraint, so as not to influence participants actions and because off-side (right hand side) mounts were not expected. As already noted, European riding has strong traditions and one of its strongest is the left hand mount (explained in detail in the Literature Review chapter). Only one rider, riding an Icelandic horse where there is a tradition of mounting from both sides, did use an off-side (right hand) mount during three of the data capture sessions and these data were subsequently not used.

Real life training: Subjects were specifically asked to “act as you normally would in any other training session” while being recorded during the data capture sessions. Of course, the video camera and attention from the researcher may well have influenced riders to act out of character to some extent but there is no control or allowance for this within the data. It should, however, be considered when looking at how these results might be moved into real world training devices.

A different aspect of this constraint is that most of the rider sessions were normally scheduled training sessions, sometimes with the rider's coach present and giving instructions. As a result, if anything went wrong with the researcher's equipment then the rider training session continued on without a pause and either the researcher dealt with the issue or data was lost. At no stage were riders influenced to repeat actions lost due to faulty equipment except in a limited number of cases by rescheduling completely new data capture sessions. This imposed a strong constraint on the researcher to act conservatively with regard to equipment changes and preparation.

Data was lost as a result of this practise, most often when the researcher had scheduled multiple data capture sessions on the same day and where there was little or no time allowance within that schedule for recovering from problems. Even where there was time, the data capture venues were always at horse specific arenas and sites that were remote from the university and its laboratories and so errors encountered in the field often caused some data loss for the whole day. The researcher did, however, become adept at improvising where this was possible.

Variety of subjects: The original intention was to recruit substantially more than 20 subjects so that it would be possible to chose 20 from amongst that number and control to some extent for sex, age, height and handedness. However, exactly 20 applicants were left after sickness, accident, horse injury, family crises amongst the riders, Summer vacation and drop outs for unknown reasons and so all riders who applied and presented themselves were accepted. In conjunction with the Snowball recruitment techniques this may have skewed the rider sample. This is somewhat mitigated by the publication of a magazine article about the research that brought in ten of the 20 subjects independently of other participants and so the riders weren't completely from a single pool of riders known to each other. Seventeen of the subjects came from the greater Stockholm area and three from Örebro and so there is a geographic skew to the participants.

Sensor: Data collection is constrained to a single, inertial sensor module for reasons that are fundamental to the research question. Two similar but not identical sensors were developed so that there was the opportunity to monitor both the left and right hands of riders to check for handedness of the rider as a factor. The sensors were not identical for financial and time constraint reasons.

Project Scope

The following items are specifically in or out of scope for this project. Out of scope activities are largely defined in that category because of project constraints. Many of the out of scope activities represent excellent opportunities for future research projects.

In Scope

- Overall project management of the research project
- Identification and acquisition of resources needed within the project such as the sensors, video camera, video editor, data visualisation software, video conversion software, data storage, programming compilers/loaders, data transfer facilities, video tapes, batteries & power supplies, on-body sensor mounting facilities, wooden horse, transport and Internet facilities.
- A review of prior research in relevant areas
- A review of possible research methodologies and the choice of one of these
- Design goals for the recognition method
- Design and Development of a method for recognising mounting including modifications made as lessons were learned during usage of the method
- Design and Development of a wrist mounted sensor to collect inertial data including modifications carried out as a result of lessons learned
- Subject recruitment for field trials
- Structured laboratory trial to collect sufficient data to highlight possible areas of commonality between different instances of mounting
- Data collection (video & sensor data) during real rider training sessions that include both the mount activity plus pre-mount, riding and post-mount activity
- File management of video, sensor and field note data
- Conversion of raw video files into smaller and more usable mpeg files

- Visualisation of raw sensor data along with derivatives of that data
- Categorisation of video data by marking the beginning and ending of each mount activity and the marking of the synchronisation movements used to synchronise the video data with the sensor data
- Synchronisation of the raw sensor files with the appropriate video file using synchronisation marks from each data type
- A visual search of the raw and derivative sensor data in the specific area where mounting occurs to identify possible common features that may identify mounting, initially within the laboratory data and extending to the real data
- Evaluating the features and marks found by comparison with other data from mount sequences including a comparison between laboratory mounts and mounts in the real world
- Forming conclusions based on the features and marks found
- Reflecting on the project
- Writing up the project results

Out of Scope

- A programmatic search of the sensor data for feature identification
- The derivation of a recognition algorithm from the recognition method
- A search within the extended sensor data for possible false positives
- A method for recognising dismounting
- Tuning of the sensor data feature considered the best candidate for recognition
- A search across the extended sensor data for other features of interest that may be consistently recognised and that have possible utility such as recognising, horse standing still, walk, trot canter, jump and rider posture while on the horse
- Work to relate the sensor data feature back to specific postures or movements

- Conversion of the raw sensor data into some sort of model of rider movement
- Any form of rider monitoring other than inertial sensor monitoring with a corresponding video record for background frame of activity reference
- Any possible user tests for acceptability of mounting and dismounting as appropriate boundary conditions for riding or user tests for acceptance of the use of context to modify user feedback
- Further real world tests to evaluate the reliability of the recognition method under wider circumstances
- Any form of knowledge transfer to existing or future horse riding training aids other than via this document

Definitions

Context

The Concise Oxford Dictionary (McIntosh, 1964a, p. 263) gives a meaning of *context* as "*Parts that precede or follow a passage & fix its meaning*". This general definition relates to the context of a written passage of text and needs extending for our purposes. In the sense that context is used within this project, it is that which surrounds the thing that is being contextualised and is what gives us (humans) the wider meaning. Chen and Kotz define context within the area of wearable computing as "*the set of environmental states and settings that either determines an application's behavior or in which an application event occurs and is interesting to the user*" (Chen & Kotz, 2000, p. 3). For the purposes of this project, Context is defined as the set of environmental states and settings that help define (give meaning to) an activity or state. That is, "is this rider mounted or not?" helps to give meaning to the activity of horse riding.

Chen and Kotz also differentiate context into active and passive, where active context is where "*an application automatically adapts to discovered context by changing the application's behavior*" (Chen & Kotz, 2000, p. 3). This active context is the ultimate goal in that ideally measuring and providing feedback is only done when the rider is actually mounted. Context is further defined in more detail within the Literature Review chapter as it is a key concept for this project.

Ride & Mount

By definition, in order to ride a horse one must be mounted on the horse. The Concise Oxford Dictionary (McIntosh, 1964b, p. 1073) gives one meaning of *ride* as "*Sit on & be carried by horse etc., go on horseback etc. ..... sit or go or be on something as on a horse especially astride, sit on and manage horse*". Given that in the normal course of everyday events most people are not normally already sitting on or astride a horse then it follows that in order to ride one must first get on the horse. The Concise Oxford Dictionary (McIntosh, 1964c, p. 789) goes on to give one possible meaning of "mount" as "*Get on horse etc., for purpose of riding*". Similarly, when finished riding it is usual to dismount from the horse before going about other activities.

Given that mounting and dismounting form event boundaries around riding then if it is possible to detect a horse rider mounting then there follows a reasonable implication that after mounting they are on the horse and usually remain there until they dismount. Mounting is further defined in more detail and a variety of mounting techniques are discussed in the Literature Review Chapter and in Appendix 1.

Heuristic Method

The Concise Oxford Dictionary defines heuristic method as "*system of education under which the pupil is trained to find out things for himself*" (McIntosh, 1964d, p. 574).

Somewhat more helpfully the Webster's Online Dictionary defines heuristic in a general sense as "*A common sense rule (or set of rules) intended to increase the probability of solving some problem.*" and has a computing specific meaning of "*A rule of thumb, simplification, or educated guess that reduces or limits the search for solutions in domains that are difficult and poorly understood. Unlike algorithms, heuristics do not guarantee optimal, or even feasible, solutions and are often used with no theoretical guarantee.*" (Parker, 2009).

The definition of heuristic method within this project aligns with the Webster's On-line Dictionary's computing definition being "a common sense rule of thumb method that reduces the search for solutions in domains that are difficult".

Chapter 2 – Literature Review

Introduction

This chapter briefly recaps the research question along with some key definitions, then examines current research that contributes to and impacts on the research question via some of the inherent assumptions within the question. This chapter is structured around the alternate questions that were highlighted in the Introduction chapter. This falls into two parts, one covering horse riding aspects and the other covering the technology aspects, finishing with a summary.

In setting out to answer the question “Is it possible to distinguish in real life when a horse rider mounts a horse using inertial data captured from a single electronic sensor module worn on the rider's wrist?” there is a need to understand the contributing aspects of this question in order to answer it satisfactorily and to avoid answering a question that has already been adequately answered elsewhere within the research literature.

The question has two basic contributing components and then within those some sub-components. The first component relates to horse riding and why it might be interesting to distinguish when a horse rider mounts a horse. In essence, the answer to this will be covered in the following sections in more detail, but is because of a desire to understand when a horse rider moves from the state “unmounted” to the state “mounted” while going about their horse riding activities so that feedback from a wearable electronic riding coach can be tailored so that it matches the current state.

The second basic component relates to the technology aspects and they are linked through context (activity) recognition. Context recognition is a fundamental part of Wearable Computing and wearable computing is an area that has grown out of Ubiquitous Computing. In turn, the technology areas link back to riding via wearability and a desire to provide more effective coaching advice associated with what the rider is doing when the advice is given. The earlier definition of Context and context sensing is expanded on in the following sections. The other, additional questions from the Introduction chapter are also used as a guide to a review of a selection of the prior research that is related to this work.

Why choose a horse rider mounting a horse?

The domain of Horse Riding is an area of personal interest for the researcher and follows on from prior research in this area. In turn, this project is designed to lead on to future research and has possible value in improving commercial instantiations of future electronic coaching devices for horse riders. This desire to improve an existing tool and to create new ones ties into the chosen research methodology of Design Science.

Mounting and dismounting are significant events in horse riding because they usually form boundaries around the activity of riding a horse. As noted in the Introduction, by definition, in order to ride a horse one must be mounted on the horse.

Mounting involves a series of actions, which take time to accomplish. A typical series of actions involved in mounting and applicable to many riders is described in Appendix 1. This series of actions provides multiple opportunities to recognise individual movements that may be unique to mounting while not being overly simplistic and it presents a good research target for activity recognition and for this project. There is no obvious prior research in this area and so this research is novel to the extent that it investigates context sensing within the domain of Horse Riding and in particular the goal of creating a method to sense mounting is novel.

Mounting

Within traditional European riding (also called English riding in New Zealand) riders are universally taught to mount a horse from the horse's left-hand side. This teaching stems from long tradition and can be traced back to techniques used and taught to cavalry riders in Greek times.

Brownson, C. L., Marchant, E. C., Todd, O. J., Miller, W., & Bowersock, G. W. (1968) in their translation entitled "*Xenophon: In Seven Volumes*" of the earliest known publication on equitation, written by Xenophon in approximately 430 – 355 B.C. (Section 7.1 Horse), describe in detail the preferred method of mounting a horse that is not only from the left side of the horse but also matches quite closely how a modern rider, in the traditional European style, might mount without the aid of stirrups (as these had not been invented at that time).

Xenophon gives firm instructions for mounting from the left but also advocates teaching the horse and rider to mount from the off (right) side in case a cavalry rider finds himself dismounted and on the right side of his horse during a battle and needs to mount quickly without going around to the other side of the horse. Some aspects of riding such as the side from which a rider mounts a horse have remained relatively constant, especially amongst *traditional* riding styles and knowledge of and adherence to these traditions is strong.

While Xenophon did not say why he recommended mounting from the left it has been generally suggested that this relates to cavalry riders wearing a sword on their belt and in general being right-handed. A right-handed person finds it easier to draw their sword quickly if the sword is hung on the left side of the waist. Mounting a horse from the right side with a sword attached to the left waist of the rider would have the sword much more likely to bang into the horse as the rider mounted as the sword has to cross the horse's back and this would possibly make the horse shy and therefore difficult to mount. Mounting from the left makes it less likely for the sword to bang into the horse as the sword never crosses the horse's back. Most riders no longer carry or wear a sword while riding but horse riding is an activity where traditions play a strong part.

There are a variety of methods of mounting and dismounting, including involuntary dismounts (a fall), however, most riders usually mount and dismount using very similar techniques. While this is partly because horse riding is an activity with long traditions, it is also partly as a result of common purpose (the rider needs to get from the ground onto the horse and then back on to the ground) combined with common ingredients (rider, horse, saddle and stirrups) and lastly partly as a result of horse and rider training. As a result, there is reasonable commonality amongst many horse riders in what they do and how they do it when they mount and dismount. This commonality is very useful and makes it simpler to recognise a common marker within the sensor data stream that indicates when a rider has mounted a horse.

Dismounting, while important is outside the scope of this project and is not further defined or discussed. However, it is assumed that similar research methods could be applied to recognising dismounting and this is left for future research.

Why distinguish something? - Context/Activity Sensing

Mark Weiser (1993) in his vision for a new relationship between people and computers proposed one possible model of a computer as a knowledgeable assistant that could be present in the background and then come forward with appropriate advice when it was needed by its owner/user. In order to do this, the computer would constantly monitor the user's context and would be able to distinguish when it was or was not appropriate to come out of the background and provide advice or services to the user.

Schilit, Adams and Want (1994) in their paper on context aware applications defined context in terms of three important aspects, namely where someone is, who they are with and what computing resources may be available around that place. At this stage context awareness was more about finding possible resources for mobile devices that were relatively primitive and so needed all the help from nearby non-mobile or mobile devices that they could find and from a user perspective it was about the possibility of taking your (virtual) computer environment with you when you moved around.

Abowd et al. (1997) described their CyberGuide application and mention both its wearability and location and orientation as two aspects of context awareness that the application possesses. The authors of this paper allow for other aspects of context awareness and do in fact give some examples of applications that use other aspects such as user augmentation but they don't attempt to define Context Awareness in this paper.

Pascoe (1998) took Schilit et al.'s and other authors ideas and applied them to wearable computers, keeping Schilit et al.'s ideas of resource discovery and formally added the idea of application adaptability and user augmentation. In Pascoe's explanation this application adaptability is a by-product of what he calls reality-process couplings which he envisaged as a sort of event driven architecture for contextual triggers that would automatically fire off an application or part of an application when the triggers were sensed.

Billinghurst and Starner (1999) went back to define the principles of Wearable Computing and in the process defined three goals, namely: Mobility, Ability to augment reality (Feedback) and Context Awareness. Thus defining Context Awareness as a fundamental and intrinsic characteristic of wearable systems.

In the same year Schmidt et al. (1999) are clear that context awareness is more than just knowledge of location and they define context awareness as "*knowledge about the user's and IT device's state, including surroundings, situation, and, to a lesser extent, location*" (p. 2). They then suggest that context has three aspects; Environment, Self and Activity but don't expand on how these aspects of context might be used.

Chen and Kotz (2000) in their often cited survey of context aware mobile computing research cover both what context is and how it can be used, giving the definition that is mentioned in the Introduction chapter, introducing the idea of time as an aspect of context and differentiating active context (when an application takes some action as a result of a context change) from passive context (when an application merely makes a user aware that an aspect of context has changed, without taking any other action). Included within Chen and Kotz's description of how context can be used is the idea of "*context-triggered-actions*" (p. 3).

Dey (2001, p. 3) gives a much more generalised definition of context as "*Context is any information that can be used to characterize the situation of an entity. An entity is a person, place, or object that is considered relevant to the interaction between a user and an application, including the user and applications themselves*". While this is certainly more encompassing than prior definitions it seems to be too general and so it is harder to grasp at first reading and so, perhaps, is less useful.

Starner (2001, p. 3) lists four ideal characteristics of wearable computing that include aspects of context in three of the four characteristics, thereby binding wearable computing closer to context awareness and Starner advocates that Wearable Computing should be described in terms of its (Smart Assistant) interface with the user rather than in terms of hardware characteristics. Starner's ideal characteristics are: "*Persist and provide constant access to information services*"; "*Sense and model context*"; "*Adapt interaction modalities based on the user's context*" and "*Augment and mediate interactions with the user's environment*", where environment is a simile for context.

However Starner envisions a single wearable device, worn constantly and responding to every possible context change, a very ambitious vision and one that is some way off from being realised. Starner does not specifically provide for the ability for a context change to automatically trigger an application action although perhaps that is an assumed part of the Smart Assistant Interface.

The researcher's own experience with a wearable horse riding training aid supports this idea of the Smart Assistant Interface being a key part of wearable devices. During usability trials of a wearable coaching device for horse riders that preceded this project, it was found that user confidence in the device was reduced when it provided feedback at times when feedback was inappropriate (because the user wasn't riding), such as when the user was getting their horse ready to ride. From this it can be deduced that user confidence would be improved if it was possible to ensure that feedback was only provided when a user was on a horse ready to ride. As a result, having knowledge of user context became a design goal for this project.

However, this project's goals are much simpler than Starner's and others who envisaged wearables as a single (or cluster of) powerful, ever present computer that can distinguish any user context from any other. While this is an expansive goal, it is possible to get useful service from a more limited and therefore easier to build (now) wearable device that is only designed to operate in a particular domain. In the case of this project, the ultimate goal is to provide horse riding coaching assistance and so there seems no need to build a device that is capable of providing assistance in other areas of a person's life. The ultimate device is envisaged to be a specialist tool that a user would put on, as they put on their riding clothes or a tool that is embedded into existing riding clothes.

If, when looking at someone's movements and postures it is possible to infer (hopefully correctly) from contextual information that they have mounted a horse then the range of all possible movements and postures that a person would likely do or have after that point is reduced to that range of movements and postures that are usually associated with being on and riding a horse. Further, it would then become somewhat easier to interpret further movements if the device only needed to search for meaning within the domain of "being on a horse" rather than within all possible domains.

An understanding of context can make the other aspects of the device's use simpler and more "natural". For example, a human coach would usually stop giving postural advice to a rider who had stopped riding to answer their mobile phone and would then restart their advice once the rider was again actively riding. An electronic device that was capable of this same differentiation and reaction would be easier and simpler to use.

Other later authors such as Barnard, Yi, Jacko, & Sears (2007, p. 2) have tended to use a more general definition of context such as "*context is presumed to be a set of conditions or user states that influence the ways in which a human interacts with a mobile computing device*" or have not bothered to define context at all. Such general definitions are probably adequate within current thinking because of the background to this subject provided by prior authors however, it is a bit too general for this study.

While Erickson (2002) doesn't give a formal definition of context or context awareness he helps ground context recognition in reality by reminding us that just because we can create a definition that allows for automatic action on a context change doesn't also mean that we are capable of delivering a sensible outcome for that goal in a non-trivial situation. Erickson warns of the dangers of brochure-ware in design thinking.

Erickson points out that current sensors and their associated recognition methods are not as comprehensive as a person's ability to sense most things and so context aware applications must often make wide assumptions about the meaning of what is being sensed and that these assumptions are not always obvious. He also points out that in situations where the application takes autonomous action based on what was sensed, that there are a further set of often concealed assumptions that relate to what actions are appropriate to take. Erickson gives some clear examples of where this process can break down in some very common situations. One of his examples is that of an automobile designed to sense when the engine is running and the doors are closed, so that it can then automatically lock all the doors for safety reasons, potentially locking a driver outside the car. Using this and his other examples Erickson points out that while it is possible to add further rules in an attempt to correct this situation (unwanted lock-out) that for all but the most trivial of situations it may require a deep and complex set of rules to get reasonable behaviour.

Having deep and complex rule sets can have two further unwanted aspects. As the rule set gets deeper and more complex the ability to understand them gets less and at some point a situation is arrived at, particularly around the edges of behaviour, where it becomes impossible to reliably predict how the application will behave in some obscure branch of its logic.

Having unpredictable applications is discomforting, particularly when the application has the ability to take autonomous action. Erickson points out that unless this is taken into account in the design of such applications that this tends to take control away from people with potential detrimental consequences.

Erickson makes good sense, especially when sensors are applied to situations where human sensory systems already perform well, however, in some areas modern sensors and others that will follow have the ability to sense well beyond where our human senses are capable of performing. In these situations the use of sensors is, in a sense, adding new senses to people who use these applications or devices and so if the designer is careful to design how the device reacts to what it senses (its autonomous actions) then it is possible to supplement and add to overall human potential rather than detracting from it. Anti-skid braking systems where sensors monitor brake pressure and wheel movement hundreds of times a second in order to prevent skidding the tyres while braking and to ensure minimum possible braking distance are perhaps just one example of this. Nothing is ever likely to be perfect though and while anti-skid braking systems are an important safety feature for the vast majority of drivers it would still be possible to come up with a scenario where an expert driver on encountering a rare situation may be safer without an autonomously acting application (anti-skid brakes) than with that application. In such cases the designer and society needs to weigh up the potential value of the desired result from using the context aware application against the possible undesired results.

In other less time critical situations, designers should perhaps consider appropriate ways to signal when a context aware application has sensed an event that it is programmed to act on and to provide for possible ways to override that programmed action if the user so desires. Thereby giving people the choice of control when they want it and allowing the application to have control at other times.

An incident that happened to the researcher while in Stockholm doing the field study highlights some of what Erickson says by reminding us how good we are as humans at detecting key contextual cues and responding sensibly to them but how difficult some of this may be to try to replicate within a computer application.

The researcher is a mono-linguistic English speaker. While shopping in a local grocery store in Kista, Stockholm one evening after a particularly long and tiring day the researcher found himself behind a customer who moved backwards and forwards at the checkout counter forcing the researcher to also move backwards and forwards so as to avoid the person and as a result one of the researcher's items for purchase became separated from the rest of the groceries on the checkout belt. The checkout operator (who had never previously demonstrated an ability to speak English) scanned the first group of groceries for the researcher and then stopped scanning, held up the last item and said something in Swedish. The researcher answered automatically (in English) “Yes” and the checkout operator scanned the last item along with the rest. On reflection the researcher realised that he had understood what the checkout operator was asking “*is this also your purchase?”* or something similar, purely from the situation context. None of the words the checkout operator had spoken meant anything at all to the researcher but the situation (context) was such that the researcher could guess what was meant. This demonstrated how automatic and useful context is and (perhaps) how useful it could be for our implements, tools and devices to also understand something of the context within which they are being used but this is a non-trivial goal.

The use of domain specific knowledge in Context Recognition

The definition of the domain of Horse Riding in the Introduction demonstrated that the domain can be partitioned off from the rest of a rider's life by dint of the pre and post riding activities that most riders perform. In other domains this is not necessarily so simple. For example a work domain may well be separate from a home domain but often for people in office job type environments there are no simple ways of partitioning the activities of one from the other, that are also simple for a computer or sensor to spot.

The clear demarcation of the riding domain from other activities provides more opportunity than in other domains/activities to make use of domain specific context. This is something that has previously only been used by some of the researchers in this field and so there remains an element of novelty about this approach. Given the heuristic approach to creating a method for context recognition used within this project, constraining the domain of interest to include only horse riding activities is also useful because it restricts the activity range to search across and this probably makes it simpler to spot the mounting activities and actions that are of interested.

It is suggested that a horse riding specific wearable coaching aid would naturally be something that riders would put on when preparing to ride, based on the researcher's personal observations of how riders prepare for riding. By only (usually) wearing the sensor device while within a horse riding domain it becomes possible for this device to be domain specific. Once the device is domain specific there is less need to be concerned about incorrectly recognising a non-horse riding activity as being a riding activity because, by design and intended use, the device will never be used (correctly) in a non-horse riding situation.

Of course there is nothing to prevent someone from using a horse rider coaching device in another domain but if they do that and the device incorrectly recognises an activity as a riding activity then that is only a problem for the person using the device incorrectly. Despite Erickson's (2002) warnings, Garbage In – Garbage Out is still a useful phrase. What that means, is that during the search to recognise mounting, it is possible to ignore the possibility that activities from other domains would also be incorrectly recognised as a horse mounting activity. This simplifies the search for a recognition method although it is still necessary to ensure that alternate activities within the domain of Horse Riding that are not mounting are not incorrectly recognised as being mounting.

Some other researchers such as Blum (2005) make passing reference to relationships between activities but not to activities being domain specific. Blum suggests, a little simplistically, that typing (on a keyboard) is associated with sitting but not with standing. Other researchers such as Stiefmeier et al. (2006) are clear that relationships between activities are key to simpler recognition. Stiefmeier et al. (2006) base their research on work done within the automotive assembly industry and their work is domain specific. Gu, Pung, & Zhang (2005) and others seeking to create a generalised method for recognising and communicating aspects of context are very much aware of domain and the usefulness of domain dependencies for context recognition.

Abowd et al., (1997) is also aware of how the use of domain based dependencies can speed up and assist with the development of context aware applications and mention that their CyberGuide is designed to operate within the domain of automated tourist guide systems, however, it is not clear that they have used domain-activity dependencies to make activity recognition simpler, perhaps because they were looking at activities that are common across wide domains, such as walking and standing still.

Why choose to distinguish context in real life?

A number of researchers such as Foerster, Smeja and Fahrenberg (1999), Bao and Intille (2004) and Ravi, et al. (2005) have reported that they were able to achieve reasonably high recognition levels for activities and context (84%-95%) when tests were done in a controlled laboratory situation but that reliability fell off markedly (24%-66.7%) when similar trials were conducted in real life situations.

In addition, Randell and Muller (2000) were able to recognise activities such as running and walking in realistic situations at high confidence levels with a single sensor but found that their results were person and clothes specific. That is, the recognition algorithm that they used had to be trained for the specific person that was using the jacket that had the accelerometer embedded in it and so the results did not carry across to other people and even where the person whose data was used to train the algorithm changed their clothes then the algorithm also had difficulties reliably recognising activities.

Kjeldskov, Skov, Als and Hoegh (2004) report a counter example where their research showed improved results when carried out in a laboratory using structured methods as opposed to in real world conditions but Kjeldskov et al. were testing for usability within their research project whereas the other researchers mentioned are testing for context recognition. The research goals and methods affect the result. Usability testing can (obviously) be done effectively within an artificial laboratory situation (in fact Kjeldskov et al. suggest that it is better done there) because the structured nature of the environment assists in comprehensively identifying usability problems whereas for context recognition, researchers are trying to emulate real world conditions even when testing within a laboratory situation and so it seems reasonable that real or realistic situations are a better foundation for modelling reality than laboratory situations.

Intille, Bao, Tapia and Rondoni's (2004) research confirmed that it is possible to collect data from subjects under realistic conditions and then recognise features from that data at high reliability rates (80%-95%) however, the researchers noted carefully that recognition was only tested against data containing the specified (and known activities). It was not tested against real world data that contained a wide variety of activities, especially activities outside of those chosen for recognition.

Stiefmeier et al. (2006) report on their research on tools to assist car assembly workers with assembly tasks but unfortunately they do not state if they conducted their research on the factory floor or within a laboratory and nor do they give any statistics on recognition reliability. They do state that they only had limited users (4 subjects) and that most of the activity recognition was done as a result of non-worn sensors such as those placed on the vehicles rather than on the workers body. It is difficult to conclude much from this study with reference to the viability of real world data collection.

Zappi et al. (2007) who are also working on car assembly issues have published reliability statistics and they managed 98% reliability with activity recognition however the authors don't mention the number of subjects they used within their study although at one point they talk about "*the*" subject, implying that only a single subject was used. Again, they do not specifically say if their research was carried out on the factory floor, under real conditions or if it was carried out under simulated factory conditions. Lastly they report that the data for each activity that they set out to recognise had already been manually separated out from the sensor data stream and so they did not have to recognise activities within a continuous data stream, significantly simplifying the recognition process. This again makes it difficult to draw conclusions about real world context data collection methods from this particular study and highlights some of the issues associated with learning from prior research that is reported via short articles where there may not be the room to clearly specify some important research parameters.

Looking ahead to the possibility of using any recognition method in a product that people will use in every day riding situations, it seems that while recognition during this research will be more difficult using data from realistic situations, if a reliable method is found then it is likely that this method will be more suitable for implementation in future, real-world product improvements.

In their review of methods used within mobile HCI research projects, Kjeldskov and Graham (2003), initially review research method classification and conclude that some of the general weaknesses of laboratory and highly structured studies are limited realism and unknown generalisability. These are both weaknesses that this study attempts to minimise by grounding the research in realistic data collected from a field study. Kjeldskov and Graham (2003) also highlight that the research methods that employ more realistic methods of data collection such as Field Studies suffer from difficulties in collecting the data and unknown sample biases. These are both issues that are dealt with within this project. As a result, while it is believed that the methods used within this project will produce good data to work with, the extended time needed for field study data collection has resulted in reduced time available for data analysis. This has significantly reduced the ability to apply any knowledge gained during this project back into the real world.

Kjeldskov and Graham's (2003) categorisation of Applied Research includes Design Science and fittingly they conclude that this methodology sits across both Laboratory Experiments and Field Studies and so it is appropriate to have included both of these methods within this project. Kjeldskov and Graham highlight that of the 42 papers that they reviewed that they had categorised as having evaluative goals, 30 (71.5%) were conducted as laboratory experiments in (obviously) unrealistic situations, 4 (9.5%) were surveys and 8 (19%) were field studies conducted in realistic situations.

They also point out that of the 45 papers that they reviewed with product engineering goals, only 17 (37%) went on to evaluate the product/algorithm/method and of these 61% were evaluated using laboratory experiments, 22% via field studies and 17% via surveys (Kjeldskov & Graham, 2003). Within the papers that they reviewed Kjeldskov and Graham found an overwhelming majority of researchers had chosen to evaluate their work using laboratory experiments. The work of Foerster et al. (1999), Bao and Intille (2004), Ravi et al. (2005) and others demonstrates that algorithms and methods that were developed and worked well in laboratory situations did not generally translate well to real world situations and were markedly less reliable when used on realistic data.

This project is designed to conduct the data gathering under realistic conditions using a form of field study that can loosely be called field observations. This choice was made as a result of both the gap within the prior research in this area and as a direct result of the undesirable effects of trying to transfer laboratory based results into the real world. The goal of this project and likely follow-on projects is to be able to eventually apply any recognition method that is developed within the real world.

Why use inertial data to distinguish context?

Verplaetse (1996) was an early researcher who advocated using inertial sensing devices (accelerometers and gyroscopes) to measure motion. Traditionally motion and posture has been accurately measured in special laboratory spaces and occasionally out in the field using special high speed video cameras and appropriately placed light reflectors.

Verplaetse points out that accelerometers and gyroscopes measure acceleration rates and rate of rotation with respect to an external frame of reference (gravity) that is relatively omnipresent and constant both indoors and outdoors (on earth). Other forms of motion detection require their own frame(s) of reference such as known marks and measurements for video camera systems, for example. In addition video camera and other systems, with their own frame of reference, require that the reference frame not be occluded and so video camera systems typically require multiple cameras in fixed positions. Such systems usually require careful and accurate set up and because of this typically subjects for study are often brought to specially designed spaces where the cameras are pre-set up. Such spaces and systems are typically expensive to obtain.

One of the goals of this study is to record data in realistic situations and so bringing horses and riders to a specially prepared space that is large enough to allow them to prepare, mount, ride, dismount and undertake post riding activities within the pre-prepared space would require extensive organisation and access to financial and other resources that were out of scope for the project.

Mayagoitia, Nene and Veltink (2002) did a comprehensive comparison of accelerometer and gyroscope motion capture sensors against optical motion analysis systems and concluded that inertial sensors such as these two types (accelerometers and gyroscopes) were marginally less accurate than optical motion analysis systems but were considerably cheaper to obtain, could be used in the field in natural situations, were accurate to acceptable levels, did not inhibit body movements and allowed long term recording. However, at that stage the algorithms used were computationally intensive and they found that they needed to run the recognition algorithms off-line.

The use of accelerometer and gyroscope sensors fits both the project time and resource constraints and apart from possible computational difficulties is consistent with the desire to use context recognition within a device that already used inertial monitoring to provide rider feedback. The possibility of the recognition algorithm being too computationally intensive to run within the target device was considered to be out of scope for this project, although there is a preference for a simple recognition algorithm.

Bernmark and Wiktorin (2002) described the use of accelerometers to measure arm movements. Smith, R. M. (2002); Baudouin and Hawkins (2004) and Anderson, R., Harrison, A. and Lyons, G. M. (2005) describe the use of accelerometers in sport to investigate biomechanical factors affecting rowing. Michahelles and Schiele (2005) and Brodie, Walmsley and Page (2008) use accelerometers with snow skiers.

Researchers such as Schmidt et al., (1999); Foerster et al. (1999); Bao and Intille, (2004); Intille et al., (2004); Edmison (2004); Blum, (2005); Ravi et al., (2005); Minnen, Starner, Essa and Isbell, (2006a, 2006b); Stiefmeier et al. (2006); Barnard et al., (2007); Dong and He (2007); Zappi et al. (2007); and Junker, Amft, Lukowicz and Tröster (2008) have demonstrated that it is possible to reliably differentiate activity context using on-body accelerometers. These authors have demonstrated greater than 80% reliability in recognising activity context and in some instances up to 95% reliability (Intille et al., 2004, p. 3) using multiple on-body accelerometers.

There are a plethora of other studies that use and validate the use of accelerometers and compound inertial measurement units to accurately and reliably measure human motion and activity context. In particular there have been a number of studies using inertial devices since the project was first envisaged during mid 2006. The use of such inertial monitoring devices is, therefore, reasonable and consistent with current research.

Why is the device wrist mounted?

Kern, Schiele and Schmidt (2003) have suggested that appropriate placement for sensors on a human body would be close to major joints and tested placements just above the ankle, knee, thigh, wrist, elbow and above the shoulder. For activities that required use of the hands they found that wrist and above shoulder placement were sufficient for their purposes. They found that the elbow sensor did not add significant information and recommended not using it if trying to limit the number of sensors.

They also found that the sensors placed on the upper body (wrist and above the shoulder) performed best overall at recognising all activities. While the lower body sensors were better at recognising sitting, standing and walking the upper body sensors were also accurate at recognising these activities but the lower body sensors performed poorly at recognising hand-based activities.

They identified handedness as an issue to be considered when placing sensors, as a right-handed person would use their right hand when both shaking hands and writing on a whiteboard and they found that the sensors placed on the left wrist, elbow and above the left shoulder were unable to recognise hand activities that were primarily one handed and which were performed by the dominant (right) hand of their test subject.

Given this choice of above shoulder or wrist, an understanding of the role of the hands while mounting, along with a number of other studies that had successfully used wrist placed sensors and the desire for a single sensor along with the existing coaching aid it was decided that a sensor placed on the wrist was most appropriate for this project. A small selection of the prior research that includes inertial sensors placed on a subjects wrist or wrists to measure human motion and/or human activity context includes Foerster et al. (1999); Randell and Muller (2000); Stiefmeier et al. (2006); and Zinnen and Schiele (2008).

The issue of handedness did present a dilemma though. It was decided to make two sensors and use one on each wrist but to analyse the data from each sensor separately so as to retain the ability to test if one sensor was sufficient to recognise mounting.

Why restrict the research to only one device?

One of the ongoing pragmatic goals is to feed the knowledge that is gained from this research back through into product improvements in real world products and as existing real world products have been designed to operate as single, stand-alone wearable coaching aids, then it is also useful if it is also possible to recognise context using a single compound sensor. If this can be done then it becomes possible to embed the sensor or method within an existing stand-alone device.

In prior research most other researchers have used multiple sensors to reliably recognise context or human gestures and for those researchers who have used a single device, the majority of these have used them only within non-realistic laboratory experiments. As noted earlier, it is easier to recognise human activity in the laboratory than it is in the real world and recognition methods that work reliably in the laboratory often do not work reliably in the real world. As a result there is an aspect of novelty to research that attempts to use a single compound sensor to recognise activity within the real world.

It is clear from prior research that context recognition using a single sensor is non-trivial and some of this evidence will be reported later in this document. However, while there is a desire to extend knowledge with this research, it has already been acknowledged that the desire to collect real world data has placed significant time constraints on the project and so it would be foolish to compound this by taking on additional complex analysis within the limited time available unless there was a method to assist with reducing the complexity of context recognition with a single sensor. The proposal for managing and reducing the complexity of context recognition with a single sensor is to use knowledge of the domain of Horse Riding to assist in constraining the data that needs to searched across and to use a manual heuristic method to analyse that data.

Within this project it is assumed that the compound sensor will always be put on and turned on as the rider dresses immediately prior to riding, thereby restricting the domain to that of horse riding. This restriction together with the assumption that most riders mount a horse using a relatively common process may be enough of a simplification to allow the study to find a method of recognising the contextual trigger of mounting within the limited project time frame. These assumptions will be carried across into the field study, data collection phase.

Benbasat (2000) was one of the earliest researchers to attempt to recognise human activity using a single inertial measurement unit that was quite advanced for that time. He used the device to recognise a standard set of human gestures. Benbasat had six subjects wear his sensor during laboratory experiments where they performed the gestures under supervised conditions and while he declared himself satisfied with the results he did not disclose what level of recognition reliability he achieved.

In the same year Randell and Muller (2000) also published research documenting their study that used a single accelerometer to recognise walking, running and standing still, within a real world situation. They did not publish the number of subjects that they used within their work but they do state that they achieved between 85% and 95% recognition accuracy and that is very good from a single sensor. However, this result is tempered by the information that the recognition method resulted in subject specific recognition for each individual tested and that there was no commonality between subjects and further that even if the same subject changed the clothing that they wore then their recognition method failed to recognise the activities correctly.

Van Laerhoven, Schmidt and Gellersen, (2002) used 32 sensors on an unknown number of subjects in a laboratory situation with unstated accuracy and concluded that it was best to use multiple sensors to recognise activity rather than attempting to do it with a single sensor. Kern, Schiele and Schmidt (2003) used 12 sensors in a real world situation, achieving between 40% and 90% recognition accuracy and concluded that a single sensor was insufficient to recognise general activities.

Chambers, Venkatesh and West (2004) used two sensors on a single subject in a laboratory situation (using an actor) and achieved between 76% and 100% recognition accuracy within the sport of Cricket. In the same year Intille et al., (2004) used five sensors with 20 subjects under semi-realistic situations and achieved between 79% and 89% recognition accuracy. Also that year Bao and Intille (2004) again used five sensors with 20 subjects recording an 84% recognition accuracy level and concluded that the minimum number of on-body sensors required to reasonably accurately measure activity context was two and this was confirmed by Blum (2005). Since then other researchers such as Ravi et al. (2005), Minnen et al., (2006a & 2006b) and Zappi et al. (2007) have reliably measured activity context with a single accelerometer but always in artificial, laboratory type or semi-realistic situations.

Many other researchers have used multiple sensors in both laboratory and real world situations since then with varying but usually high recognition levels and most researchers in this field hold the view that reliable recognition of realistic human activity or context requires at least two independent inertial sensors (preferably more) mounted at differing points on the body of the person being monitored. The contention is that, in general, the reasons hold at a macro-level where there is a need to differentiate widely differing contexts from each other such as differentiating walking from cycling, to travelling in a train, to driving a motocross bike, to swimming and so on. Generally the activities within one of these domains differ markedly from other domains but sometimes intersect at unexpected places. For example it may be difficult to differentiate between the arm/hand action needed to open a door, turn an ignition key on a motorcycle and perhaps even to grasp another persons hand. Other activities, however may well be much more different from each other in each domain.

Swimming, for example, tends to make use of markedly different actions that say, driving a 4X4 in an off-road situation. Within some domains there are also key sub-domains that further reduce the number of normally expected actions. For example the domain of Horse Riding could be said to include Preparation, Riding and Post-Riding activities where Preparation includes preparing the rider by putting on riding clothes and riding gear, preparing the horse by catching it, grooming it and tacking it up. Riding includes horse and rider activities once mounted and Post-riding includes un-tacking the horse, grooming and feeding the horse, putting the horse away and taking off the riding clothes and gear.

This gives a domain hierarchy structure that can be used to provide explicit or implicit clues to the current domain or sub-domain. By constraining the range of activities covered to a single, relatively unique domain it is proposed that reliable activity recognition may be possible using the data from a single wrist mounted sensor. If this goal is achieved then there is an element of novelty to the research.

Summary

Chen and Kotz's definition of context within the area of wearable computing as "*the set of environmental states and settings that either determines an application's behavior or in which an application event occurs and is interesting to the user*" (Chen & Kotz, 2000, p. 3) is more useful for the purposes of this study. This study is interested in the set of environmental states and settings that help define an activity boundary. Is this riding training or is it not? Chen and Kotz also differentiate context into active and passive, where active context is where "*an application automatically adapts to discovered context by changing the application's behavior*" (Chen & Kotz, 2000, p. 3). This active context is the long term research goal in that training devices are ideally only measuring and providing feedback when the rider is actually doing riding training. As Erickson (2002) has pointed out, this isn't an easy goal and the design needs to allow for flexibility in how the pursuit of this goal impacts on potential users of the devices.

The project relies on the existing reasonably clear domain boundaries between horse riding and other aspects of a person's life to make it simpler to search for a method of context recognition. This approach is less commonly used by earlier researchers but appears to be becoming more common as the emphasis shifts in some areas of research from recognising context within any aspect of one's life (a huge goal) to recognising context within much smaller, more easily partitioned areas of one's life.

Real world context recognition is more difficult and time consuming to do and possibly as a result there is considerably less research done using realistic data than is done using data obtained from structured laboratory trials. However, methods obtained from real world data are more reliable at recognising activities within the real world and so the study is designed to collect the data in as realistic a situation as possible at the expense of more sophisticated data analysis methods.

Accelerometers and other inertial measurement sensors are commonly used within research to measure human motion and human activity context. This study chose to mount the inertial sensors on the riders wrists both because of pragmatic reasons associated with intended future use of the data from the wrist sensors and also because the human wrist has been identified by other researchers as an expressive and appropriate place from which to measure human activity.

Most researchers have concluded that at least two sensors are required to accurately recognise human activity and context. Being able to recognise activity context using a single, on-body sensor will make it easier to improve the design of future wearable, electronic riding coaching aids.

No obviously available research has addressed human activity context recognition within the domain of Horse Riding.

Chapter 3 – Methodology

Chapters 1 and 2 contain discussions that highlight how the recognition artefact will be useful. This chapter discusses why Design Science is an appropriate methodology to use to create that artefact and briefly discusses some alternative methodologies that were not used. Following this is a discussion on how the various phases of the research were designed and organised. This will include a discussion of the participant recruitment, data collection and data analysis processes.

Introduction

As discussed in Chapters 1 and 2, this study sets out to answer the question "Is it possible to distinguish in real life when a horse rider mounts a horse using inertial data captured from a single electronic sensor module worn on the rider's wrist"? A successful study project will have demonstrated that a useful artefact has been created to do this. In this sense, the artefact is the method that includes the hardware, software and processes needed to distinguish mounting in this (constrained) context.

The method need not be a succinct algorithm that is capable of being directly implemented in hardware although future research may well seek to take any method created and move that method into an algorithm that is capable of being implemented within suitable hardware. Essentially then, the goal is to build something useful. As a result, Design Science has been chosen as an appropriate research methodology within which to work while developing this artefact.

The research consists of two projects, one inside the other. At the outer level the objective is to create a method that allows for the recognition of mounting and this is the project that is directly reported on in this document. However, in order to undertake this project it was necessary to build the inertial sensor devices to be used for data collection and this forms a smaller sub-project. The sensor design and build sub-project is an integral part of the larger project and was conducted at KTH in Kista, Sweden while hosted by the Wireless@KTH research laboratory as an exchange student and as a result is reported separately in an unpublished dissertation entitled “*Building a wearable inertial sensor to monitor horse rider wrist movements”* (Hunt, D 2010a) that fulfils the KTH coursework requirements.

Further aspects of this sub-project, including the iterative process of modifying the design to suit conditions encountered whilst collecting data are described in a paper presented to the NZCSRSC 2010 conference entitled “*Real World Context Data Collection, How many errors can I make?*” (Hunt, D 2010b) and a paper presented to the AUT University Postgraduate Symposium 2009, entitled “*Challenges and Collaboration in Kista – The field Work for a Master's thesis*” (Hunt, D 2009). As a result the design and build process is only summarised within this document.

Peffers, Tuunanen, Rothenberger and Chatterjee (2007) method of presenting Design Science projects is used to present the findings within this thesis, using the structure that they recommend. This chapter deals with the choice of methodology and that is followed by a description of the Design & Development phase that includes the design objectives; justifications for the design choices; ethical issues associated with this project; data collection methods and finally the data analysis methods.

The Demonstration and the Evaluation phases from Peffers et al.'s recommended presentation structure will be covered within the chapters on Findings and Conclusions, with this document (itself) representing Peffers et al.'s Communication phase.

Approach (Chosen Methodology)

Design Science is the methodology of choice within this project.

Approach/Methodology Justification

Järvinen (2000) suggests a taxonomy and a process for using the taxonomy that has the research question guide the selection of an appropriate research method. Following this process it is apparent that in this case the research question is a non-mathematical question, within Järvinen's definition, because mathematical systems are described by Järvinen (2000, p. 1) as "*symbol systems without having any direct reference to objects in reality*" and the research question is very much concerned with objects in reality. It is concerned with horse riders mounting a horse and real inertial sensor readings that are a product of real movement and human posture orientation.

This project does not consider the research question in a pure mathematical sense "*concern*(ing) *formal languages, algebraic units etc.*" (Järvinen, 2000, p. 1). Instead, the method will create tools to capture a data stream generated from realistic actions; relate that data stream to real actions recorded on a video camera and then present that data stream in a way that it can be analysed for common features associated with mounting a horse. Where such features are found, they will be evaluated to see if they occur across different riders, horses and situations. This approach is very much associated with reality.

Järvinen's process then requires a differentiation between descriptions of reality or alternately highlights the utility of an artefact? In this project the utility of the artefact (the method) is paramount because the eventually plan is to take the knowledge gained from distinguishing the method and use that to implement a horse rider mounting recognition algorithm within a horse rider coaching device.

Lastly, Järvinen's process differentiates between building an artefact or evaluating an artefact. Within this project, the intention is to create (build) a recognition method (artefact), if that is possible. Then following Järvinen's taxonomy and process, the research question suggests that the appropriate methodology to use is Design Science.

It could be argued, that the research question is a "*theory testing approach*" (Järvinen, 2000, p. 3) because if the study succeeds in creating the desired method, that will demonstrate a proof of the theory that it is possible to create such a method. In fact, at least one highly experienced researcher suggested this during the data capture field study. However such an argument diminishes the utility of the method. The purpose is to create a method so that the method can be used, we are not merely creating it to prove a point. The utility of the outputs of this research (the method) is the central tenet and this points towards Design Science.

There is doubt about the ability to create a recognition method and so this points back to the possibility that this project is, in fact, a theory proving project. However, much of the doubt that exists has more to do with the researcher's personal abilities than with the fundamental question of if such recognition methods are creatable by anyone. Within the Literature Review chapter a number of other researchers who have created activity and context recognition methods including some that used a single sensor were cited, thus it is clear that the theory testing approach has been successfully tested by others.

Kjeldskov and Graham (2003) did a comparison of a comprehensive selection of published research within the Mobile Technology - Human Computer Interface areas and found that the majority of research reviewed used either an Applied Research methodology or used Laboratory Experiments. Given the comprehensiveness of their selection of papers (102 papers from leading conferences and publications, published between 2000 & 2002), then general applicability can be assumed.

Design Science sits within the category that Kjeldskov and Graham label Applied Research and so this study is in good company although very few of the published papers within this category of Applied Research actually specify an underpinning research methodology and even fewer cite Design Science as their underlying methodology. That aside, Design Science is accepted as a valid and fundamental Applied Research methodology for Information Systems research (Hevner, March, Park and Ram, 2004).

Hevner et al., contend that two research paradigms underlie much of the IS published research and that these are Behavioural Science and Design Science. They suggest that this is because the Information Science discipline sits across "*the confluence of people, organizations, and technology*" (Hevner et al., 2004, p. 3). Kjeldskov and Graham's (2003) research partly supports this within the specialised area of Mobile Technology - Human Computer Interface research, in that a clear majority of the research in this area is either applied or experimental research. Kjeldskov and Graham note and lament the absence of Behavioural Science based and non-applied research and account for this by the relative newness of this specialist area where most early research has concentrated on building artefacts to use within this area. While the choice of methodology within this study does not address the lack of non-applied research it is highly consistent with other research in this area.

Kjeldskov and Graham's (2003) paper contains a very useful categorisation of research methods that they cite as being sourced from Wynekoop and Conger. Within this categorisation scheme three methodologies are classified as applying to real world situations only, namely: Case Studies; Field Studies and Action Research. Another three methodologies are classified as applying to either real world of artificial settings and these are: Survey Research; Applied Research and Normative Writings. The remaining category being Laboratory experiments and that is only applicable to artificial settings (Wynekoop and Conger, (1990) as cited in Kjeldskov and Graham, 2003, p. 2).

This following section will use the Wynekoop and Conger (1990) categorisation scheme along with Kjeldskov and Graham's comments about the strengths, weaknesses and uses of each methodology to briefly discuss why an alternative research methodology was not chosen.

Laboratory Experiments

Laboratory experiments are, by definition, only applicable to the artificial, laboratory setting. Our principal aim is to collect and analyse data collected within real or realistic settings and so laboratory experiments are not an appropriate methodology for this project. However, some laboratory trials will be conducted within this project. In this case the laboratory trials will be methods, rather than an overarching methodology and the laboratory trials will be used to collect a large number of "artificial mounts" so that the data can be quickly browsed to find possible common features. If found, these features will then be used as pointers to possible similar features within the real data. This is discussed in more detail as part of the research design, later in this chapter.

Survey Research

Survey research consists of collecting descriptive data from large samples of participants. The intention is to collect real data rather than descriptive data and there will not be the time or resources to collect this from large numbers of participants and so Survey Research is not applicable to this project.

Normative Writing & Basic Research

Neither of these two methodologies will deliver a useful, real world artefact as a direct output and so neither are appropriate to this project.

Case Studies

Case studies are applicable to a real setting and so could be used within this project but Kjeldskov and Graham (2003) describe their principal use as descriptive and explanatory methods used when developing hypothesis. Their strength is that they provide rich data from natural settings but their weakness is that they are time demanding and have limited generalisability.

The principal purpose within this study is to build a method for recognising a specialist event (the artefact) and so while the rich data that is available from case studies would be useful, it will not have created anything at the end this methodology is followed and so the artefact will not exist. This methodology is rejected for this reason.

Field Studies

Field studies is a methodology that is applicable to a real setting and so is a possible methodology for this project but the principal use of field studies is to either study current practise or to evaluate new practise. This research will study current practise (mounting) in order to collect the realistic sensor data that is needed but like the case study, field studies do not have an artefact as an output and so again this methodology is rejected for that reason. Field Studies will however, be used as a data collection method because of its strengths of providing real data using a replicable method.

Consideration was initially given to conducting an ethnographic field study as a complete alternative to the current project but this was rejected as a project proposal because such studies are extremely time intensive and normally do not fit within the time frames applicable to a Masters thesis project.

Action Research

Action research is also applicable to real world settings and is a methodology that is used to generate or test hypothesis and/or theory while contributing some benefit back to the community of people who are the participants in the research. Its strengths are that it provides the researcher with first hand experience and allows the researcher to apply theory to practice. Its weaknesses are that there are often ethical issues around the possible withholding of information that would be beneficial to participants when measuring the effects on practice; there are unmeasured biases within participant samples when communities are worked with as a whole, they generally require more time to conduct than some other methodologies and the results are often specific to the community being studied and so are not generalisable to other communities.

While the results of this research project may be beneficial to the equestrian community as a whole in the longer term (and possibly to other communities) the benefits that are expected to accrue from Action Research need to be much more specific. Kjeldskov and Graham give one definition of Action Research as "*the researcher participates in the intervention of the activity or phenomenon being studied while at the same time evaluating the results*" (Kjeldskov & Graham, 2003, p. 4). This is not consistent with the research goals or intent and so Action Research is rejected on this basis.

Applied Research

Kjeldskov & Graham (2003) state that applied research is used to develop products or other artefacts and may be used to test hypothesis or concepts. Its strengths are that it is artefact directed (the goal is to produce the artefact) but its weaknesses are that further design may be required in order to generalise the artefact.

Design Science is a sub-category of applied research, March and Smith give one definition of Design Science as "*devising artifacts to attain goals*" (Simon (1981) as cited by March & Smith, 1995, p. 3). They characterise the goal of Design Science as a method to "*create things that serve human purpose*" (March & Smith, 1995, p. 3) and that its products are "*assessed against criteria of value or utility*" (March & Smith, 1995, p. 3). Thus two of the key aspects of this methodology are to build and evaluate. March and Smith go on to propose that the outputs of Design Science be categorised into four types "*constructs, models, methods and implementations*" (March & Smith, 1995, p. 3). As the project goal is to develop a recognition method to sense when a rider mounts, then clearly this fits the Design Science methodology. Consequently, the decision to use Design Science as the overall methodology for this project is confirmed.

Design Science Approach Description

Peffers et al. (2007) provide a comprehensive guide to what is Design Science and this guide is used within the following sections to explain the basics of this particular methodological approach to research.

There are six steps in the Peffers et al. process and they are listed sequentially but they need not be followed in a strict order and in fact Peffers et al. suggest that researchers will often move from one process step to another to suit the project needs rather than simply following from the first through the sixth step. In particular the design and development (3), demonstration (4) and evaluation (5) process steps may iterate through a number of cycles. Researchers may also revisit the second process step and revise the project goals after starting, produce an interim report (6) and would then re-entering the other process steps, perhaps iterating through them several times before producing a final report. The six process steps as outlined by Peffers et al. (2007) are:

1. **Problem identification and motivation**

   This process phase defines the research question and justifies the value of a solution.

2. **Goal setting or objectives of the solution**

   Goal setting infers the objectives of a solution from the research question. The goals may be measurable (e.g. “X% improvement”) or may be more qualitative (e.g. “a better solution that A”). A background knowledge of the problem area helps in this process.

3. **Design and development**

   Design and development actually creates the artefact. The process includes designing the architecture of the artefact and then building it.

4. **Demonstration**

   This part of the process demonstrates the ability of the artefact to solve the research problem or question. This requires knowledge of how to use the artefact.

5. **Evaluation**

   This process observes how well the artefact resolves the research question during the demonstration phase and compares the function of the artefact against its design goals.

6. **Communication.**

   This communicates the outcome of the overall process to a relevant audience such as other researchers or users of the product if the artefact is a product improvement.

Research Design of This project

Here the basic Design Science methodology description is applied to this study.

This document plays an important part in applying the process steps from within Design Science to this project. Some of its component parts map directly into one of the six Design Science process steps. The Introduction and Literature Review chapters, for example, map onto step one from Design Science because within these two chapters the research question is defined and its value is established.

Then, in turn, the knowledge gained from researching the prior literature and writing the Literature Review chapter serves as a useful background in inferring the design goals in step two. The other set of background information that is useful in inferring the design goals comes from the researcher's own background in equestrian sport, coaching and in developing wearable coaching aids for horse riders.

Design Goals/Objectives

A human riding coach knows when the pupil is riding or not, mounted or dismounted and this is trivial but essential information for the coach. While some riding coaching can be done while the pupil is dismounted, for example via video examples, written, spoken, demonstrated or graphical material; this is inevitably followed up when the pupil is mounted on the horse, putting the new knowledge into practise whilst riding. An electronic coach however has no simple way of ascertaining if the pupil is riding or not unless it:

- always assumes that the pupil is riding,

- is told specifically by a person involved (perhaps via a switch or menu selection), or

- can somehow work out for itself that the pupil is riding.

While options one and two are practical alternatives they both have drawbacks associated with them. For example, during earlier unpublished usability research the researcher established that a device that always assumed that the person using it was riding, was effective but sometimes inconvenient to use when left turned on and used outside of actual and direct riding situations. Some users, while using the device outside of actual riding situations, considered the device to be dumb because of its persistence in proffering riding advice while not riding. This unpublished usability research also established that a device that needed to be turned on only when the rider was actually riding was sometimes not turned on until sometime into the ride simply because the rider forgot to do this at the beginning. Thus missing the opportunity to provide advice consistently through out the riding session.

This lead to the premise that a device that could be turned on when it was put on but that could then work out for itself when the person wearing it was riding, would perhaps have additional utility and may be considered smart (provided that its predictions were reasonably accurate and its subsequent actions were appropriate) and would perhaps be considered more usable and therefore it would be used more and so be more effective.

Then, finding a reliable method for electronically sensing the context *riding* via recognition of the assumed boundaries of riding, namely mounting and (later) dismounting would have utility and is a non-trivial exercise. The overall desired outcome is to use this electronic method to create riding aids that are smart enough to tell when someone is riding or not so that wearable devices can be produced that are more efficient at helping riders to train, thus eventually returning a benefit to the rider community as a whole.

However, this project has a more limited goal, that of finding a manual, heuristic method of recognising when a rider has mounted from the data stream from a single inertial sensor module. The translation between this more limited (and achievable) goal and the wider goal is outside the scope of this project for time reasons but, never-the-less, by keeping this wider goal in mind it will help to direct the efforts within the narrower goal. This creation of a manual heuristic method that may be capable of eventual translation into an electronic algorithmic method is then the primary goal of this project.

Secondary goals may be inferred from the project constraints, namely:

- Time – The method needs to be able to created and used against the existing data within the time constraints of this one year project. As the project has been ambitious in data collection and tool creation it needs to be unambitious with regard to the recognition method in order to balance time demands. This points to a simple method by preference and one that does not require too much time to be invested in learning how to follow a technique or to use a product.

- Experience – The method needs to be one that is consistent with the researchers, as yet, limited experience in this area. Again this points towards simplicity and to tools and concepts that the researcher is already familiar with.

- Resources – Any tools that need to be acquired should be either free by preference or as cheap as possible and consistent with their use within the method development process.

- Technical constraints – the method needs to be fully compatible with all of the technical constraints that apply to this project such as traditional European riding style, riders mounting "tacked up" horses, no unusual mounting methods, primarily left-hand mounts and using both the participants that are recruited and the sensors that are developed or acquired for this project.

- Real life data – The method needs to be able to be applied to real or realistic data although it may initially be tested against unrealistic but more structured laboratory based data.

The Research Process (Design Architecture)

A research project is like most other projects, if it is large enough, it helps to have a design before starting so that things can be monitored and the project kept as close to plan as possible.

The basic phases in this project are:

- Preparation
- Documentation
- Data Collection
- Data Transfer, Validation & Storage
- Data Analysis
- Draw Conclusions and Publish
- Post project close down

These phases are presented in the following paragraphs, the phases and tasks are presented linearly but this does not imply that the tasks are completed in a linear manner. While some tasks depend on earlier tasks for their input this does not mean that a prior task must be completely finished before a dependent task can start. For example, the data collection phase need not be complete before starting data validation and in fact it is more robust to start data validation soon after collecting the first set of data so that if issues are found during validation that relate to data capture then the data capture process can be changed early within the phase rather than capturing all the data and then discovering that there was an issue that affected all datasets that makes them unusable or less useful.

Tasks listed in one phase may be reported on within another phase. For example while the preparation phase tasks are grouped together these are typically reported on within the phase to which they apply, e.g. “Decide on and gather tools for data capture” is reported on within the Data Collection section.

Detailed information on the processes that were actually followed and the resources that were used to collect the data and analyse the data are presented following the research design outline. The description of the data collection process also includes a description of the participant recruitment process.

Research Design Outline (The Plan)

This section describes the planned actions, the actual events are described separately.

Preparation

- *Complete ethics process* - Write the ethics application, the participant information sheet that will be used to help recruit participants, the confidentiality agreement for co-workers and the informed consent forms for adults and children. Translate documents into Swedish. Await ethics approval.

- *Decide on and gather together the tools needed for data capture* - Inertial sensor, power source and case for inertial sensor, PDA for on-body data storage, mounting apparatus for sensor and PDA, video camera, video tapes, battery packs, data communications module for wireless data transfer, laptop computer for field use and camera support unipod (a tripod with a single leg) for filming.

- *Decide on and gather the tools needed for data transfer, conversion and validation* - Terminal emulation for sensor data transfer, USB Bluetooth dongle for sensor data transfer, USB to serial port dongle & cable for sensor data transfer, Firewire cable for video transfer, text editor for sensor data conversion, linear editor for video conversion, spreadsheet or text editor with scripting language for sensor data validation, linear editor for video validation and desktop computers or external storage drives for data storage.

- *Decide on and gather tools needed for data analysis* - Spreadsheet package with charting facilities for sensor data analysis and a video linear editor with good shuttle controls for video analysis.

- *Test the data capture tools* - Test the tools in circumstances similar to the expected field conditions to ensure that they work as planned and modify or change the tools as needed.

- *Test the data transfer, validation, conversion and storage tools* - Ensure that they work as planned and modify or change the tools as needed.

- *Test the data analysis tools* - Ensure that they work as planned and modify or change the tools as needed.

Documentation

- *Keep a log of significant events* - Review the log occasionally to modify any part of the process that needs changing.
- *Keep a log of insights* - Use the insight log when reflecting on aspects of the research project.

Data collection

- *Decide on participant recruitment methods* - Choose a method that will effectively recruit a group of approximately twenty volunteer participants who regularly engage in traditional European horse riding training. Up to three sessions will be recorded for each rider giving a possible total of 60 recorded sessions. Draw a balance between a larger number of participants and sessions that will result in a wider range of data for analysis and a smaller number that will allow the research to be conducted in a timely manner. It is estimated that around 60 sessions will be enough to cater for errors, to discover repeatability and should be manageable within the time constraints. This number is further justified within the sample size description.

  The aim is to record three sessions per rider so that it is possible to compare mounts for the same rider as well as across riders. Three sessions allows for some balance between the number of riders needed and the workload expected of each rider. Asking riders to take on more than three sessions each may deter them from volunteering. Each rider will be given the option of partaking in less than three sessions if that suits their circumstances better. As a result, the project outcome will define the number of riders and the number of sessions each rider participates in.

  The researcher will need to travel to where the horses are situated and travel will generally be to areas on the outskirts of Stockholm on public transport. Using an ambitious goal of recording three riding sessions per day would take 20 working days to record the data for this project. A more realistic goal of 1.5 recording sessions per day would take forty working days (almost two elapsed months). A worst case outcome of one rider session per day would require sixty working days (three months elapsed) recording data.

- *Recruit participants* - Use Snowball recruitment techniques. Obtain a Letter of Introduction from the NZ Equestrian Federation to the Swedish equivalent organisation. Use this introduction in conjunction with existing contacts between Wireless@KTH academic staff and the sports research coordinator for the Swedish Olympic Committee and personal canvassing of local equestrian related shops and publications in the Stockholm area to obtain initial contacts within the Swedish equestrian community and use these initial contacts to start the recruitment Snowball rolling. Review and modify recruitment procedure as needed.
- *Record data collection sessions with participants* - Inertial sensor readings are captured from a single device worn on the wrist of a selection of riders who go about their normal rider training activities, both unmounted and mounted. In addition, the riders are also videoed in such a way that the sensor data will later be able to be time synchronised with the video signal.

Unstructured, non-participant observation, utilising Field studies will be used. Non-participant in this context means that the researcher is not permitted to participate in the activity (Bryman, 2004) of riding training with the rider but is free to observe the rider.

Data capture will take place within equestrian training facilities within public transport commuting distance from KTH's, Kista campus. Ideally multiple training facilities will be used, preferably where the participants normally train. This will provide variability of riding conditions and convenience for riders. Greater variability will enable the data to be more realistic as riding training facilities vary in the real world. Making the data capture more convenient for the riders will help ensure a good participation rate.

Data needs to be collected from as realistic situations as possible within the constraints of the project and as far as possible during the data capture process, the riders should act as they normally would during a normal riding session, to retain realism. For this reason, the instructions to the riders need to be minimised and be as flexible as possible in terms of where, when and how the data recording sessions are conducted.

A log will be kept of each data capture sessions. The basic circumstances surrounding each data capture session and some basic attributes of the data from each session will be recorded and used to identify data that will be included or excluded from the analysis phase, based on the issues and attributes of the data.

Data Validation & Storage

- *Validate the data recorded from data collection sessions* - Feed back any desired changes to data capture procedures, note any files that have data problems or that are unusable. Note any process issues found during data validation that are associated with data capture and feed these back into a modified data capture process. Convert and store both sensor and video data in easily usable formats. The sensor data is checked for consistency and stored in a format that allows simple retrieval and analysis. The raw video data is transformed into a format that allows for easier handling and review and stored in a way that allows simple retrieval and review.

- *Organise files and resources for transport back to NZ* - Ensure that there are multiple copies of data in case any data gets damaged or goes missing on transit. As far as possible ensure key data capture tools are transported back to NZ so that they can be re-examined during analysis, if necessary.

Data Analysis

Once the data is captured it is analysed in two parts. Initially the video data is viewed to identify where the key activities of interested (mounting) take place in a temporal sense. That is, the place where these activities occur, time-wise within the video data stream. This is done primarily by the researcher with some videos also viewed by the riders themselves and by an independent and qualified riding coach to triangulate the researcher's analysis.

- *Organise for riders to review their video files* - Each rider will view up to 120 minutes of video for each session, to identify a time range on the video that corresponds to when the rider is mounting and possibly other points of interest if there is time. The video viewing will take place within the Wireless@KTH laboratory on a suitable computer loaded with an easy to use video viewing package.

- *Organise for a third party equestrian coach to review the video files* - The coach will view up to 70 hours of video and this may take 80-90 hours to do. The coach will identify a time range on the video that corresponds to when the rider is mounting, other points of interest may also be recorded if feasible for later studies. In reality the coach need not view the whole video as mounting almost always takes place towards the start of the video. Any video's with multiple mounts will be noted so that those videos can be viewed throughout. Viewing will be done with a relatively sophisticated video viewing package so that the coach has good controls for shuttling backwards and forwards through the video.

- *Review the video files* - The videos will be reviewed by the researcher to identify a time range on the video that corresponds to when the rider is mounting. This process of review is triangulated with reviews of some videos being done by the participant themselves and by an independent and experienced riding coach to provide a check against bias on the part of the researcher. All videos are reviewed by the researcher to identify the mount ranges. The researcher alone reviews the videos to identify the synchronisation points, preferably more than one synchronisation point per video so that it will be possible to test for time drift within the video signal.

- *Review sensor data* - Identify synchronisation points, use data capture logs to assist.

- *Synchronise the sensor data files with the video files* - Do this initially for the laboratory data as this is easiest and will provide good experience for the real data files. The video data and the sensor data are compared to identify the points where they can be synchronised. The sensor data is then synchronised to the video data based on pattern matching to a known movement (strong hand wave or hand clap) that can be seen both within the sensor data and on the video.

- *Identify the range within the sensor data where the mounts take place* - The area within the sensor data where mounting occurs is established by reference to the video using timings extracted from the video files together with the time associated with the synchronisation point. Extract and present this range of sensor data in a visual format.

- *Analyse the visual representation of the sensor data* - A selection of mount “points” are then analysed for consistent patterns using heuristic pattern matching. Once consistent patterns are found they are then used predictively on other sensor data streams from the study to see how accurately they recognise a mount. Modify visualisation as needed and re-analyse. Repeat until conclusions can be drawn or no conclusion is possible.

Draw Conclusions and Publish

- *Form initial conclusions, test conclusions and re-analyse if needed* - Draw conclusions based on what is found during pattern matching. Ensure that the data is presented in a way that assists the pattern matching process.
- *Form final conclusions* - Form conclusions and test on appropriate data.
- *Publish results* - This document and any possible following documents or presentations.

Post Project Close Down

- *Ensure that participants who requested their video files get them* - Mail, deliver or courier DVD's containing each participants videos to them.
- *Ensure that participants who requested a short form copy of the results get them* - Post, e-mail or present a short form version of the results to interested participants.
- *Decide on long term strategy for the sensor and video data* - Ensure either long term storage of sensor and video data if the data will be used within future projects or destroy data.

Research Design Outline Summary

The preceding list gives the minimum set of tasks that are considered necessary to complete this research project to a professional level. Within the preceding description of the steps involved, mounts are sometimes referred to as “points”, this tends to imply an instantaneous or almost instantaneous point in time where a mount or dismount occurs. In fact a mount is a series of actions that take place over a range of times that could be anywhere from several seconds to several minutes long.

The definition of when a mount or dismount starts and when it is complete is synthesised, by the researcher from the results of the triangulated video reviews and to a certain extent is relatively arbitrary. Neither the rider nor the horse really cares to any extent about how a mount or a dismount is defined. The only person who cares is the researcher himself and the only purpose for having a definition (in this context) is to allow one mount sequence to be compared with another mount sequence in a consistent manner. Lastly, when the definition is (eventually) used within a device to derive the states of “being on a horse” or “being off a horse” then the composition of the definition is also somewhat irrelevant, what is relevant, however, is the reliability of the state prediction that is derived from the definition and the usefulness of the state itself.

The sub-methodology used during the field study data capture sessions will be unstructured, non-participant observation. Non-participant in this context means that the researcher is not permitted to participate in the activity (Bryman, 2004) of riding training with the rider but is free to observe the rider. This is done to ensure, as far as possible, that the researcher has the least possible influence on how the rider acts and mounts. This is also one of the reasons why a complete riding session is recorded as this is more natural and de-emphasises the mount process. If the mount phases is highlighted by only videoing up until the rider mounted then there is a greater chance that the riders would “perform” what they consider to be a perfect mount rather than just doing what they normally do.

Lastly, having a record of the whole riding session provides the riders with something of value out of their participation and there may be a use for the data in possible follow on research into dismounts and riding activities.

Research Design Ethical Issues

This research project involves working with people to record data as they go about their normal horse riding activities and as such needs to address any reasonable issue related to informed consent from the proposed participants and to account for any possible health or safety issues that may be related to the project.

The project involves working with children between the ages of 14 and 17 inclusive in some cases and so requires special attention to informed consent to ensure that these participants and their legal guardians have adequate information, in an appropriate form to enable informed consent to be granted. Participants aged 18 and over are considered to be adults for the purposes of informed consent within this project.

All of the participants will be riding a horse during data collection. This will always be their horse in the sense that they are the person with authority to control and make decisions about the welfare of that horse. No equipment will be directly attached to any horse and all participants will be expected to go about their normal horse riding activities and so while horses are a necessary component of this project no additional ethical procedures will be implemented to take this into account. Both the welfare of the participants and that of their horses is a priority throughout this project.

Most importantly in terms of possible ethical and informed consent issues, the participants are to be recruited from within the Swedish equestrian community. This raised two further issues, that of language used to describe the project to participants so that informed consent could be properly gained and the possibility of a second level of formal ethical compliance rules associated with both KTH university and the Swedish research system as a whole.

Copies of all ethics documents are included in the appendices and include:

- A participant information sheet that sets out in non-technical language the purpose of the research and what is expected of participants if they take part. This includes a summary of possible safety concerns and methods for resolving or mitigating those concerns.

- A single consent form for participants aged 18 and above and a dual consent form for participants aged 14 through 17. The consent form requires separate affirmation that the participant wishes to take part in the research, has read and understood the participant information sheet, has no safety concerns, assigns copyright in both the sensor data and video and image data to the researcher and gives authority for the researcher to present both data and images for public viewing in an appropriate arena (such as a presentation to a conference or within a published paper in an academic, equestrian or sporting journal).

Each area of consent may be separately affirmed or denied so that it is possible to agree to take part and to assign copyright but to not agree to publish images at a conference or within a journal. In the case of a participant aged between 14 and 17 both the child and parent/guardian are required to affirm consent and this is done on separate documents so that there is a requirement for both participant and parent/guardian to actively give assent with some small degree of separation between the two.

- A confidentiality agreement that is designed to be used with co-workers and consultants who help in some way within the project and who come in contact with participant data but who are not the researcher or his NZ or Swedish supervisor.
- These documents are written in English and translated into Swedish. Swedish first language speakers were given the option of having the documents in either language and universally chose to read and sign the Swedish copies.

Data Collection (The Actuality)

The Research Design section described what was planned, what actually happened during data collection and data analysis is described in the following sections.

The first rider data collection session was recorded on the 15th July 2008 and the last rider data collection session was recorded on the 14th September 2008. Data collection could not start until the sensors had been built and tested. The data capture sessions took place around the greater environs of Stockholm, neighbouring Uppsala and with nine sessions covering three riders also being recorded in Örebro.

Data collection took three months elapsed time to complete, the worst case planned scenario. The extended data collection period occurred as a result of a number of factors including underestimating the logistical issues involved in organising each data collection session over a the Summer holiday period (when many participants went away on holiday) in a second language and the time involved with using public transport to get to widely dispersed venues across an 88klm by 62klm area of greater Stockholm/Uppsala (see Appendix 6 for a map of data collection sites).

Data Collection Time Line

Date	*Venue*	*Travel Distance*	*Travel Time*	*Mode of travel*	*Number of files*	*Data files names*	*Notes*
Jul 15	Tierp	140klms	4hr 50min	Bus/Train/Car	1	0715PH1	Rider fell, modified accelerometer sensitivity
Jul 16	Tierp	10klms	20min	Car	4	0716CF1, 0716HH2, 0716ME4, 0716HH5	Rider discomfort, replaced iPaq holder
Jul 17	Tierp	140klms	4hr 50min	Bus/Train/Car	4	0717CF1, 0717HH2, 0717CF3, 0717PH4	Rider fell, data lost
Jul 19	Mariefred	157klms	5hr 0min	Bus/Train/Car	1	0719JC1	
Jul 23	Taby	80klm	3hr 0min	Bus/Train/Car	1	0723AD1	
Jul 24	Akersberga	70klm	3hr 40min	Bus/Train/Car	1	0724MW1	Sensor upside down, modified case
Jul 29	Taby	80klm	3hr 0min	Bus/Train/Car	1	0729AD1	Power cable dislodged, data lost
Aug 12	Jarna	116klm	4hr 0min	Bus/Train/Car	1	0812AO1	First use of MS sensor, data corrupted
	Vallentuna	42klm	2hr 40min	Bus/Train/Car	1	0812HH2	MS data corrupted by serial driver
Aug 13	Kista Lab	1klm	10min	Walk	1	0813JC1	Lab session, MS data corrupted, replaced driver
Aug 16	Jarna	116klm	4hr 0min	Bus/Train/Car	1	0816AO1	Logging not turned on, modified set up process
Aug 18	Bro	70klm	2hr 0min	Bus/Train/Car	2	0818MZ1, 0818LW2	No sync signal recorded & power problems
	Uppsala	120klm	1hr 45min	Train/Car	4	0818LL3, 0818ML4, 0818ES5, 0818ME6	Broken power cable found, repaired cable next day
Aug 21	Kista Lab	1klm	10min	Walk	1	0821PH1	Replaced external battery with internal battery after session

Date	*Venue*	*Travel Distance*	*Travel Time*	*Mode of travel*	*Number of files*	*Data files names*	*Notes*
Aug 22	Taby	80klm	3hr 0min	Bus/Train/Car	1	0822AO1	
Aug 26	Sollentuna	10klm	45min	Bus/Train/Car	2	0826BF1, 0826Sl2	Off-side mount
Aug 27	Bro	70klm	2hr 0min	Bus/Train/Car	2	0827AW1, 0827LW2	
Aug 28	Bro	70klm	2hr 0min	Bus/Train/Car	1	0828AW1	Power problems, data truncated
	Sollentuna	10klm	45min	Bus/Train/Car	3	0828BF2, 0828SL3, 0828AO4	Battery problem, data from 2 sessions lost
	Bro	70klm	2hr 0min	Bus/Train/Car	1	0828AW5	New battery with predictable usage curve used
Aug 29	Bro	70klm	2hr 0min	Bus/Train/Car	2	0829AW1, 0829MZ2	
Aug 30	Uppsala	120klm	1hr 45min	Bus/Train/Car	3	0830ME1, 0830ML2, 0830LL3	
Aug 31	Gudo	80klm	2hr 30min	Bus/Train/Car	1	0831NH1	
Sep 01	Bro	70klm	2hr 0min	Bus/Train/Car	1	0901AW1	
Sep 02	Bro	70klm	2hr 0min	Bus/Train/Car	2	0902AW1, 0902MZ2	
Sep 9	Sollentuna	10klm	45min	Bus/Train/Car	2	0909SF1, 0909BF2	
Sep 10	Uppsala	120klm	1hr 45min	Bus/Train/Car	3	0910ML1, 0910ME2, 0910ES3	Battery displaced during sync, 1 data file lost
Sep 12	Orebro	215klm	3hr 20min	Train/Car	3	0912HE1, 0912EE2, 0912PZ3	
Sep 13	Orebro	10klm	20min	Car	3	0913PZ1, 0913EE2, 0913HE3	Battery displaced during sync, 1 data file lost
Sep 14	Orebro	215klm	3hr 20min	Car/Train	3	0914EE1, 0914PZ2, 0914HE3	

Table 1: Data Collection Time Line

Recruitment Methods and Ethical Issues

20 participants were recruited using Snowball techniques. All riders were given the Participant Information Sheet (Swedish translation) to read after they indicated they were interested in taking part in the research. All riders were then allowed several days to read the Participant Information Sheet and were then contacted again and any questions that had come up were answered. All verbal conversations took place in English and it appeared that all riders were confident English speakers. Many riders did not appear to be as confident reading and writing English and so having the Swedish translations of the original English ethics documents was vital for rider assurance.

The researcher ensured that every participant filled in and signed the Informed Consent Form (Swedish translation) before taking part in the first data collection session. All riders were asked to give verbal assent to acknowledge that they had read the Participant Information Sheet and that they had received answers to any questions that they had. For the children who were involved, both the parent giving assent and the child were asked these same questions before any data collection took place.

Two co-workers read and signed the appropriate ethics confidentiality documents. The two co-workers were the NZ riding coach who reviewed the videos back in NZ to triangulate the mounting time ranges and a Swedish riding coach with a video editing background who reviewed some early videos in Sweden and provided useful feedback on improving the synchronisation signal within the video.

Recruitment of participants for the field study was a significant problem because of a lack of existing contacts within the Swedish Equestrian community. The researcher's inability to speak Swedish and unfamiliarity with Swedish customs meant that there were initial difficulties with getting the Snowball recruitment process rolling by finding someone who was willing to either participate themselves or prepared to recommend someone else to participate.

Some difficulties with recruiting participants had been anticipated and so a Letter of Introduction to the Swedish Equestrian Federation (Svenska Ridsportförbundet) with a request for assistance was obtained from the NZ Equestrian Federation prior to leaving New Zealand. This Letter of Introduction did subsequently get the Snowball rolling two and a half months after arrival. The first participant was recruited in June 2008.

Documents explaining the field trials and the role of the participants were translated into Swedish and were both printed out and loaded onto a web site (http://sites.google.com/site/ridingcontext/) so that they were readily available.

The recruitment of the first participant was the key to recruiting the following participants. The first participant introduced the next two participants (a mother and son who both ride). The first participant (a co-researcher) maintains a website for Swedish riders that highlights horse riding related research. This co-researcher put a small item on her website about the research project and the need for local riders to participate. This item was, in turn, read by a reporter from a Swedish Equestrian Magazine who became interested enough to phone to discuss the research. This lead to her interviewing the researcher and featuring the research on the website for her magazine.

In addition the magazine reporter and her husband, who both ride, agreed to be participants and she asked and gained permission for the researcher to attend a planned riding clinic to record sessions with her and her husband. At the riding clinic two additional riders agreed to participate while at the clinic and one of those riders also agreed to participate after the clinic and subsequently referred three additional riders who all agreed to participate. This gave ten participants from the first Snowball contact.

The article on the equestrian magazine web site generated a lot of interest and over forty people enquired about being participants. Of these, fourteen finally agreed to participate and eight of these subsequently withdrew for various reasons such as horse got injured (x2), elderly parent became sick (x2 - husband and wife), person went on holiday and didn't return until after the trials were complete (x4). This provided an additional six participants. Two of these participants, in turn, referred two additional riders each who all agreed to participate giving a total of twenty participants altogether.

The researcher suspects (but this is untested) that many of the 40 people who showed initial interest after reading the magazine's web site article but who then subsequently dropped out may not have been confident English speakers and so there is a possible bias in the participant sample towards confident English speaking riders.

The twenty participants had all been recruited by early July and no further participants were added after this.

Sample Size and Selection Method

The group of twenty volunteer participants all agreed to have their riding sessions recorded. Three sessions were recorded for most riders. Fifty-five real life data collection sessions and two laboratory data collection sessions were recorded for a total of fifty-seven rider sessions. Three riders participated in a single real life recording session, three in two real life sessions, four in four sessions and the remaining ten riders took part in three recording sessions each. Two riders also took part in one laboratory recording session each.

The number of volunteers meant that it was not practical to screen and choose sample participants so as to stratify them into differing mounting styles, differing age groups, differing sexes, differing dominant hand or on any other criteria because there was insufficient time to recruit more riders than the initial volunteers. However, the enthusiastic group of twenty participants had some natural variability in terms of sex, age and handedness.

No formal classification was attempted for rider ability or horse training level because it was reasoned that this would overly emphasise performance during field trials when the researcher's emphasis was on recording commonly occurring, everyday activity.

The video was used to record mounting style and no additional written record was kept of the three basic styles of mounting found within the sample (stirrup mount from ground, stirrup mount from mounting block or aided mount - leg up). Using the video to record this information meant that the researcher was left free to concentrate on correctly setting up the sensors and video equipment at the busy time during the start of the session rather than also needing writing materials and time to write things down.

It may well, however, have been useful to record horse height and participant height independently from the video record so that this could be tested for significance but this was not done at the time. The *relative* difference in heights between horse and rider may have some effect on mounting method. In most cases, however, it would be possible to estimate this relative height difference from the video records.

The average data collection session recorded between 55 and 75 minutes of video (approximately 8GB to 18GB of raw video) and between 2.0MB to 3.6MB of sensor data per hand for a total of around 860GB of data for all recorded sessions (includes raw sensor data, raw and compressed video files).

Bao and Intille (2004) analyse the participant numbers in a selection of 11 papers that involved studies that used inertial data for context or activity recognition and found that nine papers conducted their data collecting within laboratory settings and used from 1 to 24 participants with three of those only using a single participant and with a mean number of participants of 8.5. Of the two remaining papers that conducted their data collecting within a natural setting, one paper used a single participant while the other paper used 24 participants with two sessions each giving a total of 48 recorded sessions.

An offer of 10 riders was received from Strömsholm riding school (one of three Swedish National Riding Schools) but all riders were of a similar age, sex and training level and there was a danger of skewing the data with this group. However, the riding school was closed during the data collection period and the offer was not taken up.

In this project a balance was attempted between a larger number of participants and sessions and a smaller number that would allow the research to be conducted in a timely manner, with the bias being towards more data collection than less.

A reasonably large number of rider sessions were needed because in general there was only a single mount per session. For most other similar studies, including studies that collected data from realistic settings, the researchers were able to record multiple occurrences of the event or events of interest during each recording session.

A decision was made not to attempt to record multiple mounts from a single real world session for two reasons and these were for animal ethics and methodological reasons. Mounting a horse is one of the more physically stressful activities that a rider does with his horse. Unless a rider mounts using a mounting block that is high enough for the rider to swing their leg over the horses back without pulling up on the horse or they get a “leg up” that is high enough that they don't need to pull on the horse, then when a rider mounts they need to put their whole weight on one side of the saddle/stirrups while they pull themselves up high enough to get a leg over the horses back.

For the period while the rider is lifting themselves up, their weight acts to rotate the saddle towards the rider and so to counteract this the girth that goes under the horse's chest and holds both sides of the saddle close to the horses skin needs to be done up tight enough that the saddle cannot slip towards the rider. Even with a well fitting saddle and properly adjusted girth this one-sided weight is uncomfortable for a horse and they will change their stance and balance to prevent themselves from being pulled over on to the rider.

Commonly many saddles do not fit their horse that well and girths are often not properly adjusted. In these cases mounting can cause these horses pain. It was considered unethical to put any horse through unnecessary discomfort simply to collect data at a faster rate for the project.

Secondly, the methodological aim is to collect real data from naturally occurring conditions with the least possible interference or direction from the researcher and so it was reasoned that asking for multiple mounts during data collection would possibly bias the data collected.

Riders used a wooden “model” horse that was constructed by the researcher when they took part in multiple mounting sessions within the Wireless@KTH laboratory. Use of the wooden horse both resolved the animal ethics issues and provided a stable and relatively unchanging platform that made it simple to compare one mount instance with another, both for the same rider and across riders.

Participant Table

Age group	*Male*			*Female*		
	Left	Right	Ambi	Left	Right	Ambi
Under 18	0	1	0	0	2	0
18 and over	0	1	0	5	10	1
TOTAL	0	2	0	5	12	1

Table 2: Participants by sex, handedness and age group

Horse riding is a female dominated sport. In New Zealand approximately 87.5% of Equestrian sport participants are female and 12.5% are male (van Aalst, Kazakov, & McLean, 2003a), while in Sweden approximately 83% of members of Svenska Ridsportförbundet (Swedish Equestrian Federation) are female and 17% are male (*Sports in Sweden*, 2002). The mix of participants in the study approximately matches the Svenska Ridsportförbundet membership figures with a slight over representation of females at 90% female and 10% male participation.

However the New Zealand figures are from samples taken from the general population whereas the Swedish figures are membership figures for the official equestrian sport governing body in Sweden (no Swedish general population figures for equestrian sport participation were found in English). It is quite possible that males are over represented within the membership of the official sport governing body and so the sample may well represent underlying Swedish horse riding population participation levels. In any case it is not thought that the sample is significantly skewed from an expected sample of the underlying Swedish horse riding population with relation to the sex of participants.

Annett (1967) cites various studies that suggest that approximately 70% of the population are completely right-handed, 25% mixed handed and 4% completely left-handed. According to Annett there is no significant difference between males and females for handedness.

While the study figures suggest an over representation of left-handed riders and an under representation of ambidextrous riders (70% right, 25% left and 5% ambidextrous in the study) this may well be a mislabelling issue on the part of the researcher that has occurred as a result of the verbal (rather than written) questions on handedness and possible language difficulties rather than representing a significant difference in the sample itself.

Participants were required to specify if they were aged 18 and over for ethical reasons. Participants aged 17 and under were required to gain parental consent to participate. Participants aged 18 and over were not required to state their actual age, just to signify that they were over the age of 17. Age was not initially considered a significant factor for mounting technique but this assumption may not stand without specific tests. Age and levels of physical fitness may be significant factors affecting mounting technique as it takes considerable strength and flexibility to stirrup mount from the ground onto a horse that is often significantly taller than the rider.

No readily available statistics were found in English on a stratification of Swedish horse riders by age and so there is no independent evidence of how representative the sample is of the underlying Swedish horse rider population with regard to age. In any case anecdotal evidence is that there are significant numbers of Swedish horse riders aged under 14 years and this age group is specifically excluded from the study for ethical reasons and so there is inherent skewness towards mature riders.

New Zealand figures suggest that 77% of the young people aged 17 and under who actively participate in equestrian sport are aged 12 and under, with 23% aged 13 through 17 (van Aalst, Kazakov, & McLean, 2003b). If Swedish young riders follow a similar distribution then the sample is significantly under represented in this age group and this age group may well use differing mounting techniques due to rider height. From this it is suggested that the study conclusions might best be generalised across an adult population rather than being applied to younger children especially those aged under 14, without further testing.

Real Life Setting – SF Sensor	*Worn on Right*	*Worn on Left*	*Total*
right-handed participant **Usable data**	**20**	0	**20**
Unusable data	10	0	10
left-handed participant **Usable data**	**1**	**8**	**9**
Unusable data	0	3	3
Ambidextrous participant **Usable data**	**1**	**1**	**2**
Unusable data	0	0	0
Real Life Setting Totals	32	12	44

Table 3: Real life SF sensor data collection session data by handedness and usability

Of the 44 SF sensor datasets collected under a real life setting, 31 SF datasets were usable and 13 SF datasets were unusable for various reasons (typically power failure or connection problems). Participant wore the SF sensor on their right arm for 22 of the usable datasets and on the left arm for the remaining 9 datasets.

The participant's right hand was consistently used differently from their left hand during mounting. Typically a participant would hold the horse steady with their left hand while using their right hand to assist with mounting, often grasping the cantle with the right hand while mounting. This specialisation occurred regardless of the underlying handedness of the participant involved and related more to the side from which the horse was mounted (almost exclusively the near side or left hand side of the horse) and the mounting technique used than other person specific factors such as dominant hand.

This consistent differentiation meant that data collected from the sensor while worn on the participant's left arm was different from data collected from the sensor while worn on the right arm. This meant that the two collections of datasets needed to be analysed separately, although using the same underlying technique. There was insufficient time within the project to analyse both sets of data and so the largest collection of datasets, those collected from the right arm, was chosen for analysis. Given that the goal is to develop a recognition method it is reasonable to develop this using the larger collection of data sets and then postulate that the same or a similar method could be developed for the smaller collection of datasets. This is the approach that was taken and as a result the analysis is restricted to the datasets collected from participant's right arms. There is further comment on this within the conclusions chapter.

The decision to work exclusively with data collected from the right arm reduced the sample size and skewed the sample towards right-handed participants because the SF sensor was generally set up so that it was worn on the participant's dominant arm. This meant that most left-handed participant's had their data excluded because the sensor was mounted on their left arm. In one case a left-handed participant wore the SF sensor on their right arm and in another case an ambidextrous participant wore the SF sensor on their right arm. Both cases have been included in the analysis.

On reflection, there would have been a greater quantity of less skewed data if the SF sensor had been consistently mounted on the participant's right arm. The data collected from the left arm is, however, available for possible future studies.

Data Collection Instruments/Tools

The data collection tools used to capture the sensor and video data from the rider sessions were a Sparkfun (SF) 6 degrees of freedom inertial sensor with Bluetooth data communication, an iPaq Pocket PC PDA with corresponding Bluetooth data communications to receive data from the inertial sensor, facilities to mount the inertial sensor on a rider's wrist and facilities to mount the iPaq PDA on the rider's waist, a PanasonicNVDS60 portable video camera with two third party 2200mAh rechargeable batteries, a Firewire cable for connecting the camera to a PC to download video, a Davis & Sanford DACSSQ Steady Stick waist mounted camera unipod, extended-record 80 minute Mini DV video tapes, Zterm terminal emulation software for iPaq Pocket PC, Microsoft Pocket PC file sync software, a laptop computer running Windows Vista for downloading sensor and data files in the field and a desktop PC running MS Windows XP for data storage. A wooden horse (Diana) was constructed for use during the laboratory sessions. These items are described in more detail in the following sections.

Sensor Description

The SF inertial sensor contained a Freescale MMA7260Q triple-axis accelerometer, two InvenSense IDG300 500°/second gyroscopes and both a Honeywell HMC1052L and HMC1051Z magnetic sensor. The sensor can output up to 12 fields of data per cycle; a start character “A”; a counter that increments from 0 to 32767 in increments of 1 and then rolls over back to 0; X, Y & Z 10 bit magnetic axis readings; X, Y & Z 10 bit accelerometer axis readings; Pitch, Roll & Yaw 10 bit gyroscope readings; followed by a ”Z” stop character and line feed-carriage return.

The control programme delivered with the sensor has a command interface that allows various parameters to be set, they are:

- Selection of active channel list. Each of the nine data readings (3 x magnetic, 3 x accelerometer & 3 x gyro) can be turned on or off individually. Set for **all nine sensor channels to be active.**
- A selection of binary or ASCII format for the output. Set to **ASCII.**
- A toggle to allow auto-run on power up or to require manual input before running after power up. Set to **auto-run.**

- A choice of four sensitivity levels for the accelerometer, from 1.5g, 2g, 4g to 6g. During initial testing and for the very first data collection session this was set to 1.5g as this was the most sensitive setting. However an initial analysis of the sensor data from the first session found that the accelerometer readings often peaked at maximum and minimum levels and so from the second data collection session through to the last the sensor set to the **2g** setting**.**

  Verplaetse (1996) suggests that during active arm movement (such as swinging a tennis racket or baseball bat) that acceleration ranges for the hand and lower arm can reach from 0.5g to 9.0g. However, when set to 2.0g the sensor rarely reached maximum or minimum levels during normal riding or during pre and post riding activities. Maximum and minimum levels could, however, be relatively easily induced when generating the synchronisation signals using an overhead clap and this was useful for data synchronisation.

- A choice of output frequency, from 10Hz upwards. During tests using Bluetooth SPP connections the device frequently dropped data packets when set to frequencies higher than 100Hz regardless of distance between the Bluetooth transmitter and receiver. For frequencies between 30hz and 100Hz the frequency where data packets were dropped depended either on the distance between the Bluetooth transmitter and the receiver or on possible signal interference. Verplaetse (1996) suggests that the human hand and lower arm moves at a frequency of less than 12Hz.

  The sample frequency rate was set to **10Hz.** This was done to keep the sensor data volumes at a manageable size while taking into account Verplaetse's observations. On reflection, a sample frequency of 25Hz may have simplified synchronisation with the video data that was filmed at 25 frames per second and would have been consistent with the Nyquist–Shannon sampling theorem at the expense of 2.5 times bigger sensor files and the possibility of dropped packets.

- A choice of Bluetooth or hard-wired serial TTL output. Set to use **Bluetooth.**

A detailed specification for the SF sensor device is given in appendix 2.

Sensor Justification

The inertial sensor was a key tool for data collection and this was identified during the planning stages for this project. A search was made to try to find a commercial sensor that could be used and a number were identified including motion capture products from Xsens (Xsens Technologies B.V., 2009), and inertial measurement units from Microstrain© Inertia-Link® (MicroStrain Inc., 2009), MEMSense wireless IMU (MEMSense LLC, 2009) and several other products from other companies. In all cases the purchase cost of these devices was well over US$1,000, often much higher than this. These costs were outside the scope of the project.

The possibility of building a sensor from scratch with extended support from other schools within AUT was investigated but the lead times on this were from 8-10 months are so was not practical. A survey of sensors used within other projects was undertaken but no suitable sensor was found that was available at a reasonable cost. Whilst undertaking the survey, Professor Smith of the Wireless@KTH laboratory at KTH university in Kista, Sweden offered to assist by building a sensor. He had built similar devices and had an existing SmartBadge platform that was a contender for modification to meet the project needs. Professor Smith offered to host both the device build phase and the data capture phase within the local area. This became the preferred option.

The initial design goals for the sensor build sub-project specified an accelerometer as a movement sensor with four simple tilt sensors to detect gross angular movement. During the build process and after some tests with prototypes the design goals were changed to add a requirement to refine the sensing of angular motion within the device.

Illustration 1: An early prototype based on a modified SmartBadge platform

The requirement for more refined angular motion sensitivity meant adding a gyroscope. By this time a device based on the original design was almost complete and so a decision was made to keep that design as it was and to look again for a cost-effective commercial device with both an accelerometer and a gyroscope integrated into the one device. This was to be the device to be used on the dominant arm while the original sensor device would be used for the non-dominant arm. This second search had the advantage of several months knowledge of working with prototype sensors and so there was more knowledge about the area of inertial sensors in general and possible sourcing sites in particular and a suitable commercial bare-board device from Sparkfun in the USA was found that both met the technical requirements and was affordable.

The SF inertial sensor, a Sparkfun IMU 6 Degrees of Freedom v4 device, used the same accelerometer chip (Freescale MMA7260Q triple-axis) as the KTH purpose built board (hereafter referred to as MS) and so the readings from both devices were broadly comparable although the MS board used an 8 bit analogue to digital converter to read the accelerometer readings while the SF board used a 10 bit ADC. Papers that fully describe the sensor build process are referenced on page 53.

The SF sensor consisted of two bare boards linked together. This dual-board combo needed to be mounted within a suitable case and provided with a battery operated power supply before it could be used. The SF sensor was mounted in a 70 x 50 x 30mm plastic case that was locally sourced and in its initial configuration used an external battery pack connected via a short wire, see page 94 for photos and description. This was the most convenient configuration when used during initial tests within the lab but the external wire and additional mount for the battery proved inconvenient and problematic during field data capture, see page 94 and 95 for problem descriptions and design iterations. The sensor was modified to use a larger 70 x 50 x 45mm case with an internal battery.

Illustration 2: Side view of SF sensor in final form, Velcro button on bottom of case.

iPaq Pocket PC and Zterm terminal emulation software

An HP iPaq Pocket PC running the Zterm terminal emulation software from cool.stf was used to receive and capture the data from the SF sensor. During each data capture session a Bluetooth SPP session was established between the SF sensor and Zterm on the iPaq. Using this, Zterm's screen dump output log file was set up and logging was started. On start up the SF sensor settings were confirmed, the sensor reading count reset to zero and the sensor readings captured to the log file on the iPaq.

The sensor was placed on the rider's wrist and the iPaq is placed in a “water bottle” belt that was worn around the rider's waist. The iPaq has a piece of duct tape (top right hand corner) placed over the on/off switch so that the iPaq could not be accidentally turned off if the rider brushed the switch with a hand or any riding equipment.

At the end of the data collection session Zterm on the iPaq was checked to ensure that data had been recorded correctly, then the log file was closed and the iPaq battery checked and changed if necessary, ready for the next rider.

The HP iPaq was used because it was wearable, had reasonable battery life, it had internal storage capacity of 64MB of data, enough for approximately 20-30 data collection sessions, it was simple to use and to connect to a desktop PC running MS Windows XP to download the data, it had the option of running the Zterm terminal emulation software over Bluetooth SPP protocol and because it was freely available from the Wireless@KTH laboratory equipment store. Some problems with fully charging the iPaq battery (a known issue for this device) were encountered and as a result a second battery was used to ensure that a full day's data collection could be collected using both batteries. The Zterm terminal emulation software was chosen because it worked on the iPaq, it fulfilled the requirements and because it was relatively cheap to purchase at under NZ$100.


Illustration 3: HP iPaq in its charging and syncing cradle

Sensor and iPaq mounting equipment

A Velcro button was glued to the bottom of the SF sensor case and this button connected with a stretchable band of wide, double-sided Velcro tape that was wrapped around the rider's wrist. This proved to be a cheap and effective way of attaching the sensor to the rider's wrist. The sensor never accidentally came off the mount and it proved secure. Initially the iPaq was worn around the rider's waist in a linen money-belt but this was uncomfortable for riders and so was replaced with a much wider and stronger belt that was originally designed to hold a water bottle for distance runners.

Illustration 4: Sensor & iPaq mounts after washing - iPaq belt on left (plastic holder for iPaq is at bottom), sensor mounts are two brownish straps, strap on right is battery holder for an early version of the SF sensor.

Illustration 5: A participant wearing the iPaq on her right hip and the SF sensor on her right wrist

Panasonic NVDS60 portable video camera

The Panasonic camera was used with a Firewire cable for post-videoing download of video files to a MS Windows XP PC and in the field was used with a Davis & Sanford DACSSQ Steady Stick Compact waist mounted camera unipod and two after-market 2200mAh rechargeable batteries to allow up to seven hours of videoing.

Eighty minute mini DV video tapes were used to ensure that most rider sessions could be completely captured on a single video tape. Tapes were only used once because the video camera would only write a consistent uninterrupted time code signal to the video tape if the tape was new (previously unused) and if the tape was not stopped from when filming started through until filming ended.

The Panasonic camera was already owned by the Wireless@KTH laboratory and the costs of an alternate camera was unaffordable. The camera worked well both indoors and outdoors. Two issues were that the tapes cost approximately NZ$17 per tape (x 60 tapes = NZ$1,020) and video downloads took as long as it took to video the original tape (I.e. up to 80 minutes to download one tape) and without a tape changer, downloading multiple tapes overnight meant waking every 90 minutes to change tapes.

Illustration 6: Panasonic video camera

Diana the wooden horse

Diana was constructed to allow the capture of multiple mounts within a controlled situation, so that there would be a larger number of instances of a mount to search across while looking for possible commonalities during mounting. Diana had a saddle height of 163cm and was constructed from 4x2 timber, saw-horse hardware, wood screws and Vet Wrap elastic bandages to provide a smoother surface for the girth to sit on. This ensured that the girth was not damaged while mounting.

Illustration 7: The researcher next to Diana

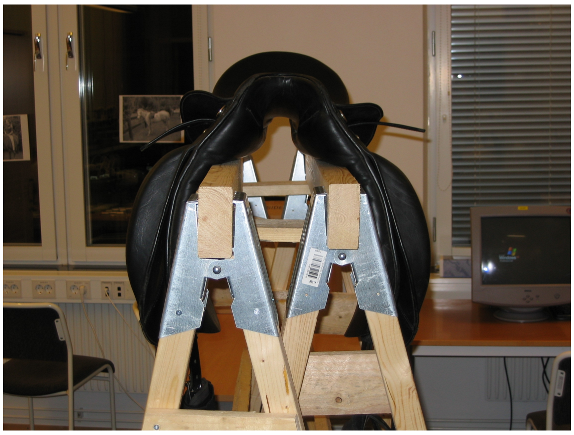


Illustration 8: Diana with saddle fitted

Illustration 9: Vet Wrap to protect the girth

Data Collection Validity & Reliability Measures

The data collection and reliability measures can be categorised by contrasting procedural and mechanical measures at design and implementation time, yielding a four quadrant validity and reliability table, shown following.

Pre and immediately post-data collection - validity and reliability table

	Design	*Implementation*
Procedural	Write pre-data collection check-list	Do actions listed in pre-data collection check list including set sensor params
	Write data collection session organiser “tip sheet”	Send organiser “tip sheet” to organiser ahead of first data collection session
	Write data collection session “tip sheet” for solo riders	Send solo rider “tip sheet” to rider ahead of data collection session
		Allow time for set up procedures prior to session start
		Allow time for data checking & download after session end
	Design an enthusiastic synchronisation arm movement for riders	Ensure riders do enthusiastic arm movement at start of session
	Ensure video and sensor data can be correctly identified	Have riders say their name at the start of videoing
		Ensure video Time of Day clock is set to the correct date and time
	Keep a participant-session log	Record rider name and date of session within sensor file log
		Name all files with rider name and session date
		Update participant-session log each day when data collection is done
		Write down notes daily on any unusual or noteworthy occurrences

	Design	*Implementation*
Mechanical	Design reliable sensor power supply	Monitor power use & change batteries when needed
		Monitor video camera and iPaq battery use and change when needed
		Recharge batteries overnight
	Design sensor case with obvious orientation marks	Ensure sensor is correctly aligned with orientation mark when worn
	Design covers for any external power switches on iPaq, sensor and battery pack	Ensure power switch covers are in place before starting
	Design equipment mounting apparatus for rider comfort, safety and secure mounting	Ensure equipment (sensor, iPaq & battery) are correctly mounted
		Carry spare video tapes
		Backup all new files to a PC daily

Table 4: Four quadrant table of data collection validity and reliability measures

For example, a check-list of actions to be carried out immediately prior to each data collection session was developed. This check-list is a *procedural design* measure as the process was designed to cover actions that needed to be performed immediately prior to data collection so that there was data available after the session in a standard format, using desired sensor parameters such as sample frequency rate, accelerometer sensitivity and active sampling channels. The check-list is shown in appendix 3.

Following the check-list procedure on the day became an implementation issue. In one example the check-list was followed except for the step that turned on logging of the sensor output to the log file. Resulting in a data collection session that collected no sensor data. Initially an informal check-list was run through and the sensor set up was done from memory. However, after the session where no data was recorded to the log file the set-up actions were reviewed and a formal check-list was developed to help make future data collection sessions more reliable. The check-list went through several revisions as the process iterated through problem discovery during implementation and resolution through design.

An example from the mechanical axis concerns power to the sensor. Issues associated with providing reliable power to the sensor over the full data collection sessions were the largest class of mechanical reliability issues overall. After early prototype testing the SF sensor was designed to use one of two similar 5v USB rechargeable battery packs. Both battery packs provided sufficient power to operate the sensor continuously for 14 hours or more, sufficient for a full day's data collection, and recharged overnight. However, both battery packs were larger than the sensor itself and one was a similar weight with the larger, 4 x AA battery device, being heavier than the sensor.

The size and weight of the battery packs meant that it was not possible to mount them with the sensor on the rider's wrist and so they were designed to be mounted on the upper arm/shoulder, with a connecting cable running down the arm to the wrist. The power cable became a point of failure and more importantly, the weight and position of the battery pack and cable became a source of annoyance for some riders while riding and may well have influenced rider actions while wearing the device.

Illustration 10: Two USB power packs for the SF sensor

Illustration 11: SF sensor, USB battery & cable. The joint where the cable broke is circled

The SF sensor was subsequently redesigned to use a smaller battery that was integrated into the sensor case and mounted on the rider's wrist. This resolved the weight and discomfort issues but introduced issues related to the battery not lasting over a full days use and subsequent data loss. Different battery types were tried in an attempt to balance battery size, weight, power capacity, cost and predictability. The final and most reliable configuration consisted of 2 x non-chargeable, 3 volt digital camera batteries. This was also the most expensive option and required new batteries every four days.

The SF sensor required the input current to be maintained in a range from 4.2 to 7 volts DC. This proved awkward when considering off-the-shelf rechargeable batteries , requiring at least 4 x 1.2v rechargeable AA batteries to meet the minimum requirement (bulky, heavy and current delivery quickly fell below 4.2v). Various after-market, rechargeable, cell-phone batteries were considered but all came in either 3.7 or 7.4v configurations (outside current range and so required additional circuitry). Both rechargeable and non-chargeable “button” style batteries were tried in series but these had insufficient amperage to drive the sensor without additional circuitry.

Post-data collection validity and reliability measures

Sensor data

- A copy of the raw sensor file was edited using Notepad++ to extract all comments and set-up parameter documentation notes, changing the “line feed-carriage return” combination to a “carriage return-line feed” combination and inserting commas between all fields. The file was then saved as a .csv file.

- The sensor.csv file was loaded into Open Office Calc (spreadsheet programme) and the incremental sample counter field was tested for contiguity. Where the sample counter field had overflowed back to zero after reaching 32767, the overflow values were replaced with a corrected sample count. The sensor reading fields were checked for missing values and for any out of range values (range is 0 to 1023). Each row was checked to ensure that it had an “A” start character at the beginning and a “Z” stop character at the end. Any files with invalid data were noted. The total number of sensor rows in the file was divided by 10 (10Hz sample rate) to obtain an elapsed time period covered by valid sensor readings and then the file was saved as an Open Office Calc file.

- The elapsed time of the sensor file was compared with the elapsed time of the video and any notes in the data collection log file concerning the elapsed time for that data collection session. Any inconsistencies were noted.

Video data

- The end of the video tape was reviewed on the video camera and the elapsed time was noted. The video tape was rewound and the start was reviewed to ensure that the synchronisation arm wave had been captured.
- The raw video file was transferred from the tape in the camera to computer using a Firewire cable and Sony Vegas Pro linear video editor. The video was reviewed on the computer to ensure that the file was contiguous , that there were no obvious issues and that it contained the footage of the rider mounting. The elapsed time was compared with the tape file and inconsistencies were noted.
- The raw video file (AVI format) was converted to MPEG format to reduce disk space from 6-18 Gigabytes per file to 1.3-3.9 Gigabytes. This considerably improved computer response times for any subsequent action on the files.

Immediately prior to returning to New Zealand the remaining unconverted video tapes were bulk captured and converted from AVI to MPEG video format and the rider DVD's were produced and posted to them. This was done to both ensure that backup copies of the video data were produced prior to travel with the associated possibility of loss and also to give the participant riders their DVD's before leaving Sweden.

Six PC's were used to speed up the conversion process. The laptop, Sony Vegas Pro software, Firewire cable and video camera were used to capture the raw tape files to PC AVI format while using five PC's and Sony Vegas Pro freely copyable conversion utility to convert from AVI to MPEG format and then to write a copy of each MPEG file to two DVD's, one for the rider and one as a data backup. In addition an additional PC was used as a file server for network file transfers and an external 670GB hard drive was used to transferred the AVI files between the laptop and the networked PC's.

Illustration 12: Mass capture and conversion of video files. Six PC's with five monitors.

Synchronise the video and sensor data files

- Each valid mpeg video file was reviewed with Sony Vegas Pro and the key frames where the participant's hands met on each of the three synchronising hand claps at the start of the video were identified. The time interval between the claps was measured and noted.

- The validated sensor data file was loaded into Open Office Calc and the three accelerometer axis were graphed. The graph was reviewed until the three peaks and troughs associated with the three hand claps were identified. The graph time scale was zoomed so that the hand clap features were clearly identifiable.

- The graph was used as a pointer into the sensor data to find the spreadsheet row number for each of the clap peaks (note: this is not always an acceleration or deceleration peak although it often is and it is not always on the same X, Y or Z axis as a prior sensor file – this is because of possible arm rotation during the clap). The sensor data sample numbers were identified from the row numbers in the spreadsheet. The difference between the sample numbers was converted into a time interval by dividing by 10 (10Hz = 10 samples per second).

- The time interval between the video claps and the presumed sensor features that represent the claps were compared. If the time intervals matched within one tenth of a second between claps and across all three claps then there was presumed to be a probable match.

- The video offset with regard to the sensor data was calculated. The sensor usually starts first and so the video timer is usually behind the sensor timer by some fixed interval.

- If the video and sensor files had a second synchronising clap sequence at the end (most files do) then the start clap from this second sequence on the video was identified and using the video timer offset the expected position within the sensor data was calculated for the start clap on this second clap sequence. This area was then also graphed.

- The graph of the second sequence of sensor data was examined to confirm that the expected clap features did appear where predicted, within three tenths of a second of the expected sample number. A three tenths of a second drift over sixty minutes was considered acceptable.

- If everything lined up then the original video file offset was considered confirmed and this was noted in the documentation for the sensor data file. If things didn't line up on the second sequence then the sensor data file was revisited and an alternate set of features that could represent the original clap sequence was identified. The process was repeated until both starting and ending clap sequences lined up within three tenths of a second.

- All valid files were successfully synchronised in this manner. It is not necessary to synchronise the sensor data with the video data down to an absolute video-frame-to-sensor-sample point across the full 80 minute video.

A series of tests were conducted early on in the project to test both the video and sensor data time signals for drift using an electronic stop watch and it was found that across an 80 minute segment there was usually less than two tenths of a second difference between the stop watch, video timer and sensor timer. Of course this did not take into account any potential inaccuracies within the stop watch timer but multiple tests were conducted with consistent results. It was concluded that even if the stop watch was inaccurate it did seem to be consistently accurate/inaccurate and the most important factor was the relative difference between the sensor timer and the video timer and that remained consistent. As a result, the study assumes that there was no significant time drift in excess of three tenths of a second across an 80 minute video segment.

The hand clap used for synchronisation was the one at the start of the tape and rider mounts typically also occurred at the start, usually within 10 minutes of starting the video and often earlier than this. This meant that it was only necessary to be concerned about possible drift over an 8-15 minute time interval at the beginning of the video.

It was only necessary to identify the general area within the sensor data where the mounts took place and then graph the data in that area and for a short period either side. This ensured that the sensor data that coincided with the mount was included.

The laboratory trials with multiple mounts and multiple hand claps between each mount was used to further test for drift by comparing each of the first twelve sets of three claps and a further series of six sequences of three claps at the end of the video and less than two tenths of a second mismatch across the whole series was found. This synchronisation process was repeated for each valid set of sensor and video files.

Data Collection Steps

The tenets of the Unstructured, non-participant observation protocols as listed in Bryman (2004) were followed during data collection. The intention was to observe, via video, the actions of the rider with minimal participation from the researcher. The purpose and position of the sensor and iPaq were explained to riders but the only instructions given to riders was “to do what you normally do when riding”.

The researcher did not give the riders any riding directions except where the rider indicated that they would ride outside and then they were asked to let the researcher know if they intended to ride away from the camera for more than 100 metres so that the researcher could follow them on foot. This process was designed to interfere or change the rider's riding habits the least. Thus providing the best estimation of real life circumstances. Of course, in real life the rider would not normally be being videoed and would probably not be wearing a sensor on their wrists.

High Level Description of Field Data Collection steps

The data collection process began with scheduling riders for data collection sessions. A date, time and place for the session was agreed. Then public transportation options were checked (see appendix 6 for the transportation planning map). The data collection sessions were sometimes rescheduled once all rider sessions for the upcoming two weeks were known so as to make the best use of the researcher's time with regard to transportation, provided that the new schedules also fitted with the rider's requirements.

The evening before a data collection session the equipment was checked, particularly that batteries were recharged. Bus and train timetables were rechecked. Any maps needed were printed out, contact details were loaded into a mobile phone and the alarm was set. On the day, the equipment was packed into a bag for transport and the researcher journeyed out to the data collection site.

On-site the researcher greeted the rider or organiser and riders. If a first time rider was involved then the ethics forms were gone through to ensure that they were understood and signed. The equipment and the process of collecting data was explained. The rider would then be asked to put on the belt for the iPaq and the Velcro straps for the sensors. The researcher would go through the pre-ride check-list including turning on the sensor and connecting it to the iPaq and starting data logging. The rider would then be videoed during the synchronisation sequence, preparing to ride, riding and after riding. After riding, the files were checked, saved and the equipment checked to ensure that it was functioning correctly. If there were additional riders at that site then the researcher would iterate through the events in this paragraph. When data collection was complete for all riders at the site then the organiser and riders would be thanked and the researcher would then travel back to Kista or to the next site if additional riders were scheduled that day.

During the field trials a full a record of the rider's pre and post-mount horse riding activities was recorded. Generally, the riders activities from the time that they started putting on their riding specific equipment (such as riding boots, riding helmet, riding gloves) through until after they had dismounted and taken off their riding equipment was recorded on video. This provided data over the full life cycle when a wearable riding coaching aid would most likely be worn and as a result, it provides the most complete data to test against for both positive and false positives mount recognition.

Laboratory Data Collection Steps

The laboratory data collection session was set up to record multiple mounts and dismounts using two participants for one session each and a wooden horse that was purpose built for this type of recording session. Each participant wore the SF sensor on their right (dominant) wrist and the MS sensor on their left (non-dominant) wrist. Both participants stated that they were right-handed. The sessions were recorded on video using a canon DV (Digital Video) camera recording on to the AVI data format.

The video was recorded at 25 frames per second (25Hz) while the samples from both sensors were recorded at 10 samples per second (10hz). Both accelerometers were set to +/- 2g sensitivity. SF data was recorded over a SPP Bluetooth connection to a Lenovo Laptop PC running MS Windows Vista and the MS data was recorded to an internal static ram buffer and downloaded via a serial cable after the session.

The participants were told to follow the following process:

1) Clap your hands above your head three times, vigorously to created an easily recognisable gesture with an associated sound (hand clap) that would be relatively easy to find on both the video and sensor data streams.

2) Stand relatively still while silently counting 1001, 1002, 1003 up to 1010. This was designed to provide a relatively still period between the clap gestures and subsequent movement of approximately ten seconds that would provide some contrast between the movements and that would allow a reasonably clear buffer for movement to settle and that would subsequently allow the researcher space to conveniently differentiate the start and end of each mount and dismount sequence into its component parts.

3) Mount the wooden horse using the usual way of mounting.

4) Once mounted, to again silently count from 1001 to 1010 to provide an approximate 10 second time buffer between movements.

5) Dismount the wooden horse using the usual way of dismounting.

6) Once dismounted, silently count from 1001 to 1010 for a third approximate 10 second interval and then to restart the process from step 1 until ready to stop.

The participants chose to start facing the camera at step one in each sequence and so step three, additionally involved turning left approximately 90 degrees from the face-the-camera position to the prepare-to-mount position and step six correspondingly involved an additional step where the participants rotated right approximately 90 degrees after dismounting to get back into the face-the-camera position.

The participants were provided with written instructions that covered steps one through six and that also stated that the participants were to take their own safety and comfort as being of paramount importance and that other than the written instructions and any questions that they might ask for clarity that they should decide any other points for themselves while staying as close as possible to how they would interface with a real horse during mounting and dismounting.

The six step process was designed to give the following time/action sequence:

A period of easily recognised sync signals (claps), 10 seconds of the Unmounted state (minimal movement), a variable period while Mounting, 10 seconds of the Mounted state (minimal movement), a variable period while Dismounting followed by another 10 seconds of the Unmounted state (minimal movement).

The participant's additional movements (turning left 90 degrees prior to Mounting and turning right 90 degrees after dismounting) were included in the Mounting and Dismounting phases because of where they occurred on the time-line and because of the relative difficulty of differentiating them from the other movements in the Mount and Dismount sequence. In addition, such movements are encountered in real world horse mounting and dismounting activities although after dismounting the rider often turns left 90 degrees (to face the front of the horse) rather than turning right at this point.

Data Analysis Procedures

Introduction

Prior to analysis the inertial datasets have been synchronised with their associated video files and checked for completeness. Each valid video file has had the start and end mount points noted by the researcher and an independent riding coach and in the case of two riders, also by the riders themselves. This provides triangulation of the areas where riders mount.

The definition of the start of a mount is open to interpretation and the definition used by the researcher is **when the rider raises one leg off the ground/mounting step, during a continuous sequence of movements that ends with the rider mounted**. This excludes false starts where a rider starts to mount but does not complete the mount (often because the horse moves while mounting) and also usually excludes pre-mount activities such as gathering the reins prior to mounting. Likewise the definition of the end of the mount sequence is also open to interpretation and the definition used by the researcher is **when the rider is astride the horse, with balanced weight in the saddle**. This often excludes post-mount activities such as re-gathering the reins and adjusting the stirrups and may not always include the rider putting her feet in the stirrups.

The definition of both the start and end of mounting was found to be a subset of the definitions of the riding coach and both riders who marked their own videos. That is, the definitions used by the riders and coach started earlier (usually with gathering the reins prior to mounting) and ended later (usually once the riders feet were in the stirrups). However the coach and riders definitions lead to inconsistencies when applied across all recorded mounts as some riders did not gather the reins prior to mounting and some rode off without putting their feet into the stirrups until some time later.

The essence of when the rider is mounted is when the rider is astride the horse (this is also the dictionary definition of mounted) and so the more stringent definition is defensible as it only include actions at the start that consistently lead to being astride and the mount is complete once the rider is astride. This approach provides a more consistent definition that assists recognition and it is the adopted approach

Given that many riders get on in a similar way it seems logical to assume that this would show up as a regular pattern within the data. If it was this simple then a relative simple search across the raw data may well reveal the pattern. When looking at riders mounting some features are commonly seen such as lifting the left hand prior to mounting to gather the reins, holding both hands relatively still (sometimes resting on the horse or saddle) just before lifting the body off the ground to mount, rotating the left wrist as the right leg comes up and over the saddle, moving the right arm forward as the right leg comes over the saddle and gathering up the reins once mounted.

However these features have highly variable times between them and they also tend to vary depending on how tall the rider is in comparison with the horse; how still the horse stands while mounting; if the rider uses a step to get on, has assistance (called a leg-up) or gets on from the ground without assistance and whether they put their right hand on the rear of the saddle or the front of the saddle as they get on. Shorter riders tend to put the right hand on the rear of the saddle (cantle) when mounting from the ground while taller riders, those with short horses and riders using a mounting block sometimes put the right hand on the front of the saddle (pommel) as they get on.

The following sections describe how the inertial data was analysed. The method used was heuristic human visual pattern matching. This method was applied to graphs of the raw inertial data at the time of mounting to identify any distinguishing characteristics that consistently occurred within the inertial data during the mounting sequence.

Data Analysis Tools Used

Video linear editor and visualisation

Sony Vegas Pro Version 8.1 was used for viewing and annotating the video files. Sony Vegas Pro was chosen because it had the video editing and viewing features required, particularly the ability to "shuttle" the video backwards and forwards at varying speeds and to advance and rewind frame by frame. It ran natively on Windows Vista and therefore had a better reputation for reliability under Windows Vista than some of the other Apple Mac based video editors, it is easy to use, it can be used to annotate video files, it was reasonably affordable to purchase and it had an associated 30 day free trial version that allowed the researcher to test it using real video files prior to purchase.

Sony Vegas Pro was run on the Lenovo laptop because the Lenovo is reasonably highly specified in terms of video editing and the researcher owned the Lenovo himself. Sony Vegas Pro is “keyed” to the machine that it is installed on and so by installing and using it on the researcher's own PC this allowed Vegas Pro to be brought back to New Zealand to continue to be used within the project and to be available for future projects.

Sensor data annotation and visualisation

Open Office Calc Version 2.4 was used for visualising and annotating the sensor files. Open Office Calc Version 2.4 was chosen for data visualisation and annotation because it is free to use, it provides good graphing and it meets the project funding constraints.

Version 2.4 was chosen because that was the current stable version during April 2008 and a decision was made to stay with this version throughout the project as there were no issues within that version that unduly affected the project and it was useful to have a stable and consistent platform through the project lifetime to reduce conversion time and possible issues caused by upgrading. Open Office Calc was run on a PC clone desktop PC.

Computing resources

The Lenovo 3000 N200 laptop runs MS Windows Vista Home Premium, has an Intel Core Two Duo 2GHz processor with 4GB of RAM, nVidia GeForce Go 7300 graphics, 14 inch screen and a 140GB hard drive with a Western Digital external USB2 1000GB hard drive for video storage.

The PC clone runs MS Windows XP Professional SP3, has an AsusTek motherboard, AMD Athlon 64 model 3200+ processor with 2GB RAM, nVidia GeForce 6150 graphics, 19 inch screen, 640GB hard drive, internal 190GB backup drive and external Maxtor USB2 750GB backup drive.

Data Analysis Process Description (The Heuristic Recognition Method)

The heuristic recognition method assumes that all video and data files have been validated and that the sensor data has been synchronised with the video data during prior processes.

Run through the complete mount sequence on the video to see what happened when the rider mounted the horse.

The mount sequences are viewed in order to:

- Understand what is happening with the riders and horses during mounting in a general sense
- Understand what is happening with a particular horse and rider during a particular mount
- Develop some sense of understanding of what varies for a horse and rider from one particular mount to the next and to develop some understanding of why these things vary
- Develop a sense of what doesn't vary or what varies less than other things.

This understanding is not directly applicable to the recognition method because the understanding is of what is happening in the videos whereas the recognition method will look at the raw (uninterpreted) sensor data. However, after viewing a number of mounts, particularly concentrating on what the riders hands do during a mount then it becomes possible to start getting a feel for the types of movements that are involved such as hand raised, quiet periods, wrist rolls and similar movements and in particular the time between such movements. This helps give a feel for how wide a view to take, in a time sense, when looking at the raw sensor data.

The heuristic recognition method training phase

The method used supervised training and so the video files were first loaded into Sony Vegas Pro for annotation of each mount. This annotation was used later when looking at the sensor data files during training. Annotations allowed the researcher to quickly bring up the associated video for a sensor data segment to see what was happening with the rider. Sony Vegas Pro has a feature that allows segments of videos to be annotated and indexed so that it is possible to jump directly to a particular indexed segment. This sped up the process of comparing sensor information with its associated video segment.

- Load the selected mpg video file into Sony Vegas Pro either via the appropriate associated .veg file or load the .mpg file directly.

- The .veg file holds meta-data and data associated with annotations of the video file as well as a pre-rendered sound file and this speeds up the file load.

- If pre-annotated then jump to the mount point. If not pre-annotated then use the data session analysis file and identify the mount point using the video time recorded in that file. Fast forward through the video until that time point.

- Once the general area of the mount is found, zoom on the temporal plane until it is possible to see individual video frames. Move backwards and forwards until the start of the mount is identified, annotate this point.

- The start point for the mount varies with each rider and on each occasion. The general rule used is to identify the point when the rider has completed any preparation to mount and at the point immediately prior to lifting a foot off the ground for mounting. Sometimes details are obscured because of camera position and so a guess must be made.

- Identify and annotate the point where the right hand is put on to the saddle cantle (if this occurs) with the intention of grasping the cantle prior to body lift. Often the hand will be placed on the cantle prior to this point, simply for balance while the rider does something else. The rider will often shift their weight and/or bob down (so they get the benefit of an upwards bounce after the bob down) immediately prior to grasping the cantle.

- Identify and annotate the frame where the subjects body starts to lift up so that they can put their leg over the saddle. Annotate the point where the riders right forearm starts to tilt upwards. These points are often close together and in some cases occur together. With mounts from the ground body lift usually occurs a number of frames prior to arm tilt but when using a sufficiently high mounting block then they often co-occur.

- Identify and annotate the frames where body lift and arm tilt stop. These are usually close but often not at the same point.

- Identify and annotate the point where the right hand lets go of the cantle and starts to move forward so that the right leg can move over and past the cantle. Annotate the frame where the hand stops moving forward.

- Annotate the frame where the rider finishes mounting by sitting with their weight in the saddle, either comfortably not with the right foot in the stirrups but still balanced or when the right foot is in the stirrups.

- Transfer all the mount times and the video start and stop times to the Mount sheet within the video analysis spreadsheet for this session/rider (VA prefix spreadsheet).

- The pre-set up Mount sheet within the VA file will calculate the start and finish point for the mount sequence and the annotated points within the sensor data, based on the synchronisation point. Print this out and save the spreadsheet file.

Next look at the associated sensor data file. Start with the sensor data captured during the two laboratory data collection sessions because these two files contain multiple mounts within each file and it is easier to display a graph from each mount side by side with other graphs of other mounts. This helps highlight similarities and differences.

1. Open the SF Mount Analysis (SFAN prefix) graphing spreadsheet, load the sensor data for the first laboratory data collection session and manually key in the synchronisation point from the VA file Mount print-out.

2. View the graph of the Mount sequence and modify the data range that is graphed so that it matches the range calculated for the mount sequence in the VA file.

3. Verify that the mount graph looks reasonable and investigate if it does not look reasonable.

4. Analyse the graphs heuristically, looking at the graph generated from the accelerometer, gyroscope and magnetometer separately and in combination. Then look at graphs of multiple mounts on a single page for the accelerometer, gyroscope and magnetometer.

5. Identify potential common features and print out graphs showing these features so that they can be compared with mount graphs from other sensor data files.

6. Repeat the five steps above using the data from the second laboratory data collection session.

7. Discard any potential features that were identified in step 5 that do not also commonly occur within the graphs from the second laboratory session.

8. Repeat steps one through five for three sensor data files collected from real world riding conditions.

9. Discard any potential features that were identified during step 7 that do not also commonly occur in graphs from all three real world sessions.

The heuristic recognition method recognition phase

1. Search the remaining real world sensor data files and identify which files contain the feature or features identified during the training phase.

2. Compare the look and shape of the feature across real world sensor data files.

The heuristic recognition method evaluation phase

The heuristic method was evaluated by a simple comparison of the number of cases where recognition was possible however, it was not appropriate to test the reliability of recognition using a statistical measure. Using a statistical measure would imply a level of comparability that is not present in a definitive form and would be misleading. When doing heuristic comparisons there is a danger that features that are being looked for will be seen simply because they are being looked for. This tendency towards confirmation bias is a real problem and without an independent and consistent measure of sameness, statistical values should not be added to the description of comparability. While it is reasonable to be cautious on this point, it does not invalidate the use of heuristics.

Data Analysis Process Justification and Discussion

The general methods of analysing movement data collected by inertial sensors can be categorised into two basic approaches, each of which can be further differentiated into another two approaches.

1. Use sensor data to build a model of movement (understand the data)

    i. Use a real world frame of reference (where is the body part in reference to the rest of the world?)

    It is highly probable that using a real world reference frame requires either a sensor capable of sensing within that real world frame (such as a GPS sensor) or multiple inertial sensors on separate parts of the body so as to differentiate between whole of body movement and body part movement.

    ii. Use a proprioceptive frame of reference (where is this body part in relation to the rest of the body or an adjacent body part?)

        It is highly probable that using a proprioceptive framework requires at least two separate sensors on different body parts so as to be able to differentiate between the body as a whole moving and the body part moving.

2. Treat the sensor data as a "Black Box" (look at its intrinsic features and relationships without attempting to understand it)

    As a result of not needing to build a model of movement in either a real world or proprioceptive frame of reference this approach no longer has to differentiate between whole of body movement and body part movement and so it may attempt to recognise patterns based on a single inertial sensor. To be clear though, such recognition may well be complicated by an inability to differentiate between whole of body and body part movement.

    i. Analyse the raw data

    ii. Analyse derivatives of the raw data

Within each of these four approaches, different "chunking" techniques can be applied to break down the data into discrete parts (or chunks) to help in the search for patterns. There seem to be three basic chunking approaches:

a) Don't chunk the data stream, leave it as a continuous stream

b) Chunk the data stream using time slots windows or sample counts (usually fixed length)

    Much of the prior context recognition research seems to focussed on techniques in this area and there are many approaches to pattern recognition using this idea.

c) Chunk the data stream using features from within the data stream (usually variable length)

   Techniques such as those used with speech recognition seem appropriate in this area and recently string searching and matching techniques have been applied by Stiefmeier et al. (2006) and undoubtedly others.

Both supervised or unsupervised training techniques can be employed to identify features for recognition.

Supervised versus unsupervised

The method used within this project is a defined as a supervised search because hints from the video are used to direct attention to particular parts of the sensor data stream.

Chapter 4 – Findings

Introduction

This chapter looks at the data, presents graphs of the raw sensor data associated with mounting and notes features that may occur commonly within the data.

The Data

Data was collected during two laboratory sessions and fifty-five real life sessions. Both laboratory sessions were used for recognition training. Eleven data collection sessions did not create SF sensor datasets, leaving forty-four sessions that did. Thirteen of the forty-four SF datasets from real life data collection sessions were discarded because of a number of issues that are detailed in the following sections. Of the thirty-one real life SF datasets, twenty-two were from sessions where the participants wore the sensor on their right arm and nine were from sessions where participant wore it on their left arm.

It was clear both from experience and from viewing the videos that the left hand was used differently from the right hand during mounting, regardless of handedness, and so data collected from the sensor while it was worn on the left would need to be analysed separately from data collected from the right arm. The data collected when the sensor was worn on the participant's right arm was the larger data set and as there was only time to look at one set of data in any detail, his larger (right-arm) data set was chosen.

Data description

Dataset Naming Conventions

MDDXX9 – A six character file name that uniquely identifies the sensor data.

MDD – One digit for month and two digits for days: Date data recorded.

XX – Two characters for participants initial.

9 – Sequence number of the data collection session that day.

Two Laboratory sessions with SF sensor

2 x Adult, 1 male, 1 female, right-handed, wearing sensor on right – both datasets used.

Twenty-two usable field sessions where SF sensor worn on right arm

Handedness	*Sex*	*Age*	*Number of sessions*
Left	Female	Adult	1
Ambidextrous	Female	Adult	1
Right	Female	Adult	11
Right	Female	Child	6
Right	Male	Adult	1
Right	Male	Child	2

Table 5: Stratification of usable sessions where sensor was worn on the right arm

Nine field sessions where SF sensor worn on left arm

Eight left-handed and one ambidextrous adult female. None of these datasets were used.

Discarded datasets

The collection of real life data in a field setting presents significantly more potential problems than data collection in the laboratory. The riding sessions took place either literally in a field or in a riding arena. All locations were remote from the researcher's laboratory, associated diagnostic equipment and repair tools. Public transport was utilised for travel and there was limited space for equipment or tools to be carried. Mains power was rarely available close to where the data collection took place.

In most cases the participants had specifically scheduled the time for the data collection session and the sessions within the indoor arena's were specifically booked to enable sole use of the facility. As a result it was impractical to delay sessions by more than a couple of minutes if a problem was discovered. If a problem occurred and the cause of the problem wasn't immediately apparent and simple to repair then no repair was done in the field. The sensors underwent continuous, in-field development in terms of battery power and placement with occasional failures during development. These factors combined and resulted in some datasets being discarded. Reasons for the failures were fed back into either the sensor design sub-project or the recognition method development process and were used to refine the designs in both areas.

Analysis of ten sessions when SF data was not collected

Reason	*Num*	*Comment*
Rider fell twice during session. Equipment suffered minor damage and no data was collected.	1	The session was not re-started for safety reasons
Researcher failed to turn on data logging	2	Rushed set up on both occasions meant that data was not logged. An on-site check-list was developed to prevent this from recurring.
Power cable between SF sensor and external battery broke while in the field on a busy day	3	The fault could not be diagnosed and fixed until back in the laboratory. Data from these sessions was collected with the MS sensor. SF sensor redesigned to use an internal battery.
Unable to connect iPaq to SF sensor in the field	1	The iPaq was subsequently found to be misconfigured and this was corrected for other sessions that day. iPaq configuration checks were added to the on-site, pre-collection check-list.
SF internal battery failed in the field without warning	3	Following prior cable problems with the external batteries, the SF sensor was initially redesigned to use specialised 6 volt camera batteries that were internally mounted. These batteries had excellent power to weight ratios but the camera batteries had an initially flat and then a rapid power drop off curve once they got beyond their capacity and so they tended to fail rapidly and without warning. The SF sensor was again redesigned to use a slightly larger battery with a flatter and progressive power drop off curve over the entire life of the battery. This enabled battery capacity to be measured accurately prior to sensor use. Both battery types were uncommon and it was necessary to carry spares in the field at all times along with tools for disassembling the sensor cases to replace the batteries.

Table 6: Analysis of reasons for ten sessions not collecting SF data

The above table summarises the reasons why SF sensor data was not collected in ten cases during the data collection phase.

Reasons for discarding thirteen SF datasets

Reason	*Num*	*Comment*
Battery low power caused Bluetooth connection problems and dropped data packets within the data file, invalidating the data	4	Power issues were the largest cause of data problems. Continuous redevelopment eventually lead to a consistent solution. In addition, the iPaq had an inherent fault that meant it could not be fully charged.
iPaq controls bumped and data logging stopped after sync but prior to mount	1	Duct tape was used to cover the iPaq on/off switch to prevent this from reoccurring.
Sensor worn upside down, data not comparable with other datasets	1	A large, clearly visible direction mark was placed on the sensor case to help prevent this and the pre-session check list was amended to include it.
External battery cable caught on obstacle and disconnected after sync but prior to mounting	1	A flexible strap was introduced to keep the cable close to the arm and less likely to catch on things. SF sensor redesigned to use an internal battery.
Off-side mount	3	Rider chose to mount from the off (right) side of their horse. These mounts are rare and are excluded by the scope.
Video camera stopped unintentionally	1	Obtained unipod camera holder to make it easier to hold camera and to prevent fatigue when videoing multiple data sessions.
Battery unseated by vigorous movement	1	Redesign sensor case to hold battery better.
Undiagnosed	1	Unknown problem caused data corruption within iPaq, possibly Bluetooth connection problems.

Table 7: Reasons for discarding SF datasets

Notes: Three riders of Icelandic ponies were recruited as participants. Icelandic ponies are a relatively unusual and uncommon breed of horses that have their own riding style. Included within this riding style is a requirement to train the horses to be mounted from the off-side. Off-side mounts are excluded in the project constraints and it was apparent when these participants were accepted that they would employ off-side mounts. Most mounts done with the Icelandic ponies were near-side (left) mounts. Nine sessions with Icelandic ponies were conducted and only three of these were discarded as a result of being off-side mounts. Outside of Icelandic and Fjord horse breeds, off-side mounts are rare. The data from these off-side mounts may be used in a future project.

Applying the Heuristic Recognition Method

Video Analysis of Mounts

The first step in the recognition method examines the videos of the mounts closely to gain a deeper understanding of what happens when a rider mounts.

Mount from a mounting block seen from the left rear of the horse.

Start prior to foot lifting off (frame 19,961)

Right hand firmly on cantle (frame 20,056)

Right arm pitch has ended (frame 20,061)

Body lift has stopped (frame 20074)

Right hand has moved forward (frame 20,081)

Weight in saddle (frame 20,103)

Illustration 13: Mount from mounting block seen from left side of horse – elapsed 5.68 seconds (25fps)

Mount from the ground as seen from the left of a horse

Start prior to lifting foot off (frame 34,906)

Right hand on cantle (frame 34,942)

Start of body lift (frame 34,949)

Right arm starting to pitch (frame 34,956)

Right arm about to move forward (frame 34,978)

Weight in saddle (frame 34,995)

Illustration 14:Mount from the ground from left of horse – elapsed 3.56 seconds (25fps)

Close up of right hand during mount, seen from right side of horse

Start of body lift, right hand on cantle (frame 25,698)

Right arm pitching up (frame 25,708)

Right arm just prior to moving forward (frame 26,729)

Right arm stopped moving forward (frame 26,734)

Illustration 15:Close up of right hand during mounting – 0.20 seconds elapsed for hand to move forward (25fps)

Observations

When riders grasp the cantle (back of the saddle) prior to mounting, their right arm starts either horizontal or pitched down towards the rider (depending or rider height versus horse height), holds relatively still for a period, pitches up as the rider's body rises and then quickly moves forward to the front of the saddle once the rider's right leg comes over the cantle. The move forward from the cantle is often very quick (tenths of seconds) as the rider is effectively balanced on their left hand and left leg during this transfer forward.

Supervised Recognition During the Training Phase

The first graphs looked at were the three sensor outputs for the first mount within the data from the mounts done by participant PH during the laboratory trials on the 21st August 2008. The file naming conventions for graphs are detailed on page 114.

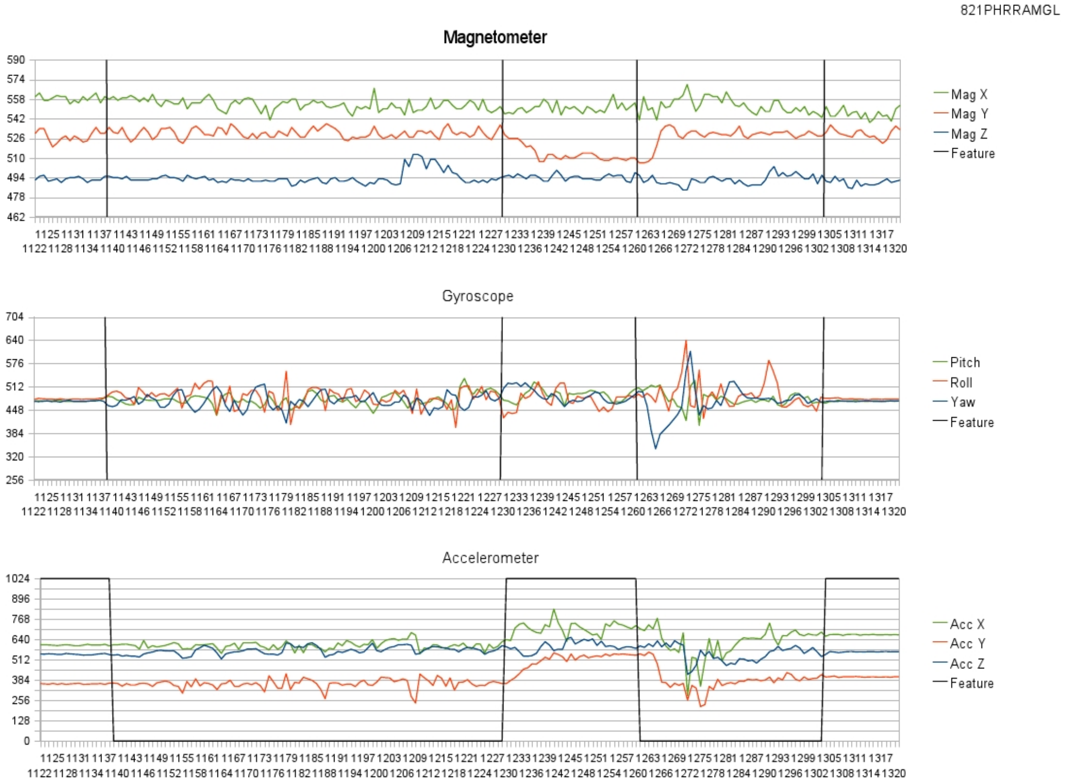


Illustration 16: Mount 1, 3 sensor output (PH1 21/08/2008)

The mount starts at around sample number 1140 (1st black line), at around sample 1230 (2nd black line) the participant lifts his right arm to grasp the cantle, at around sample 1260 (3rd) his arm pitches as he lifts himself up and at around sample number 1305 (4th) he is seated in the saddle and starts his ten second quiet period before dismounting. As expected, features that coincide with these (and other) movements are seen.

The magnetometer Y axis shows a downward slope that coincides with the arm pitch and an upwards slope that coincides with the wrist roll (this U shape is feature **a**). There is also a hump feature on the Magnetometer Z axis between sample 1206 and 1222 (feature **b**), this coincides with the participant stepping up onto a mounting step to assist with the first mount. This mounting step was discarded after the first mount for safety reasons and the step up action doesn't appear in subsequent mounts. The first mount also differed in other ways as the participant got acquainted with the process.

A small U-shaped feature is seen on both the Pitch and Roll axes of the Gyroscope graph, starting at around 1224 (feature **c** & **d**) that corresponds with the participant lifting his arm and a corresponding small hump in the Yaw axis at this point (feature **e**). At around sample 1260 a tick-shaped (√) feature (**f**) can be seen that first drops sharply, rises quickly and then drops again at around sample 1275 on the Yaw axis. There are similar but less distinctly shaped features on both the Pitch (**g**) and Roll (**h**) axes at similar times although the feature on the Roll axis starts after the Yaw feature but finishes before it. There is an inverted V hump on the Yaw axis at around sample 1280 (**i**) and a similar but taller feature on the Roll axis at around sample 1290 (**j**).

On the Accelerometer graph the X axis rises in two stages as the participant's arm is raised (**k**), and this is followed by three short V's (**l**), is relatively flat for a short period (**m**), then drops in a stepped V (**n**) as the participant moves their hand from the cantle to the saddle pommel area before rising again (**o**) to a steady state for the rest period. The accelerometer Z axis stays relatively stable until the participant's hand moves forward from the cantle to the pommel when it drops in a sharp V (**p**) then a shallow V (**q**) before going to steady state for the rest period. The Z axis rises steadily at around a 45 degree angle (**r**) at the time the participant raises their arm to put it on the cantle, holds steady (**s**) as the participant lifts their body and then drops rapidly (**t**) as they move their hand forward from the cantle to pommel, this is followed by a short V (**u**) before reaching the rest period. The second mount follows and is checked for similar features.

The sensor output is being treated as a black-box signal and so while the features are being described in terms of where movement occurs within the video there is no attempt to interpret the sensor signals in terms of movement nor will the signals be corrected for known issues such as drift or compensated for changes caused by the orientation of the sensor. The assumption is that a pattern may emerge despite these issues.

There is a special issue associated with using the magnetometer output because the integrated output is designed to give direction with regard to a magnetic field, normally the earth's magnetic field. This means that the output from the magnetometer will vary based on the geographic position of the sensor at the time it generates its signal. A signal recorded in Stockholm for the same movements as those recorded in Auckland will produce different output. Smaller geographic changes will, obviously, also affect the signal.

Instead of looking at true geographic direction and trying to find some pattern associated with mounting based on true direction, it would be possible to instead look at relative directional change. That is “did the participant turn left 45 degrees?” rather than “did the participant turn North?”. However, in order to look at relative change in direction the magnetometer output signal would need to be integrated and correct for inclination changes and this can't be done if the signal is treated as a black-box.

On the surface, this would seem to indicate that the magnetometer output cannot be used successfully in a black-box pattern matching process because the patterns generated will depend on geographic position and moment by moment orientation and these are relatively random from the system's perspective.

It would be possible, for example, to detect patterns within the magnetometer data captured in the laboratory situation where multiple mounts were collected from the same geographic location with the wooden horse orientated in the same position and the participant doing the same thing multiple times. However, as soon as data from outside the laboratory is considered or even if Diana (the wooden horse) was moved within the laboratory then the magnetometer signal is expect the to change. As a result, any patterns that are detected in the magnetometer output signal will be de-emphasised but this set of signals will continue to be monitored in case some underlying pattern does emerge.

On this second group of graphs (following page), it is easier to see the ten second quiet period before and after mounting on both the gyroscope and the accelerometer graphs. On both graphs at the leftmost side it is also possible to see the end of the synchronisation signal generated by the three overhead claps.

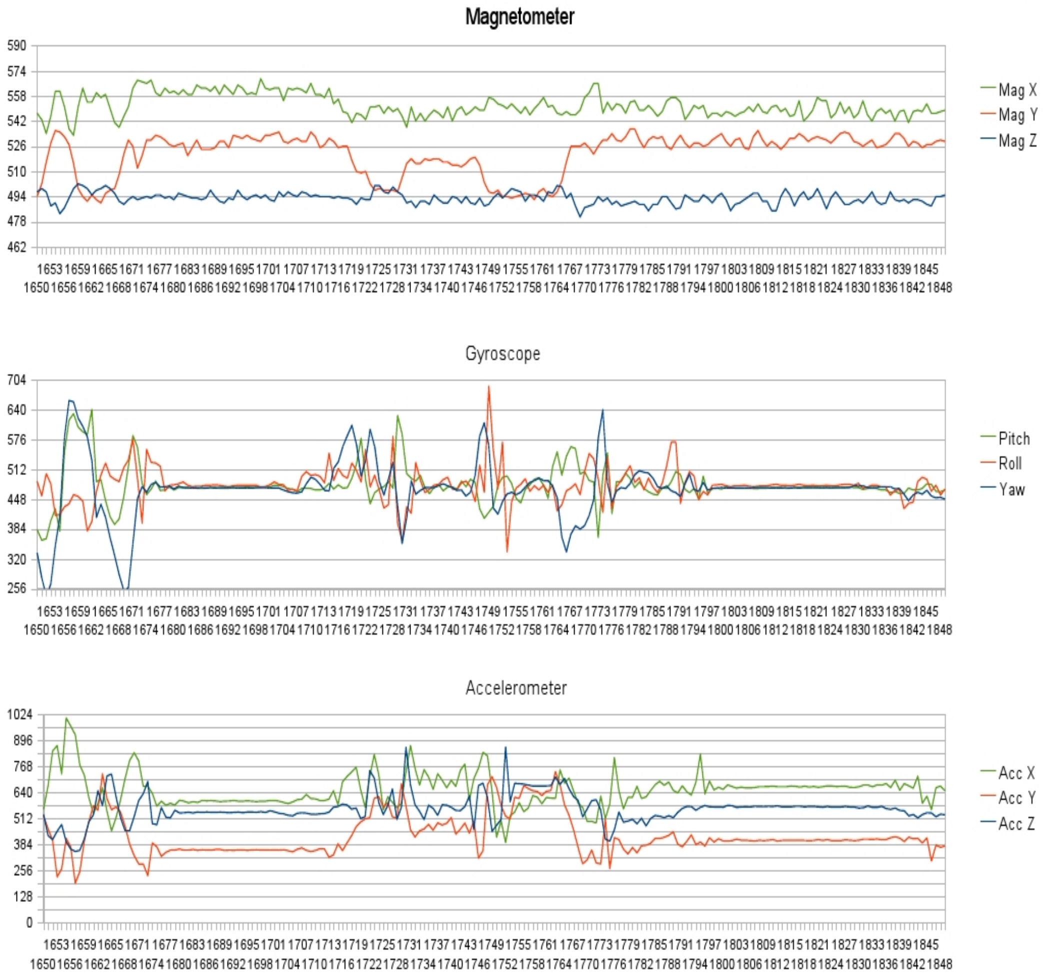


Illustration 17: Mount 2, 3 sensor output (PH2 21/08/2008)

Looking first at the Magnetometer graph, a small hump feature is seen on the Z axis that is similar to the one observed (**b**) on the first mount graph starting at around sample number 1722. Above it there is a new feature on the Magnetometer Y axis. At around sample 1746 a similar U-shaped feature (**a**) is seen on the Magnetometer Y axis at a similar spot to the one on the graph of the first mount except with the second mount the base of the U is narrower. Just to the right of this feature, starting at around sample 1770 is a very slight A shaped feature on the Magnetometer X axis and going back to the first graph it can be seen that there is a similar feature there. However, given the description of how the raw magnetometer data is location and orientation specific and looking forward into some of the field data (see appendix 7) it can be seen that the raw magnetometer data demonstrates considerable variance from session to session and so the new feature will not be formally noted and features (**a**) and (**b**) will be will discarded.

Within the Gyroscope graph the lines leading up to feature (**f** – the tick-like shape) are quite different from the first mount and a similar difference can be seen on the accelerometer graph of the second mount compared with the first.

The graphs from the first six mounts are placed together on the same page so that similarities and differences become easier to see. Both the sensor reading scale and the sample number scale are standardised so that a consistent feature has a consistent shape in each graph. The maximum and minimum values for the three different sensor readings are noted by looking ahead at the training data and a scale between 462 (minimum) and 590 (maximum) is chosen for the magnetometer, 256 (min) and 704 (max) for the gyroscope and a full 0 (min) to 1023 (max) scale for the accelerometer. It is also apparent that a ten second window (100 sample points) is sufficient to contain all mount related readings from the time the participant lifts their foot to start mounting through until the rider is seated in the saddle with balanced weight. The foot lift movement are only included for mounts that were successfully completed, no movements are included from mount attempts that were not successful. An analysis of all 55 field mounts shows a mean time to mount of 5.48 seconds with a standard deviation of 2.28 seconds. All 22 datasets that were used were able to fit within the ten second window.

Graphs are aligned so that similar features are in similar positions along the sample axis. This presented challenges because the time scale of each movement and of the mount overall changes with each mount. The laboratory data has less variability but the real life data that follows has greater variability. The graphs were aligned using the right arm pitch and subsequent quick forward movement (**f**). A *black vertical feature* line was added to the graphs to show where this movement starts and ends. Other movements were also initially marked with feature lines but this was found to obscured the sensor lines to some extent and so these additional lines were removed.

The graphs for the first 12 mounts from the laboratory session on the 21st August 2008 are shown on the following pages. The graphs are grouped together for each sensor type to aid comparison and the magnetometer graphs are excluded (see appendix 7) because these were not used.

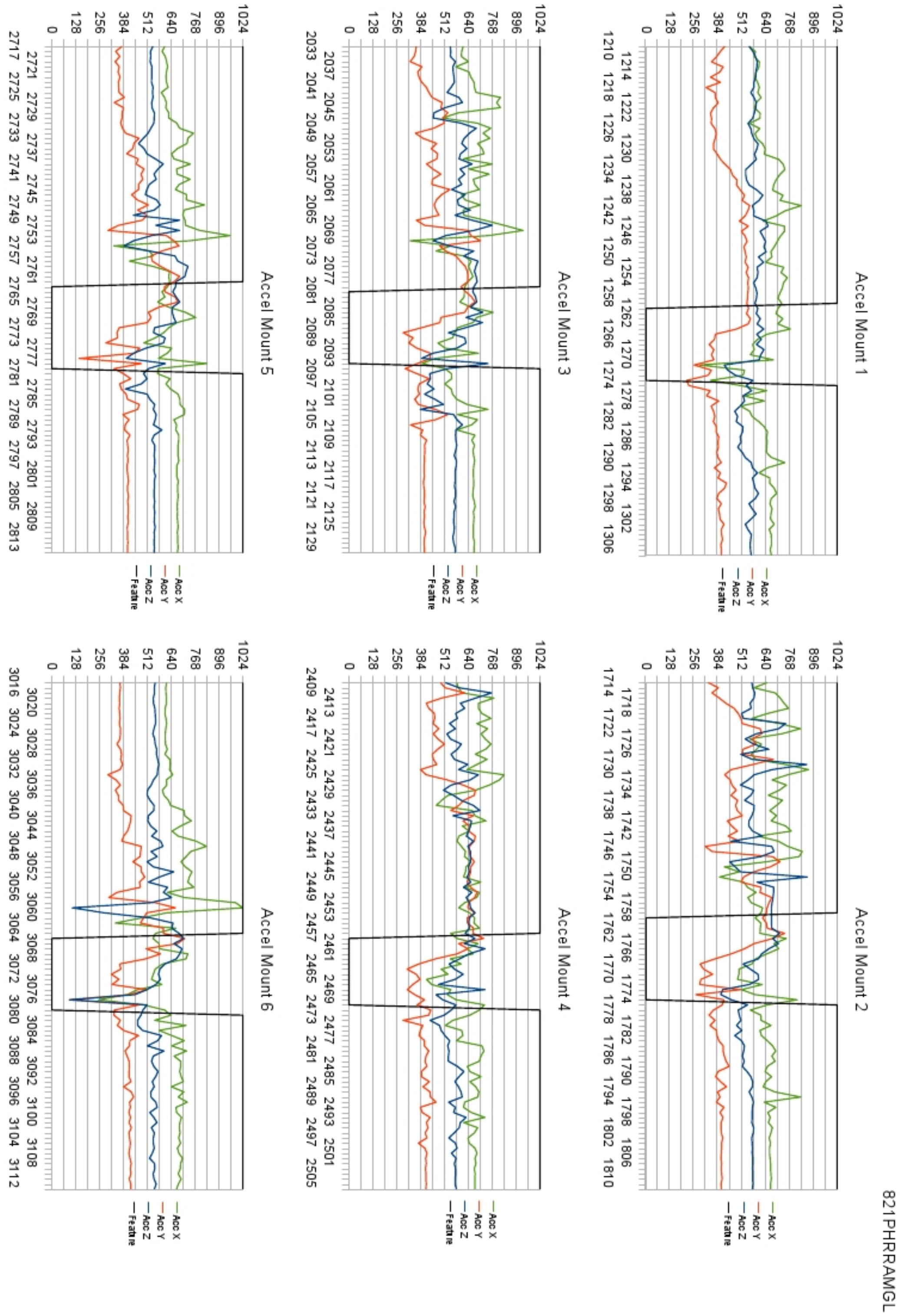


Illustration 18: Accelerometer readings from the first six mounts, laboratory session 21/08/2008, participant PH, right-handed, sensor mounted on the right wrist, adult, male.

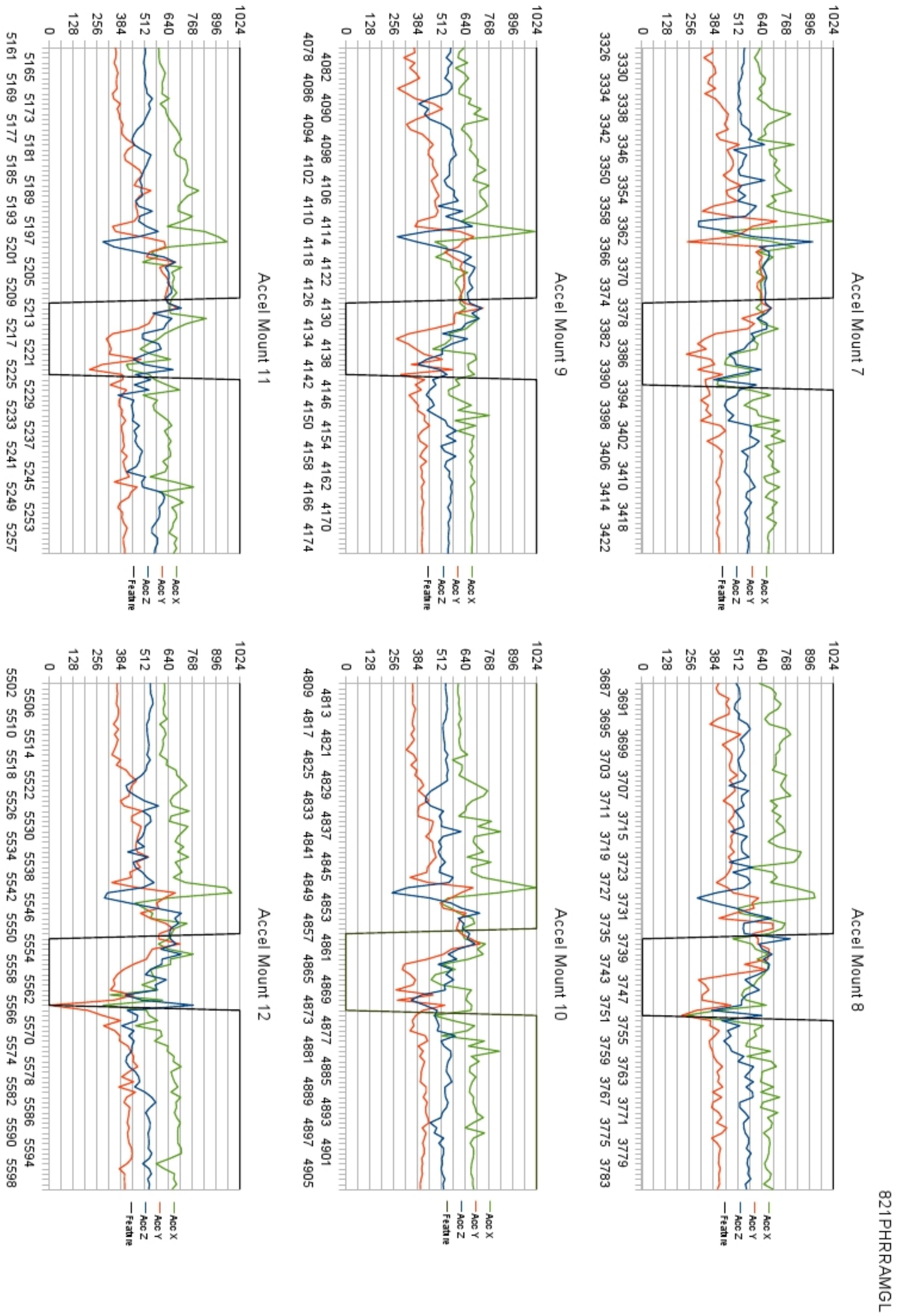


Illustration 19: Accelerometer readings from the second six mounts, laboratory session 21/08/2008, participant PH, right-handed, sensor mounted on the right wrist, adult, male.

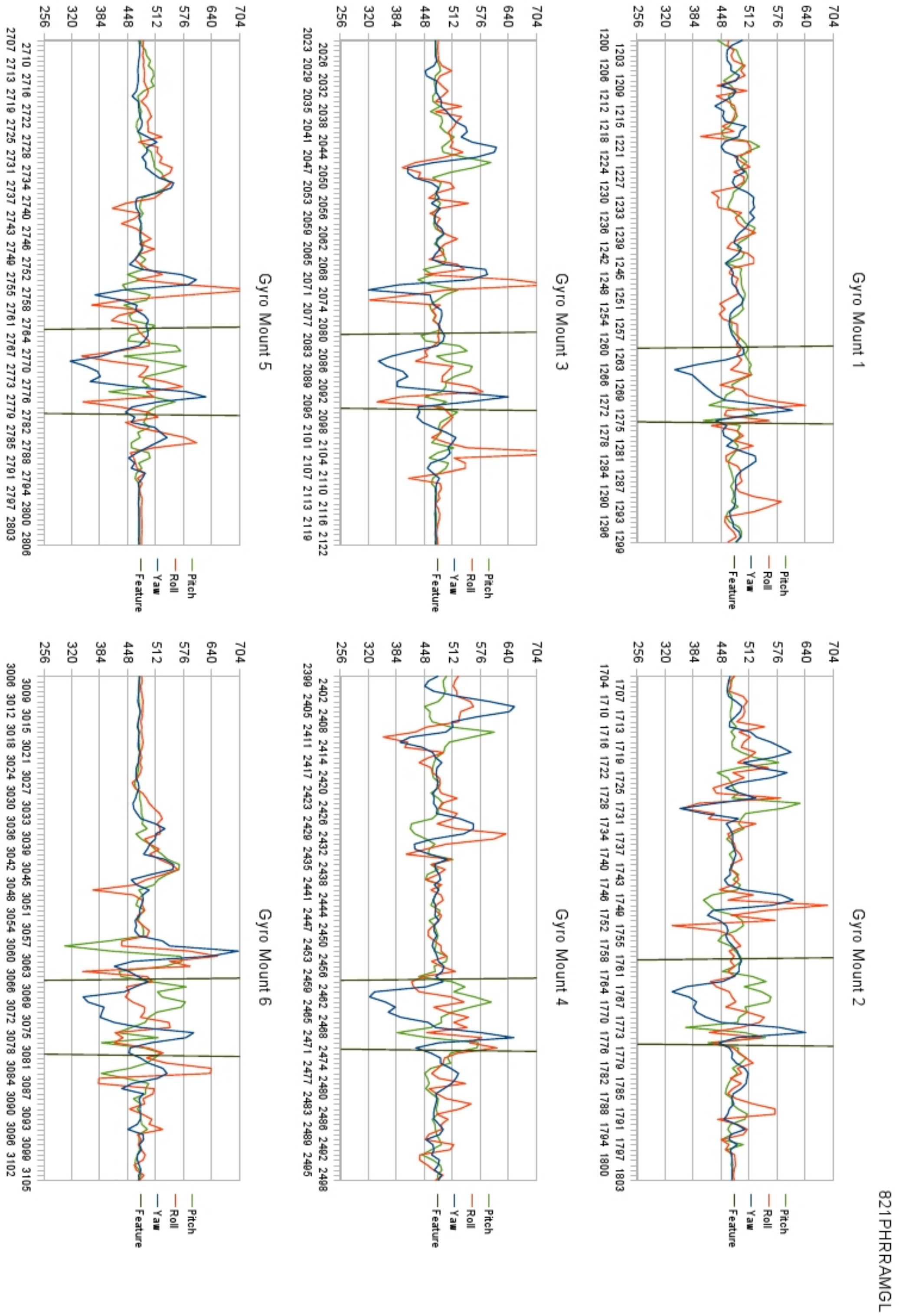


Illustration 20: Gyroscope readings from the first six mounts, laboratory session 21/08/2008, participant PH, right-handed, sensor mounted on the right wrist, adult, male.

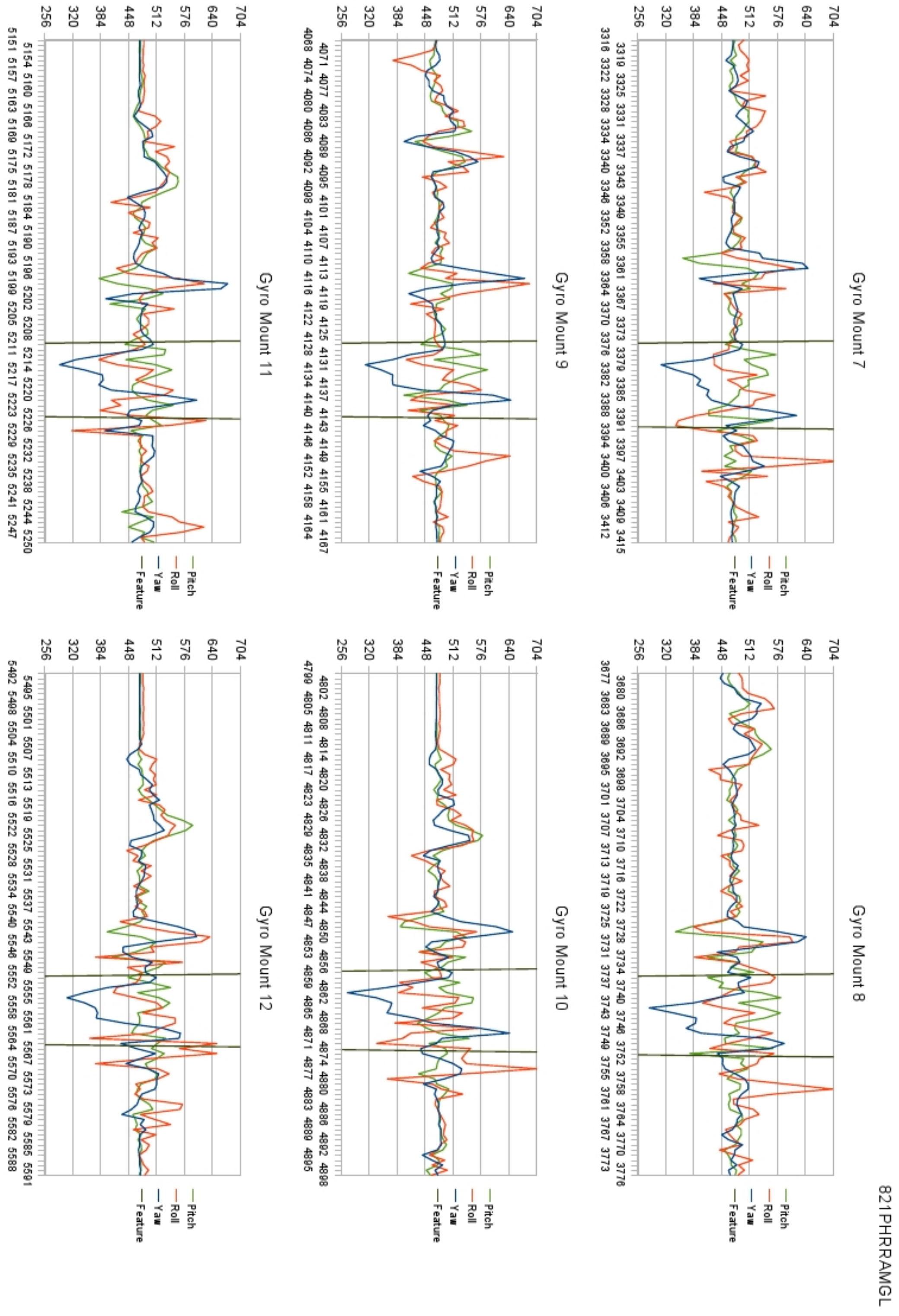


Illustration 21: Gyroscope readings from the second six mounts, laboratory session 21/08/2008, participant PH, right-handed, sensor mounted on the right wrist, adult, male.

There are similarities between features on all graphs presented, although the graph for the first mount is the least similar. During the first mount the participant PH used a different technique (the first mount used an *office step* as a mounting block but this was discarded for safety reasons in subsequent mounts). The participant starts from the same place, finishes in the same place, mounts the same wooden horse and does everything else much the same from one mount to the next. Given this scenario similar features in the sensor output are expected and this is what is observed. The differences shown on the first graph, however, highlight that features may well change or disappear and new ones may arise when different techniques or circumstances are involved.

Similar graphs from the second laboratory session that was recorded on the 13th August 2008 are examined next. This involved a right-handed, adult, female participant JC. JC used the *office step* to aid mounting throughout the session and is of a similar height to the male participant PH. Diana was placed in a similar position within the Wireless@KTH laboratory, using placement marks taped to the laboratory floor. The participant used a similar mounting technique to PH of her own accord.

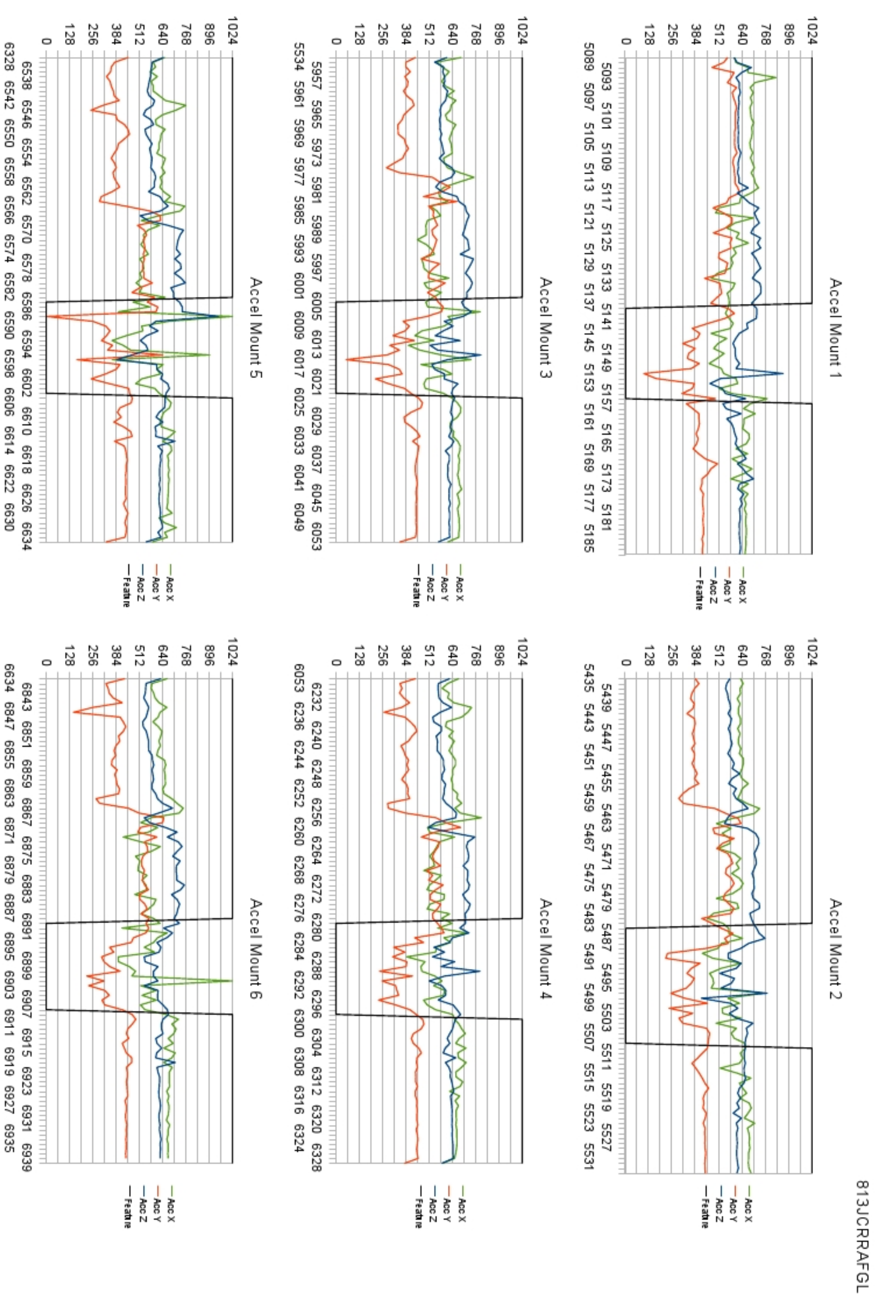


Illustration 22: Accelerometer readings from the first six mounts, laboratory session 13/08/2008, participant JC, right-handed, sensor mounted on the right wrist, adult, female.

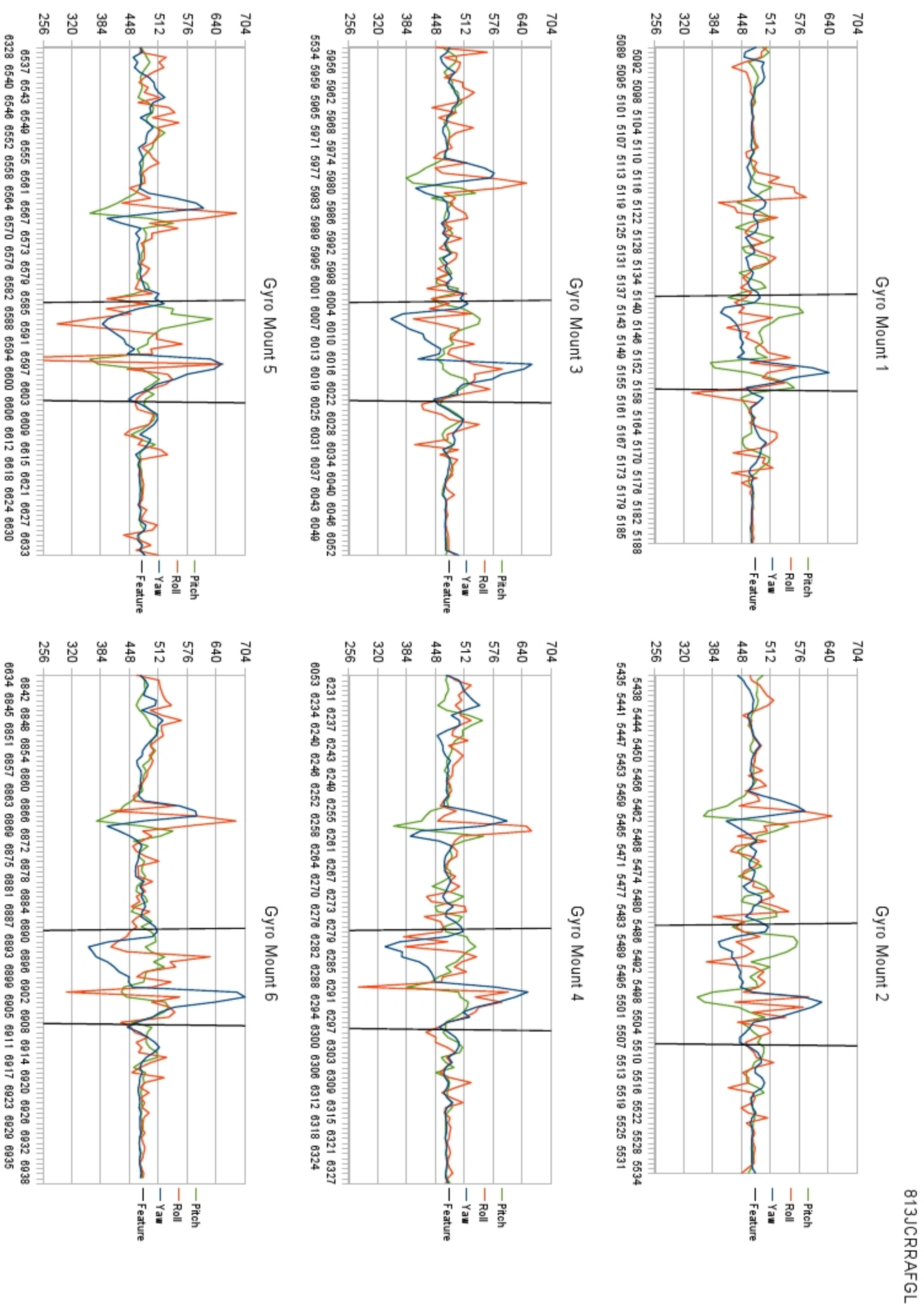


Illustration 23: Gyroscope readings from the first six mounts, laboratory 13/08/2008, participant JC, right-handed, sensor mounted on the right wrist, adult, female.

The accelerometer output graph from the participant's first mount is different from subsequent mounts and while this participant did not do anything as dramatic as removing the *office step* she obviously did do things differently enough on the first mount to be noted and then got into a more regular pattern with her movements.

This participant's data shows a consistent pattern within itself and also shares some features in common with the other laboratory test participant. In particular the accelerometer Y axis rises reasonably steeply at about the time the participant raises her right hand to place it on the saddle cantle, although JC typically does this earlier than PH. This feature was not present on the very first mount for PH and so was not noted earlier. With both participants this is usually preceded by a short V shaped feature and followed by a short inverted V and together they appear as an S-like shape (feature **v**). On the second through sixth accelerometer mount graphs for JC this feature is clearly seen as the X axis rises to intersect with the Y and Z axes towards the start of each mount. The X and Z accelerometer axes show a similar but usually much shorter shaped feature at the same time. Participant PH sometimes has the X and Z axes S-like shape taller than the Y axis S-like shape.

This is followed by a period of relative stability for all three accelerometer axes outputs as the participant grasps the saddle cantle for balance prior to lifting their body on the stirrup. Typically, however, JC has a longer period of stability than PH. This was partly noted as feature (**m**) in earlier descriptions. The definition of feature (**m**) is redefined to include a period of relative stability for all three accelerometer axes.

This is followed by a rapid drop in the accelerometer Y axis that is usually mirrored by a similar drop in the X and Z axes at the same time but occasionally the X and Z axes rise steeply initially before following the Y axis down. This feature coincides with the participant pitching her arm up as she lifts her body up so that she can swing her right leg over the saddle. This corresponds with feature (**n**) in prior descriptions and is expanded to include the definition for all three axes.

A sharp, tall peak or trough then follows and is usually present in all three axes to some extent or another although it can be a mixture of peak or trough in one or more axis, this corresponds to feature (**p**) from earlier descriptions, extended to include all three axes. This feature may be caused by the participant rapidly moving her hand from the saddle cantle towards the saddle front as her leg clears the saddle cantle.

Lastly, a period that is generally characterised by a gradual rise in the accelerometer Y axis and usually a corresponding rise in the other axes to a steady state where the participant rests quietly after mounting is noted. This was noted as feature (**o**) in prior descriptions and its definition is extended to include all three axes.

All other accelerometer features that were previously noted, namely features (**k**), (**l**), (**q**), (**r**), (**s**), (**t**) and (**u**) are discarded because they do not occur consistently across both participants. This leaves features (**m**), (**n**), (**o**), (**p**) and (**v**) as describing common accelerometer features, prior to looking at data from real life mounting situations.

In the graphs of the gyroscope data feature (**f**), the tick-like shape on the gyroscope Yaw axis, is noted as appearing consistently on every mount for both participants. The basic shape of this feature remains recognisable but the overall width of the feature varies slightly, the overall depth of the bottom of the tick varies, the height of the upstroke sometimes varies, the angle of the start of the upstroke of the tick varies and sometimes contains a step in it. While the corresponding tick-like features (**g**) and (**h**) from the gyroscope Pitch and Roll axes sometimes accompany the Yaw tick-like feature they do not do so consistently across all mounts for both participants and so both of these features are discarded.

The next most consistent gyroscope graph feature across both participants is a small hump in the Yaw axis, usually accompanied by a similar (but sometimes larger) rise in the Roll axis that immediately follows the Yaw axis tick. This was noted as features (**i**) and (**j**) in earlier descriptions.

The relative quiet or stable period in all three gyroscope axes prior to the tick-like Yaw feature has not previously been described. This relatively quiet period appears consistently for participant JC but with participant PH it is sometimes either interrupted or ended with a tall reverse S-shaped feature usually in the gyroscope Roll axis. This relative quiet period is noted as feature (**w**) for future reference.

In some graphs a reverse S-shaped feature in the gyroscope Yaw axis precedes the relative quiet period and probably corresponds with the participant lifting their right arm and grasping the cantle for balance at the start of the mount. This feature corresponds with features (**c**), (**d**) and (**e**) from prior descriptions but is not consistently present and its shape varies markedly from graph to graph and these three features are discarded along with all other gyroscope features not specifically included. This leaves features (**f**), (**i**), (**j**) and (**w**) within the gyroscope data.

The graph from the first field data collection session is presented separately because for this session the sensitivity of the accelerometer was set to a maximum of plus/minus 1.5G's. All the remaining sessions had the accelerometer setting set to plus/minus 2.0G's. The accelerometer data from the session on the 15th July 2008 are not comparable with other accelerometer data and so are not presented, however the gyroscope data is presented. The gyroscope sensitivity is not resettable and remained constant throughout the data collection process. The participant for the first field session is PH, who also took part in the laboratory trials on the 21st August 2008, and his gyroscope graph provides a useful first comparison of real world data with laboratory data from the same participant.

Illustration 24: Gyroscope readings from the first field data collection 15/07/2008, participant PH, right-handed, sensor mounted on the right wrist, adult, male.

Feature (**f**), the tick-like shape, is present on the Yaw axis in the position expected and coinciding with right arm pitch as the rider raises his body to mount and his right arm moves forward as his right leg comes across the saddle cantle. Features (**w**), quiet period prior to tick, (**i**) hump in Yaw and Pitch axes immediately after tick-like shape and (**j**) hump in Yaw and Roll axes immediately prior to the end of the mounting process are also present.

The remaining graphs that were used during recognition training, are presented, grouped together by sensor type to aid comparison and differentiation.

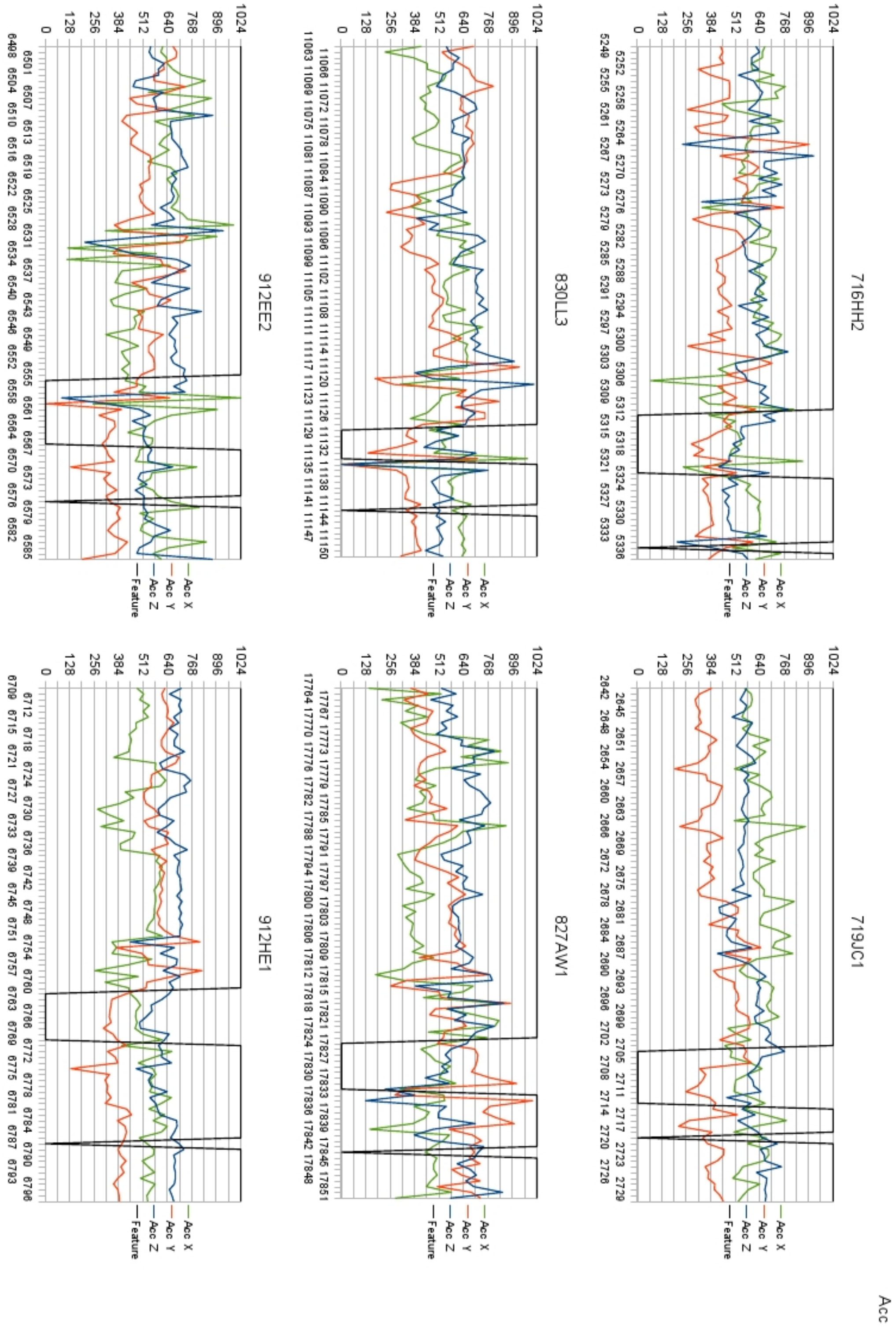


Illustration 25: Graphs of accelerometer data from 6 real life mounts used during recognition training, session identifiers above each graph.

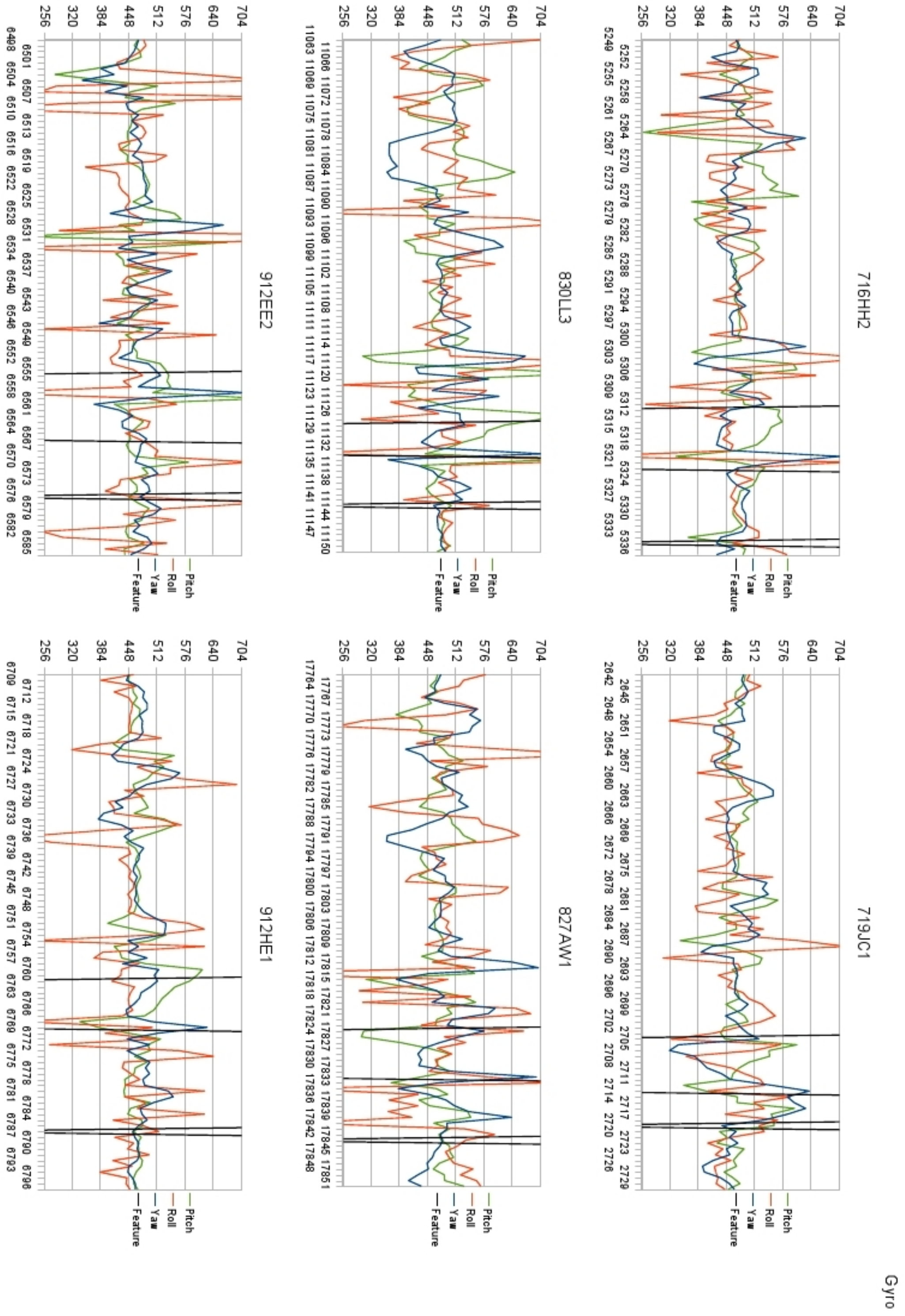


Illustration 26: Graphs of gyroscope data from 6 real life mounts used during recognition training, session identifiers above each graph.

Each of the non-discarded accelerometer features were checked against the real life data in these graphs with the following results:

- Feature (**m**) – relatively quiet and flat period just prior to body lift. Only seen in one of the graphs and so this feature was discarded.
- Feature (**n**) – two step drop in either the X, Y or Z axes as the participant pitches their right arm as their body lifts to clear the saddle. There is sometimes a stepped drop in the Y axis (three of the six cases), sometimes in the Z axis (four of the six cases) and sometimes the X axis (one case). In five of the six cases there is a similar feature of some sort in the accelerometer data.
- Feature (**o**) – a gradual rise in any of the three axes back to a steady state after the participant has lifted their body and leg over the saddle. This feature is not apparent in any of the graphs and so this feature was discarded.
- Feature (**v**) – S-like shape at the beginning of the mount as the participant raises their arm to grasp the cantle. This only appears in one case and so this feature was discarded.

Only one feature, (**n**) remained after viewing the accelerometer graphs from the real life mounts. This feature varies from case to case to some extent and is not present in all cases. In particular it is not present in case 912EE2 where the participant, a female child mounted her horse using a stirrup mount from the ground but did not grasp the cantle as she mounted. Instead she put their right hand over the saddle and grasped the front of the saddle area and so her right arm did not pitch as she raised her body to mount and she also did not have to move her right arm forward as she mounted because it was already on the front of the saddle. This is a mounting technique that had not been encountered within the observations of the data until this point.

The gyroscope data was examined and feature (**f**) is present in five of the six graphs. It is not present in the graph 912EE2 where the participant did not grasp the saddle cantle as she mounted. This is the end of the training phase of the recognition method.

The fifteen remaining unexamined, right-arm, SF datasets were examined next to see if feature (**f**) and (**n**) can be recognised in these datasets.

Heuristic method evaluation phase

The fifteen graphs used during the recognition method evaluation phase are presented and the results of applying the method to all fifteen datasets are summarised.

The first six graphs examined during the evaluation phase

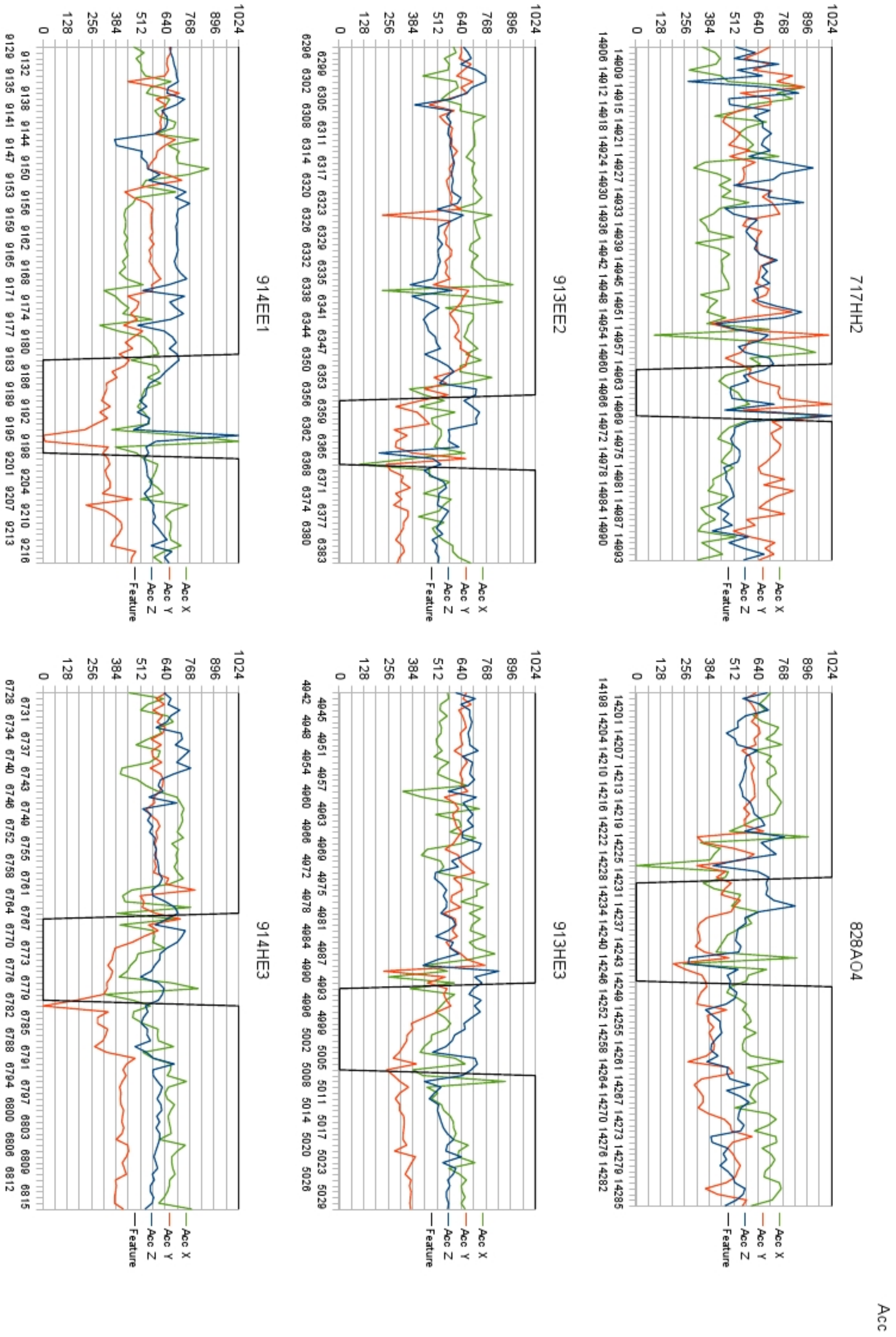


Illustration 27: Graphs of the first six accelerometer datasets used during method evaluation, session ID is above each graph.

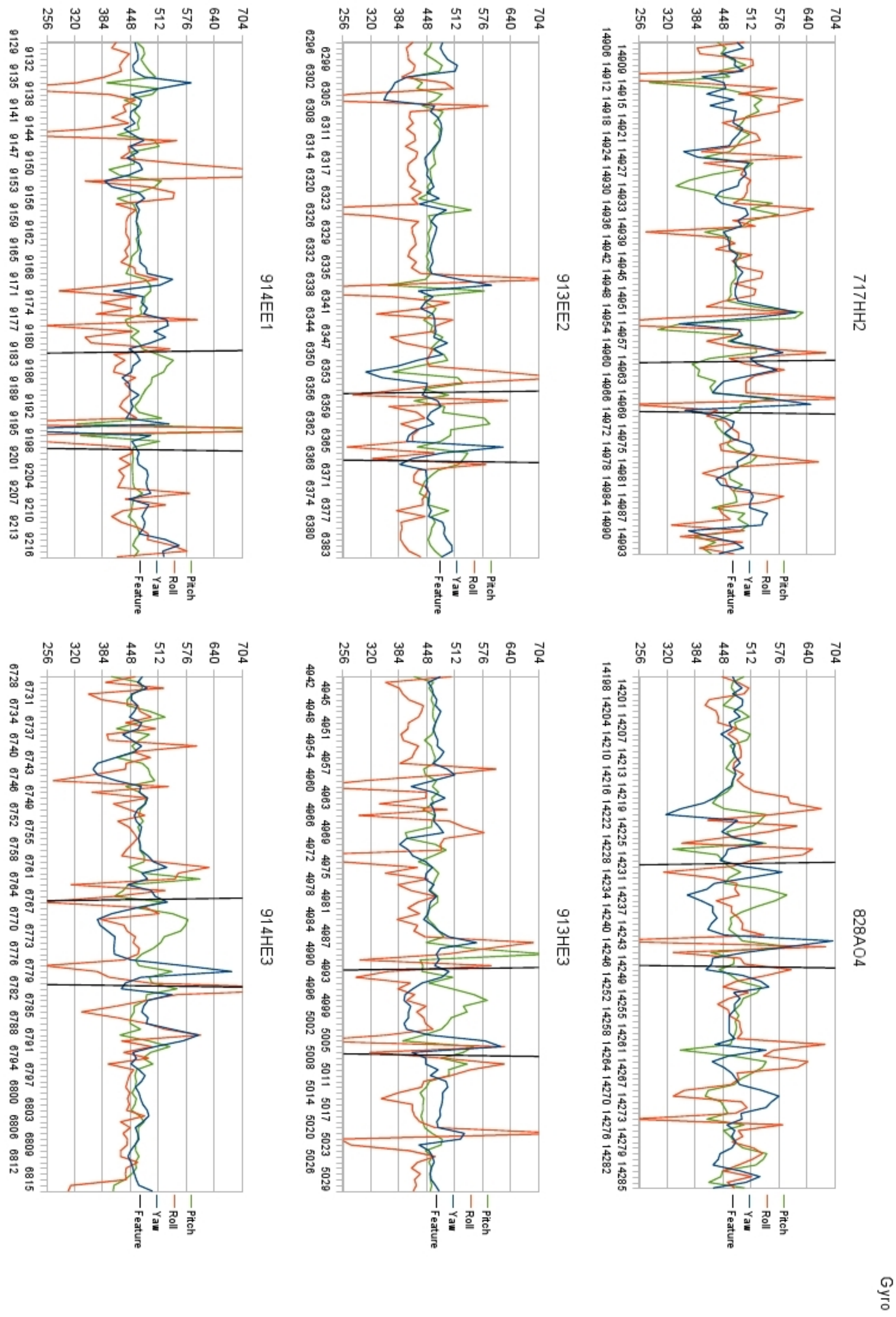


Illustration 28: Graphs of the first six gyroscope datasets used during method evaluation, session ID is above each graph.

The second six graphs examined during the evaluation phase

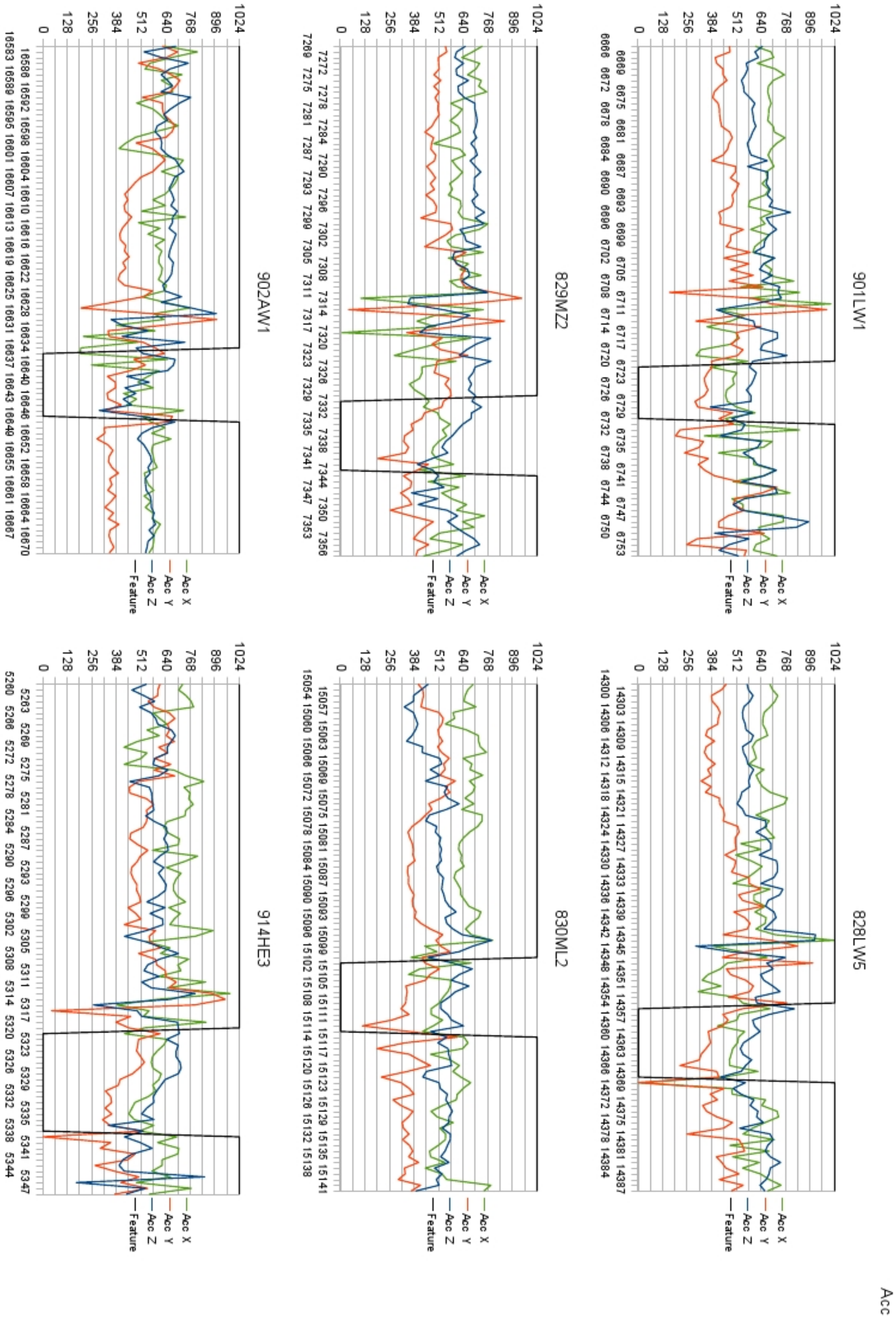


Illustration 29: Graphs of the second six accelerometer datasets used during method evaluation, session ID is above each graph.

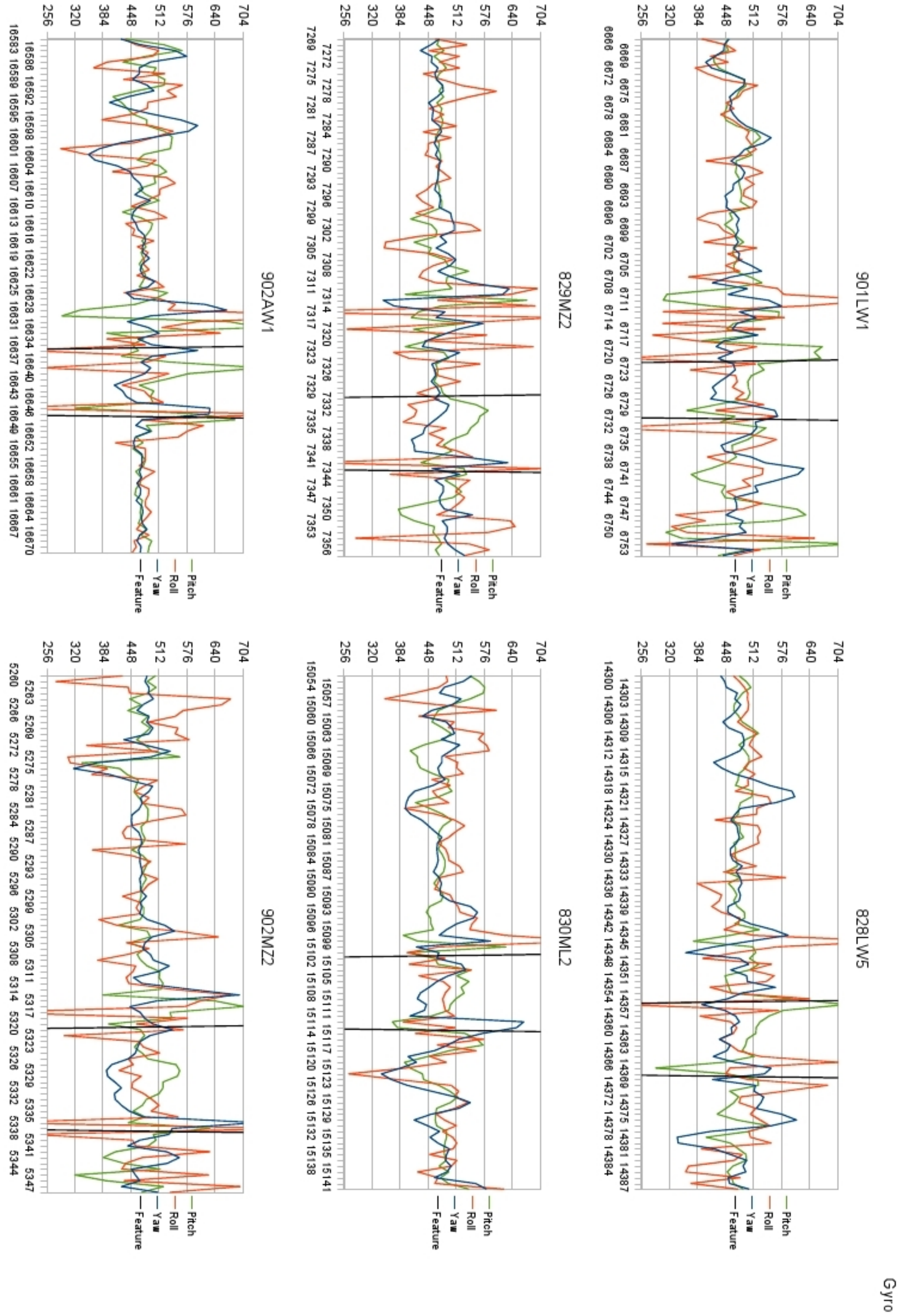


Illustration 30: Graphs of the second six gyroscope datasets used during method evaluation, session ID is above each graph.

The final three graphs examined during the evaluation phase

Hand on front of saddle while mounting

Acc

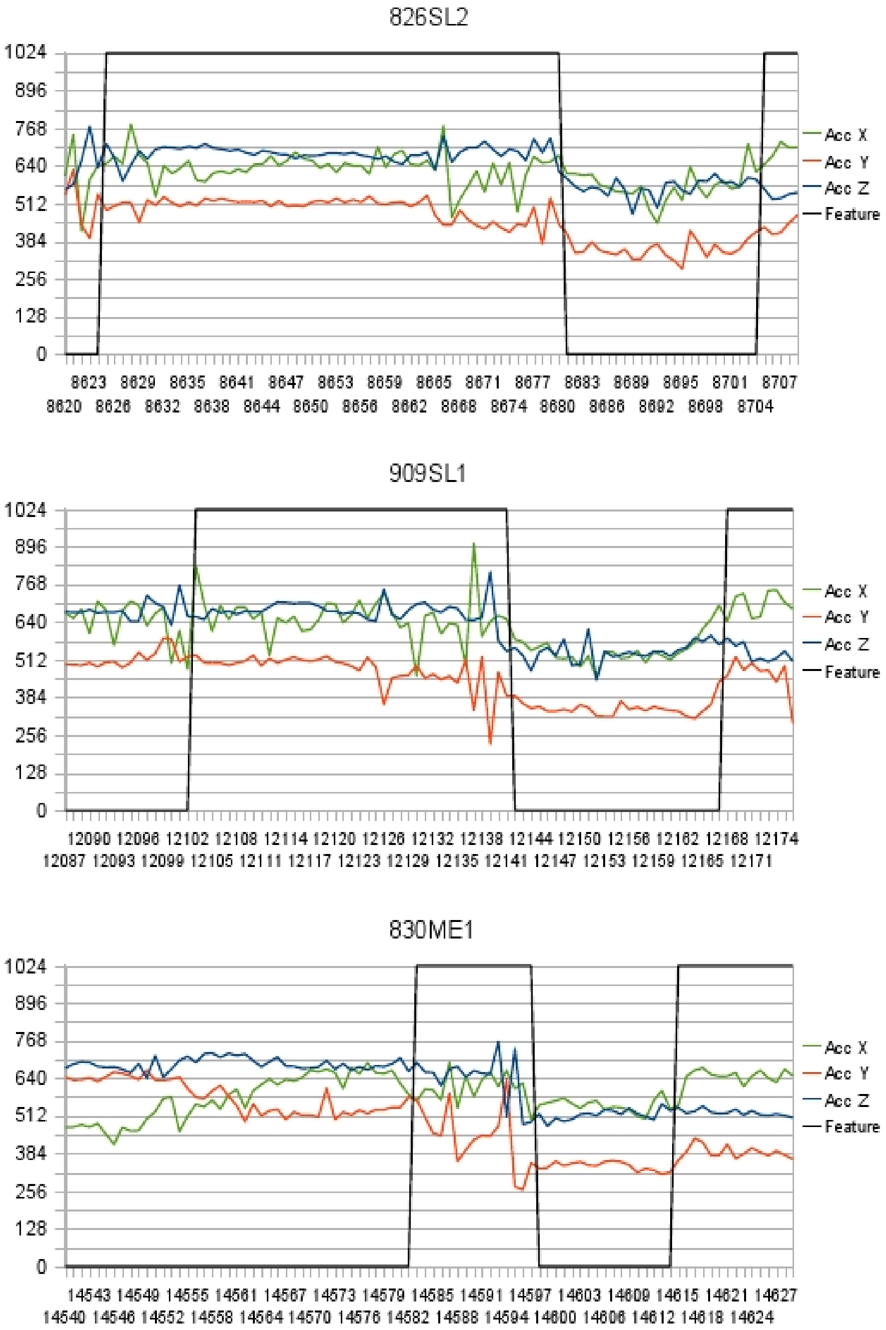


Illustration 31: Graphs of the final three accelerometer datasets used during method evaluation, session ID is above each graph.

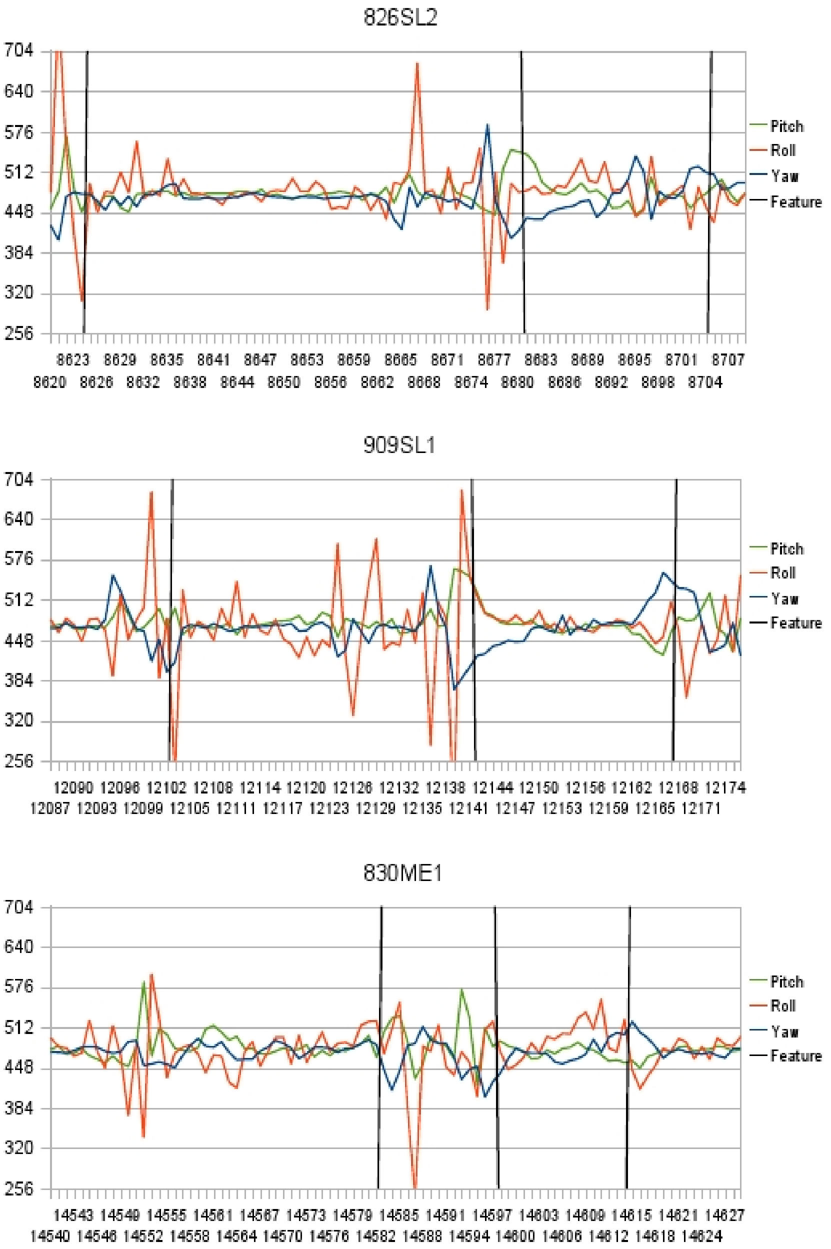


Illustration 32: Graphs of the final three gyroscope datasets used during method evaluation, session ID is above each graph.

Feature observations

The final three accelerometer and gyroscope graphs differ markedly from the first twelve graphs for each sensor type. The participants in all of the final three sessions use the mounting technique where they placed their right hand on the front of the saddle as they mounted rather than placing it on the cantle as they mounted. The different hand placement seems to account for the differences in the feature shapes in the graphs. The last three sets of graphs are similar to the set that were for the participant who used the same hand-forward mounting technique that was noted during the training phase. The observations for the two different mounting techniques are noted below.

Hand on cantle

Feature (**n**) within the accelerometer dataset graphs is described as “a stepped drop in either the X, Y or Z accelerometer axes”. Both the accelerometer and gyroscope graphs are presented with features marked to assist the reader but these marks were not needed for recognition. It was usually possible to identify the characteristic stepped fall in the data within at least one accelerometer axis provided that the graph showed data from a reasonably small window that included the mounting sequence. Later examination of the video files confirmed that the area identified coincided with the participant's upwards arm pitch and the subsequent forward movement of their arm as they mounted.

The feature of interest was quickly recognised in each of the accelerometer graphs except 717HH2, 913EE2 and 901LW1. 913EE2 and 901LW1 both required an extended period before deciding that the feature of interest was present and the feature was not recognised in graph 717HH2.

A later, detailed examination, however indicated that the feature doesn't appear as described and so this feature may have been recognised from both its downward slope and a combination of the characteristics of other accelerometer features that had been previously discarded and that surround (**n**). A possible conclusion is that the researcher has trained himself to recognise the accelerometer pattern associated with this feature but that the description of the recognition method is insufficient to enable another person to recognise it. It is not clear if this feature is distinctive enough to recognise within a continuous data stream without the prompts associated with having predefined the area of the graph where mounting occurs. This would require further investigation.

In total the accelerometer feature (**n**) was recognised in nine cases, not recognised at all in four cases and recognise with difficulty it in two of the fifteen cases. Three of the four cases where the feature was not recognised involved participants who held the front of their saddle with their right hand while mounting. Other participants held the cantle (back of the saddle) as they mounted and so had to move their hand quickly forward as their leg crossed the cantle. Holding the front of the saddle while mounting is generally a smoother action but is difficult to do when the horse is significantly taller than the rider unless the rider uses a mounting block to gain height. During the recognition training a case was also encountered where the participant held the front of the saddle while mounting and in this case the feature (**n**) was also not recognised.

In one of the cases were there was difficulty recognising the accelerometer pattern, 901LW1, the participant held a whip in their right hand as they mounted and this may well have produced a slightly different movement. The gyroscope feature (**f**) was, however, recognisable for this case. In the other case, 717HH2 there is no obvious difference and again the gyroscope feature (**f**) was recognisable for this case. In the case where the pattern was not recognised, 913EE2, the participant used the hand-on-cantle mounting method but their right hand was obscured for most of the period while they mounted and so there is no obvious influencer for the pattern that was seen in this case. The gyroscope pattern was recognised in this case. The hand-on-front method of mounting accounts for the different pattern in the other three cases where the accelerometer pattern was not recognised and in all of these three cases the gyroscope tick-like feature was also not present.

The gyroscope graphs follow a similar pattern, the tick-like feature (**f**) was quickly recognised in ten of the fifteen cases, recognised with difficulty in one case and not recognised in four cases. Three of the four cases where the tick-like feature was not recognised were the same cases where the feature (**n**) in the accelerometer data was not recognised and where the participant held the front of the saddle while mounting. The last of the four cases where the tick-like feature was not recognised was case 914EE1 where the participant's horse moved forward quickly while she mounted and this may have influenced the movement. In this case the start of the tick-like feature is present but the ending upwards stroke is inverted and goes sharply down rather than up. The accelerometer pattern was recognised for this case. In the case where it was difficult to recognise feature (**f**) the participant LW again held a whip while mounting.

Hand on front of saddle

As has already been observed, in three cases (826SL2, 909SL1 and 830ME1) the participant placed their right hand directly on to the front right of the saddle as they mounted rather than grasping the cantle as they mounted. One of these three cases used a mounting block (830ME1) to assist mounting so that the participant was able to mount from a height that allowed her to reach across the saddle and down to the front of the saddle without contorting her arm. The remaining two mounts were by a reasonably tall rider (SL) onto a short (Icelandic) pony and so again the rider was able to reach across and down to grasp the front of the saddle without twisting her elbow.

Illustration 33: Session 826SL2 showing SL mounting with her right hand placed on the front of the saddle rather than the cantle

SL is tall enough relative to her Icelandic pony to reach across the top of the saddle and down to hold the front of the saddle as she mounts. This means that her right arm pitches up in a different manner as she lifts her body and her right arm does not reach forward quickly as her leg crosses the saddle because her right arm is already forward. The right arm is relatively immobile during mounting with this technique. This technique is generally impossible with a horse that is taller, relative to the rider, unless the rider uses a mounting block to gain height.

Illustration 34: Session 909SL1 showing SL mounting with her right hand placed on the front of the saddle rather than the cantle

Illustration 35: Session 830ME1 showing ME reaching across the top of the saddle and down to hold the front of the saddle.

ME uses a mounting block in this case to gain the height that she needs to be able to reach over and hold the front of the saddle while mounting.

In all three cases where the participant used the hand-on-front mounting method there are similar patterns within both the accelerometer and gyroscope graphs. The accelerometer graphs tend to be flatter with some peaks as the participants pitch their arm up as their body rises to enable their right leg to cross the saddle, followed by a broad-based shallow U shape. The gyroscope graphs are also flatter, again with peaks as the arm pitches followed by a sharp spread between the Pitch and Roll axes of the graph and a gradually coming together again of these two axes, giving the shape of a triangle with its high side to the left and its point to the right.

Summary

Fifty-seven data collection sessions were conducted and during those sessions two SF datasets were collected from a controlled laboratory situation and forty-four SF datasets from real life field situations. Thirteen of the real life SF datasets were discarded because of problems with the datasets, leaving thirty-one usable SF data sets. Nine of the thirty-one remaining real life SF datasets were collected from participants while wearing the sensor on their left arm. A choice was made to not use these left arm datasets because they required the recognition method to be applied a second time and this was not possible within the project time constraints. Of the twenty-two remaining real life SF datasets collected while worn on the participants' right arm, seven were used during recognition method training and fifteen during recognition method evaluation.

The SF sensor was treated as a black-box and the outputs from it were simply graphed in their raw format. No attempt was made to integrate, correct or calculate derivatives of the raw data. Data captured from the magnetometer within the SF sensor was discarded because it was location specific and did not have meaningful patterns that were independent of the geographic location where they were captured in their raw format.

The two laboratory datasets used during training were examined and twenty-three features were identified as possible candidates for common identification. These twenty-three features were progressively reduced to two features as the seven real world training datasets were examined. One was a feature of the accelerometer data and the other was a gyroscope feature.

The remaining fifteen real world files had the data associated with the mounting sequence from each file separated out and graphed. These data were examined to establish if either or both of the two features could be reliably recognised.

Feature (**n**), a stepped downward drop in either of the three accelerometer axes was identified in nine of the fifteen cases. Feature (**f**), a tick-like shaped feature in the gyroscope data was identified in ten of the fifteen cases.

Failure to recognise both of the two features (**n**) and (**f**) was common to three of the evaluation cases and one of the training cases. These common cases involved the rider holding the right front of the saddle as they mounted. Holding the front of the saddle results in a different and smoother set of movements.

In all other cases where the researcher either failed or struggled to recognise one of the features, it was possible to recognise the corresponding feature within the other sensor graph for the same case. For example, with case 717HH2 where it was difficult to recognise the accelerometer feature (**n**), the gyroscope feature (**f**) was easily recognisable.

It is difficult to differentiate recognition achieved via the total picture presented by the graphs as opposed to identifying the specific features of the graph that were defined in the recognition method (such as feature **n**), particularly with the accelerometer data.

Chapter 5 – Discussion

Introduction

In the prior chapter we followed the method that we had previously defined to see if it is possible to distinguish when a horse rider mounts a horse, in real life, using inertial data captured from a single electronic sensor module worn on the rider's wrist. In doing this the domain of interest was constrained to only include horse riders who have put on specialist equipment (the sensor) or clothing immediately prior to going riding.

The data collection process delivered thirty-one usable datasets from real riding situations, nine of these were collected from the sensor when it was mounted on a participants left wrist and twenty-two when it was mounted on their right wrist. Participants used their left arm differently from their right arm during mounting and so the two collections of datasets needed to be analysed separately. The larger collection of datasets was chosen for analysis. The choice of right wrist mounted datasets had the effect of skewing the data sample towards right-handed participants.

Data was collected from a single, compound inertial sensor that produced three axes of acceleration data, three of gyroscope data and three of magnetometer data. The magnetometer data was discarded and only the data from the accelerometer and gyroscope data streams associated with each mounting sequence were selected for analysis. The selected raw accelerometer and gyroscope data was graphed without attempting to correct the data for issues such as noise, orientation induced changes and signal drift and then heuristic human pattern matching techniques were applied to approximately a third of the datasets to identify common features within that data.

After a process of recognition and elimination two features were identified that were common across the training datasets. These two features were tested against the remaining datasets and both features were successfully recognised in most cases.

The findings are discussed using the following headings:

- The use of heuristic human pattern matching to find common patterns within the sensor data.

- The successful creation and application of the recognition method.
- The role of domains within the application of the recognition method.
- The generalisation and applicability of the recognition method.
- Data skewness and its possible effects on the conclusions.
- Context recognition tools versus do it yourself context recognition.
- Single versus multi-sensors for context recognition
- A Black-box approach versus a Movement Model approach
- The analysis of raw data versus data derivatives.
- Chunking the data stream.

Some gaps in the research are noted along with suggested future research topics that may fill those gaps.

Human Heuristic Pattern Matching

The researcher is able to identify a number of gross features by simply looking at the graphs over a five minute window, these include periods when the sensor is relatively still, the participant walking and swinging their arms and a horse walking, trotting and cantering. This ability came from immersion in the data, using it and viewing the associated data, such as the video stream. In two cases the ability to recognise features at a gross level was instrumental in synchronising the files.

In one case the participant had done two non-energetic overhead arm-waves rather than the requested three energetic overhead claps and it was not possible to unequivocally identify the two waves within the sensor data stream. In this case we found the place within the video where her horse first moved from trot to canter, identified this same place within the sensor data stream (based on the sensor pattern change) and then worked back from that to identify and confirm the two overhead hand-waves.

The second example involved the PH laboratory session where the sensor was started approximately 10 minutes before the video and where the participant had performed multiple overhead hand claps. We were able to easily identify the hand claps on each occasion but had difficulty being assured that the correct set of three hand claps from the video were aligned with the corresponding set from the sensor data. In this case we found a passage within the middle of the session where we had checked the iPaq for connectivity and the participant stood with arms still for a reasonably long period, allowing the time period to be measured. We were then able to find the corresponding period of stillness within the sensor data and then work back from there.

After this immersion in the data we were generally able to identify major features in the sensor data at a relatively wide, five minute window view of the data. We were not, however, able to recognise the characteristic features found during mounting at this gross, five minute window, level of zoom.

The length of the average mount within the data is 5.48 seconds with a standard deviation of 2.28 seconds. Within the mounting period, the features that we were looking for generally lasted from half a second to one and a half seconds. Given these sizes, it was necessary to zoom to a ten to fifteen second window in order to adequately recognise feature (**n**) and (**f**).

Lack of time and viewer fatigue prevented the viewing of substantial parts of the sensor stream at a ten second window level of zoom. Instead we used the video time codes to place the ten to fifteen second viewing window over the place in the sensor data where the mount was taking place and identified the features from within that window. While this manual method would not be practical to directly implement within an automated algorithmic recognition method, it does work, computer recognition algorithms are not subject to viewer fatigue and in a real-time system the algorithm would be searching the data stream as it arrived and so it seems possible (although untested) to implement an automated feature recognition process based on the patterns found with the method.

One unresolved issue related to the use of heuristic human pattern matching is that we run the risk of simply finding what we are looking for. The identification of the tick-like or downward stepping feature is subjective rather than being objective. None of the features in each case are identical in every way, they all differ to a smaller or greater extent. Different instances of a feature that we say match the pattern may well be said to not match by a different viewer. Of course, we wanted to find a pattern and so it is in our interests to declare features as matching and this desire may influence our judgement either consciously or unconsciously. It is as a result of this subjectivity that we have purposely not calculated any statistical measure of reliability around the recognition method. The use of statistical measures of reliability would imply an element of objectivity that is not present.

Without a statistical measure we are left to note that the features that we identified seem to be present in varied forms in the majority of the data taken from the SF sensor when worn on the riders right wrist while mounting. The features are present for both right-handed, ambidextrous and left-handed riders. The features are not present where the rider does not place their right hand on the saddle cantle whilst mounting.

The successful creation and application of the recognition method

It is possible for a method that uses human heuristic pattern matching to distinguish when a horse rider mounts a horse using inertial data captured from a single device worn on the rider's wrist.

During the Methodology chapter we defined a method that we would use to distinguish mounting. Using that method we were then able to identify two patterns during training that allowed us to apply the method to the remaining datasets and to distinguish mounting with some reliability within those datasets.

Within the training phase of the method we first applied our pattern matching skills to the data that we had collected during the laboratory sessions. To some extent we fully expected to see recurrent patterns within the graphs of these data because each mount was substantially the same, used the same participant and the same model horse under the same conditions and so we would have been surprised if there weren't patterns within the data. It was pleasing that we did see patterns emerging within this first laboratory dataset. However, while there are definite patterns in these graphs, each graph is different in a number of ways from the other graphs in this series and in particular, the graph of the first mount in this series (used the office step) is noticeably different at the start from the subsequent graphs.

These differences highlight that even when each mount may seem to be virtually identical there are differences in the sensor readings captured from each one. Such differences can be caused by subtle changes in the orientation of the wrist while mounting, the presence of noise and uncorrected drift within the sensor signals and more differences in techniques used from one mount to the next as the participant first learned the movements and then started to tire and become bored with repeating them.

These differences within the data that we expected to be most similar highlighted for us that finding common features across different participants in real-life situations where we expected the possibility of quite major technique differences and where the sensor would be worn slightly differently in each case, would not be a forgone conclusion.

During our examination of this first set of mounts with participant PH, captured in the laboratory, we identified a large number of potential features that we could then test for, within subsequent data streams. When we next examined the set of graphs from the second laboratory session that used participant JC we immediately noticed a number of major differences. For example comparing the first six accelerometer graphs from JC with the first twelve accelerometer graphs from PH we see that in the case of JC, the accelerometer Z axis typically moves above the accelerometer X axis as JC starts to mount whereas with PH typically this doesn't happen until almost halfway through the mount. This may indicate either that the sensor was mounted in slightly different positions on the wrists of JC and PH or that JC uses her wrist differently from PH as she mounts.

Looking at the gyroscope graphs from these two laboratory sessions, we also note that the reverse S-like feature that appears in all JC's graphs except the first one (mount 2 through mount 6 within the graph series labelled 813JCRRAFGL), is typically further away from the tick-like feature on JC's series of graphs than it is on PH's two similar series of graphs and that with PH this feature is less consistent.

Within the laboratory graphs it became obvious that there were both commonality (as expected) within graphs and differences, sometimes major differences and this implied that we would likely see more differences as we examined the real-life data streams. If we had of stopped the training phase with the end of the examination of the laboratory graphs then we may have subsequently found ourselves in a similar position to other researchers such as Foerster et al. (1999), Van Laerhoven and Cakmakci (2000), Mantyjarvi, Himberg and Seppanen, (2001), Bao and Intille, (2004) and Ravi et al. (2005) who only used laboratory data for training and subsequently found real-life recognition more difficult.

The first real-life dataset that we chose to examine was one recorded from PH on the 15th July 2008. This was both the first real-life dataset that we collected and the first overall that we collected and so it seemed fitting that it should also be the first compared with the laboratory trials datasets. It also helped that PH was a common participant between both the laboratory and real life environments. One problem with the data from this session though was that the settable accelerometer sensitivity setting had been set to plus or minus 1.5G's and we subsequently found that this was too sensitive and so all other data capture sessions had the accelerometer set to 2.0G's. This meant that it was not possible to compare the accelerometer data but it was possible to compare the gyroscope data as that sensor did not have a settable sensitivity and so stayed constant throughout.

Upon examination of the gyroscope data for PH's session on the 15th July we saw that a number of features that we had identified from the laboratory datasets were not present but that the tick-like feature and three others were present and this provided the first concrete hint that the method may have found a feature that distinguished mounting.

We then examined six additional datasets with two taken from the start of the data collection, two from the mid-period and two from towards the end of the data collection process. We examined both the accelerometer and gyroscope data for these six datasets and examined them for evidence of the features that we had already highlighted as possible common features. These six datasets were taken from six different individuals with one of them being JC who also took part in the laboratory data collection.

One of the graphs (912EE2) was markedly different both from the other five in the set and from the laboratory sets and upon examination of the video for this mount we saw that the participant mounted using a different technique from those seen in the other videos examined up until that point. This participant used a hand-on-front of saddle technique whereas other participants had used a hand-on-cantle technique. The other five graphs while similar to prior hand-on-cantle graphs, also differed in some key details and as a result we discarded all except two features as being candidates for possible common recognition across future graphs. These features were the stepped down shape in any one of the three accelerometer axes (**n**) and the tick-like feature within the gyroscope Yaw axis (**f**). This was the end of the training phase of the recognition method.

We then applied the method to the remaining usable datasets and confirmed that the two features previously identified did occur in a majority of cases overall and occurred commonly within datasets where the participant had used the hand-on-cantle mounting technique but did not occur when participants used the hand-on-front of saddle mounting technique.

The success in finding the two identified features in more cases where the participants used a hand-on-cantle technique led us to redefine the method design goal to narrow the domain of interest to recognising mounting for riders who used a hand-on-cantle mounting technique. The redesign is consistent with the Design Science methodology that encourages a review of the design goals and the design process and so we conclude that we have successfully created and tested a method that is able to recognises riders mounting (in a majority of cases) within the constrained domain.

The Role of Domains and Sub-Domains

The original domain of interest was “mounting within the traditional European horse riding style”. This domain is a sub-domain that is an intersection between the domain of mounting techniques across all riding styles and the domain of all activities associated with traditional European riding. Both of these domains are, in turn, sub-domains of horse riding. In this sense, every domain except the domain that sits above every other domain is a sub-domain. For ease of expression though, we usually simply just call these domains rather than emphasising their possible hierarchical nature by calling them sub-domains. Our purpose in restricting our interest to a particular domain is both to narrow the search space across which we must search in order to find features that reliably define when a rider mounts and to reduce the likelihood that we will encounter false positives while searching for those features of interest.

The ability to subdivide domains at will then raises the question of why not just keep subdividing the domains until we either reach a point where there is no possibility of mistaking mounting for anything else or we get to an individual case-by-case basis? The answer to that question lies in our purpose for knowing when a rider mounts. Our declared purpose for this information is so that we can implement a user interface on a wearable training device that can usually sense for itself when a rider mounts so that it can then offer riding coaching advice without the rider having to explicitly tell the device to start. If we define too narrow a domain then we simply switch from having the rider tell the device when to start to having the rider tell the device what domain they are currently in. This more than defeats the purpose (of simplification), it actually makes the user interface based on this process more complex and less natural than it was to start with.

The trick with subdividing domains then seems to be around choosing to subdivide only when doing so makes sense from the point of view of how the application or device will use the context information that is derived from sensing within that domain. In the case where we set out to implement a device that offers coaching advise within a particular sport then obviously constraining the domain to that sport does make sense unless some universal coaching device could be designed and that is not currently practical. Deciding how much further to narrow the domain within that sport will depend both on how natural and long-lived the particular subdivision category is and how large a population it has. For example, handedness is a natural, long-life candidate for possible domain subdivision because almost all people are already either right-handed, left-handed or ambidextrous and very few change from one to the other. We see this expressed commercially by the sale of left-handed golf clubs, for example, as items that are designed for a very particular domain.

Approaching this from the other direction, cases where a rider holds a whip, for example, are not good candidates to be defined as a parameter for domain subdivision because a horse rider will choose to hold or not hold a whip while mounting on a case by case basis, depending on circumstances at the time. There is no longevity to a choice to hold or not hold a whip while mounting.

The question then arises of was our choice to subdivide the original domain into a narrower domain defined by choice of hand placement during mounting a reasonable choice, in the circumstances, or not? There can be no definitive answer to this question without further research but our own experience with horse riders is that hand placement while mounting is a habitual practise for most riders. In addition there is no consistent advice given to riders on hand placement while mounting. A simple search of the internet will turn up advice ranging from not placing a hand on the saddle at all, to grasping the saddle horn (only present with Western riding) with both hands, placing the hand on the cantle, middle of saddle or the front of the saddle and even grasping the horse's mane with both hands.

However, habit, physics and human anatomy also have a say in the matter. The majority of horse riders ride a horse that is taller than the rider's shoulder and so when mounting from the ground, without assistance, it is difficult for these riders to put their right arm up, over and down to grasp the front of the saddle without considerable contortion of the elbow. It is easier for riders to grasp the cantle of a traditional European saddle because it sits out from the saddle and so provides a good hold point and it provides a spread from the left hand that usually holds the front or the saddle or mane and so ensures a wider point of balance while mounting.

It is possible to use a mounting block to gain the additional height needed to enable a rider to grasp the left front while mounting and the data shows one instance of this (830ME1). However, a number of other riders also used mounting blocks to help them mount but did not place their hand on the front of the saddle while mounting. This provides anecdotal evidence that hand placement choice whilst mounting is often habitual and so a domain subdivision based on hand placement has longevity. Lastly, without prompting or pre-selection, the majority of the riders within the study chose to place their hand on or near the cantle while mounting. Only four out of thirty-one mounting instances that we analysed used a hand-on-front technique while twenty-seven used a hand-on-cantle technique. As a result, we conclude that it is reasonable to subdivide the original domain to narrow the domain focus to hand-on-cantle style mounting.

The generalisation and applicability of the recognition method

The recognition method that we developed for hand-on-cantle style mounting is a general method and so it is applicable to any domain within horse riding. This generality does not, however, guarantee that features will be found within other domains that lead to reliable recognition of mounting within that domain.

We have previously noted in the section on project constraints during the introduction chapter that the conversion of the manual heuristic human pattern matching method into an equivalent algorithmic recognition method is outside of the scope of this project. While accepting that this project will not attempt to convert the method into an algorithmic one, we also note that a design goal was to develop a method that was capable of being applied algorithmically, so that we could further develop an existing coaching device. With this latter design goal in mind we discuss possible strategies for applying multiple methods, assuming that it is possible to convert the existing method and any future methods that we may create, into algorithms.

Three high level strategies for applying multiple recognition methods seem obvious, they are:

a) Develop separate devices with one specialist device for each intended domain.

   If the market is large enough and the longevity of the domain selection parameter is long enough then this seems a reasonable strategy and one that may be applied if we discover that handedness is a factor that significantly affects mounting recognition. In this case, for example, we may develop left-handed and right-handed coaching devices. This approach has the benefit of being simple to implement and so may have cost advantages.

b) Develop a more general device with the capacity to be manually switched so that it is applicable to a particular domain at a time.

   This seems more suited to situations where either the market for each single domain is too small to support a specialist device that focusses solely on that domain or when there is a possibility of switching domains from time to time. This approach has the benefit of flexibility at the cost of adding some choice complexity. This approach adds complexity to construction and so would be expected to cost more than a simpler but more specialist device.

c) Develop a smarter general device with the capacity to operate in multiple domains in parallel so that it can sense which domain rules to apply without having to be manually switched.

Such a design would be suited to any domain situation but this option adds more complexity to the construction of the device and would likely be more costly to produce but if implemented appropriately this would be as simple to use as the specialist device and so has appeal from a usability point of view.

With any of these approaches we are still a long way away from any universal context recognition method or algorithm.

Effects of sample skewness

During data collection we started with a policy of asking participants to wear the SF sensor on their dominant hand while mounting. The original intention was to analyse the datasets from each hand separately so as to get a picture of usage of both hands. However both our original reasoning was faulty and we miscalculated the time we would have available for data analysis.

Our reasoning was faulty in that by asking the participants to wear the SF sensor on their dominant arm we were effectively skewing both collections of data. Using the initial policy, data collected from the sensor when it was worn on the right arm would be skewed towards right-handed people and data collected from the sensor when it was worn on the left arm would be skewed towards left-handed people. A less skewed policy would have been to randomly assign the sensor to either the left or right arm regardless of handedness, on a data collection session case by case basis, while ensuring that underlying handedness of participants was representative of the general population.

However, given the time constraints a more effective policy that would have produced a greater number of datasets for analysis would have been to assign the sensor to the same arm for all participants regardless of underlying handedness.

Given that the sample is skewed, does this effect the ability to create and test the method on the data that was collected? We believe not. There are two possibilities, namely:

1. The handedness of the participant does have an effect on how they use their right arm while mounting and that difference is enough to cause the patterns that we searched for to not appear in the data stream.

2. Either handedness does not have an effect on how participants use their right arm while mounting or that the effects that it does have, do not alter the basic patterns that were found by enough to result in not finding these patterns.

If option two is the case then there is no effect of the sample being skewed and so the skewness can be ignored. If option one is the case then we have simply identified an additional sub-domain that needs to have the method applied to it but identifying an additional sub-domain does not invalidate the use of the method in other sub-domains.

The inclusion of a single case for both a left-handed and an ambidextrous participant within the data analysed strengthens the possibility that handedness has minor or no effects on the particular patterns that we identified. There is, however, insufficient data to draw this conclusion in any emphatic manner.

While the skewness of the sample data does not invalidate the conclusion, it should be noted so that we are not tempted to generalise our conclusion beyond the domain of right-handed riders. In addition, skewness may become a factor once we start looking for false positives because of the possibility that the underlying handedness may have an influence on activities other than mounting that then produce more false positives for participants with a particular handedness.

Context recognition tools versus do it yourself context recognition

The field of context recognition is still a young area and shares aspects in common with pattern recognition from signal processing, speech, text and video fields along with aspects from Artificial Intelligence research. Many of the techniques that have been developed for context recognition or imported into the field from other areas require a deep understanding of mathematical techniques and complex algorithms. The prior acquisition of this knowledge presents a significant barrier for a researcher who does not already have a strong background in any of these areas. For a generalist researcher who doesn't have these skills to start with and who wants to do research within the general area of context recognition the alternatives seem to be to:

1. Collaborate with other researchers who already have this knowledge and who are willing to share their knowledge.
2. Take the time to learn the skills needed to successfully conduct research in this field.
3. Use tools or tool kits that others have developed to enable context recognition to be done without having a deep understanding of what context recognition entails.

Within the prior literature review we highlighted some of the current projects that have as their goal to produce context sensing tools and tool kits that enable context to be sensed without having to understand the underlying maths or algorithms. These efforts are to be applauded as they will broaden the range of researchers within the field, however, on reflection, it may be premature to advocate wide use of these tools if this means that most researchers will progress on to use context recognition techniques without a strong grounding in all of the issues associated with a particular approach to context recognition.

The informal learning involved with manually searching graphs of raw sensor data has led us to conclude that regardless of the success or not of any method that we were able to develop, the knowledge that we gained by looking at graphs of the raw data had strong but unmeasurable value in itself. Ready access to a pre-built tool may have encouraged us to skip over this learning experience.

Single versus multi-sensors for context recognition

Other authors such as Blum (2005) and Kern et al. (2003) have suggested that a minimum of two inertial sensors are required for accurate context recognition while authors such as Benbasat (2000), Ravi et al., (2005) and Zappi et al., (2007) maintain that context can be reliably recognised with a single sensor. We also conclude that context can be reliably recognised with a single sensor but provided the domain is constrained in some fashion so as to restrict the search space and the resulting false positives.

On deeper analysis both Blum (2005) and Kern et al., (2003) were attempting to recognise context within very wide domains when they concluded that at least two sensors were required whereas Benbasat (2000) restricted his domain to the activities of a single person (case-by-case); Ravi et al., (2005) constrained their domain to the artificial environment of a laboratory and Zappi et al., (2007) only managed 50% reliability using a single sensor within the restricted domain of automotive assemble. As such our conclusions are compatible with all these prior authors excepting that perhaps we have made the role of domain restrictions more explicit when concluding that a single sensor can recognise context *provided the domain that it operates in is restricted*.

Black Box versus Movement Model

Within this project we have chosen to treat the sensor signals as a "black box" and to not attempt to understand them or to relate them to specific moves or movements. This was done because it seemed simplest and because it appeared less time consuming. Most reasonably accurate movement models based on inertial sensor data require either a pre-built framework/tool or require a significant understanding of the mathematical and physical (bio-mechanical) concepts involved in building the model and require significant processing of the data in order to build those models. Where models are built from scratch, the understanding required to build the models is not in itself crucial for developing a recognition method.

Some researchers such as Bannach, Kunze, Lukowicz and Amft (2006), Benbasat and Paradiso (2002) and Westeyn, Brashear, Atrash and Starner (2003) have described tools, frameworks and tool-sets such as CRN, the MIT Media Lab gesture recognition framework and GT2k that can be used to quickly build context and gesture recognition systems without an extensive background in building models of human movement or pattern recognition. In addition, commercial tools also exist that enable researchers to use the outputs from inertial sensors without having to understand how the models are built. Tools and frameworks such as these may well enable future researchers to rapidly progress beyond capturing and then applying simple analyses to inertial sensor data.

Raw Data versus Derivatives

In this project we have chosen to work with a graphical representation of the raw data itself rather than derivatives of that data. Working so closely with the raw data gave insights that may not have been apparent if we had jumped straight into analysing derivatives of the raw signals.

For example, by working closely with the raw laboratory sourced data and raw real world data we began to understand that much of the regularity and the patterns seen within the laboratory data were a function of the regularity of the gestures performed by the participants in the laboratory and we then realised how quickly most of these regular patterns disappeared when we looked at the real world data.

After looking at a number of files we became quite adept at spotting the patterns associated with both hand claps (synchronisation gesture) and mounting without having to be directed to these events within the data streams. Such understanding might well assist when deciding how and what derivatives to apply to the data.

Chunking the data stream

We chose not to chunk the data stream because we could not define any reasonable method of chunking it within a heuristic approach, although as we described earlier, we believe that we applied an implicit chunking during pattern recognition based on the patterns that we found. In addition, by concentrating the visual search for a pattern within the data associated with the mount we did apply a chunking process of sorts in that we chunked the data stream into before-the-mount, mounting and after-the-mount.

Research Gaps

False Positives

While it is useful that a particular set of patterns can be regularly found across almost all riders within the sample that used a hand-on-cantle stirrup mount technique, this in itself is not enough to reliably recognise a mount activity. In order to reliably recognise a mount activity we also need some understanding of how regularly these patterns occur during other (non-mount) horse riding activities. If the patterns regularly occur during other horse riding activities then a simple approach to pattern recognition would yield many opportunities to incorrectly recognise an activity as a mount activity when it was in fact some different activity. This is termed a false-positive.

No comprehensive search has been made within the data collected for this project for false positives. The search has not been undertaken because it was impractical to undertake using heuristic human pattern recognition methods and has, instead, been left for a future project. Of the data that was reviewed during training and evaluation (estimated to be less than 2%), the two feature patterns were not immediately apparent outside of mounting. This informal review of a very small sample of the data is not in any way conclusive, particularly as the data that was reviewed was clustered around the mounting activity. There may be other activities that are done during preparation for riding that are also associated with these patterns.

However, a comparison with the associated video data at the time of mounting shows that the patterns most likely relate to how the right wrist and arm pitches upwards and then quickly flicks forward as the rider lifts their body high enough to put their right leg over the horse's back. It is possible that this particular set of movements may be uncommon enough that it will remain reasonably unique.

It is highly unlikely that any small set of movements is so unique that they would reliably define a horse mount activity against a background of any other possible activity. The particular two patterns that have been identified may well, for example, also occur when a gymnast does vaulting exercises while using a gymnasium “horse” or vault. Equally there may be many other types of activities outside of horse riding where these particular patterns occur. Restricting the search area to particular domains, as we have done within this project, is an appropriate way of excluding false positives from these other activity domains.

This requirement to constrain the domain within which the sensor readings will be interpreted is not as restrictive as it first may appear. For example many riders who ride and most riders who train for riding by undertaking regular, structured riding activities prepare for riding by putting on riding specific clothing such as riding boots, riding gloves, a riding helmet and/or jodhpurs and then take these items off again after riding. Given that these riders already prepare for riding by putting on specific riding clothes and then taking them off again afterwards, then it seems reasonable to put on the riding monitor device at the same time and to take it off again after riding is complete. This simple action effectively constrains the domain to that of horse riding.

Would a higher sample rate within the sensor provide better data?

We chose a 10Hz sample rate for this project however, the work by Verplaetse (1996) suggests that a human arm can experience up to 9G's of acceleration in normal activity with frequencies up to 12Hz. The Nyquist–Shannon sampling theorem proposes that we should use at least twice the highest expected frequency to fully describe the underlying signal.

We are reasonably confident that setting the sensor to a plus or minus 2G setting has not caused many movements above or below 2G to be missed, based on anecdotal tests of the data we collected but we have not tested this supposition exhaustively. There do not seem to be many instances within the data when the sensor read at its maximum reading for more than one or two samples and it did not regularly read close to either maximum or minimum. Any future research should first establish if an accelerometer is required to read at higher than plus or minus 2G's in order to fully describe the underlying signal.

We did note, however, occasions within the data streams when there were flat or nearly flat peaks or troughs and so this does suggest that a sample taken between the two sides of the flat period may have yielded a different intermediary reading. This supports the idea that a higher sampling frequency may yield more information about the underlying signal. The use of a higher sampling rate may be even more important if the sensor signal is used to build a model of the movement that it is measuring. We suggest that any future work based on arm movement use a sample rate of 24Hz or higher and that this be tested prior to data collection.

Would more sophisticated tests have found more common features?

Looking at the graphs of the raw sensor data has given us a deeper understanding of some of the underlying patterns than we would have had if we had of only applied algorithmic search tests to the sensor data and so using heuristic human pattern matching has been useful within this project. However, in future research it would also be useful to obtain a basic understanding of the underlying patterns and then also apply algorithmic search methods. It is entirely possible that there are common patterns that occur within the data streams that cannot be easily picked up using human pattern matching but that may be picked up using more sophisticated methods. We suggest supplementing human pattern matching with algorithmic pattern matching.

There are a number of approaches to applying algorithmic search methods to raw sensor data or to simple derivatives of that data and we do not have any feel from doing this project for which one may be more useful than others although the approaches reported by Stiefmeier et al. (2006) on clumping small, common movements into atomic gestures and the use of simple string search techniques to find those atomic gestures seems appealing, as does some of the work in the related areas of both written text and spoken word recognition

Chapter 6 – Conclusions

Summary

We conclude that it is possible to recognise mounting in specific circumstances using the outputs from a single sensor, mounted on a rider's right wrist.

Main conclusions

Heuristic human pattern matching can be used effectively in some cases.

In some cases it is possible to use heuristic human pattern matching to find and recognise features within an inertial sensor data stream. The synchronisation process that was used to ensure that the data stream could be synchronised with the video is a useful, neutral example of how we used heuristic pattern matching methods to accurately identify features within the data stream. In most cases a simple scan of the sensor data stream, starting from the beginning of the data file, was able to identify the characteristic motions associated with the overhead hand-claps and hand-waves that were used for synchronisation purposes.

Within this study, we set out to use Design Science as a methodology to create a heuristic context recognition method to distinguish when a horse rider mounted a horse. We constrained the domain of interest initially to the domain of rider using traditional European riding style mounting practises with a fully tacked up horse. After designing, training and testing the method we modified the domain of interest to focus in on riders who used the hand-on-cantle mounting style within the traditional European riding style and with fully tacked up horse. With this modified domain the method was able to reliably recognise mounting in a majority of cases. We conclude that it is possible to recognise mounting using the heuristic human pattern matching method that we created (within the constrained domain), that the method could be applied to other domains and that it is possible to use a single sensor to reliably recognise context provided the domain within the sensor is used is constrained in an appropriate manner.

References

Abowd, G. D., Atkeson, C. G., Hong, J., Long, S., Kooper, R., & Pinkerton, M. (1997). Cyberguide: A mobile context aware tour guide. *Wireless Networks, 3*(5), 421-433.

Anderson, R., Harrison, A., & Lyons, G. M. (2005). Accelerometry-based Feedback - Can it Improve Movement Consistency and Performance in Rowing? *Sports Biomechanics, 4*(2), 179-195.

Annett, M. (1967). The binomial distribution of right, mixed and left handedness. *The Quarterly Journal of Experimental Psychology, 19*(4), 327-333.

Bannach, D., Kunze, K., Lukowicz, P., & Amft, O. (2006). Distributed modular toolbox for multi-modal context recognition. *Lecture Notes in Computer Science, 3894*, 99.

Bao, L., & Intille, S. S. (2004). *Activity recognition from user-annotated acceleration data.* Paper presented at the PERVASIVE 2004 Conference. http://web.media.mit.edu/~intille/papers-files/BaoIntille04.pdf

Barnard, L., Yi, J. S., Jacko, J. A., & Sears, A. (2007). Capturing the effects of context on human performance in mobile computing systems. *Personal Ubiquitous Computing, 11*(2), 81-96.

Baudouin, A., & Hawkins, D. (2004). Investigation of biomechanical factors affecting rowing performance. *Journal of Biomechanics, 37*(7), 969-976.

Benbasat, A. Y. (2000). *An inertial measurement unit for user interfaces.* Citeseer.

Benbasat, A. Y., & Paradiso, J. A. (2002). An inertial measurement framework for gesture recognition and applications. *Lecture Notes in Computer Science*, 9-20.

Bernmark, E., & Wiktorin, C. (2002). A triaxial accelerometer for measuring arm movements. *Applied Ergonomics, 33*(6), 541-547.

Billinghurst, M., & Starner, T. (1999). Wearable devices: new ways to manage information. *Computer, 32*(1), 57-64.

Blum, M. L. (2005). *Real-time Context Recognition.* Swiss Federal Institute of Technology, Zurich. http://www.media.mit.edu/wearables/papers/thesis_MarkBlum.pdf

Brodie, M., Walmsley, A., & Page, W. (2008). Fusion motion capture: a prototype system using inertial measurement units and GPS for the biomechanical analysis of ski racing. *Sports Technology, 1*(1), 17-28.

Brownson, C. L., Marchant, E. C., Todd, O. J., Miller, W., & Bowersock, G. W. (1968). *Xenophon: In Seven Volumes*: W. Heinemann Ltd.

Bryman, A. (2004). *Social Research Methods* (Second ed.). Oxford: Oxford University Press.

Chambers, G. S., Venkatesh, S., & West, G. A. W. (2004). Automatic labeling of sports video using umpire gesture recognition. *Lecture Notes in Computer Science*, 859-867.

Chen, G., & Kotz, D. (2000). A Survey of Context-Aware Mobile Computing Research. *Dartmouth Computer Science Technical Report TR2000-381.*

Dey, A. K. (2001). Understanding and Using Context. *Personal and Ubiquitous Computing, Volume 5*(1), 4-7.

Dong, M., & He, D. (2007). Hidden semi-Markov model-based methodology for multi-sensor equipment health diagnosis and prognosis. *European Journal of Operational Research, 178*(3), 858-878.

Edmison, J. N. (2004). *Electronic Textiles for Motion Analysis.* Unpublished Masters, Virginia Tech. Retrieved 30 May 2008, from

Erickson, T. (2002). Some problems with the notion of context-aware computing. *Communications of the ACM, 45*(2), 102-104.

Foerster, F., Smeja, M., & Fahrenberg, J. (1999). Detection of posture and motion by accelerometry: a validation study in ambulatory monitoring. *Computers in Human Behavior, 15*(5), 571-583.

Gu, T., Pung, H. K., & Zhang, D. Q. (2005). A service oriented middleware for building context aware services. *Journal of Network and Computer Applications, 28*(1), 1-18.

Hevner, A. R., March, S. T., Park, J., & Ram, S. (2004). Design science in information systems research. *Management Information Systems Quarterly, 28*(1), 75-106.

Hunt, D. (2009) *Challenges and Collaboration in Kista – The field work for a Masters thesis*. Paper presented at the AUT Postgraduate Symposium, Auckland, New Zealand.

Hunt, D. (2010a) *Building a wearable inertial sensor to monitor horse rider wrist movements*. A dissertation presented in fulfilment of a Masters project in Computing at KTH, Kista, Sweden.

Hunt, D. (2010b) *Real World Data Collection – How many errors can I make.* Paper presented at the NZ Computer Science Research Students Conference 2010, Wellington, New Zealand.

Intille, S. S., Bao, L., Tapia, E. M., & Rondoni, J. (2004). *Acquiring in situ training data for context-aware ubiquitous computing applications.* Paper presented at the SIGCHI conference on Human factors in computing systems, Vienna, Austria. http://doi.acm.org.ezproxy.aut.ac.nz/10.1145/985692.985693

Järvinen, P. (2000). *Research questions guiding selection of an appropriate research method*.

Junker, H., Amft, O., Lukowicz, P., & Tröster, G. (2008). Gesture spotting with body-worn inertial sensors to detect user activities. *Pattern Recognition, 41*(6), 2010-2024.

Kern, N., Schiele, B., & Schmidt, A. (2003). Multi-sensor activity context detection for wearable computing. *Lecture Notes in Computer Science, 2875/2003*, 220-234.

Kjeldskov, J., & Graham, C. (2003). A review of mobile HCI research methods. *Lecture Notes in Computer Science*, 317-335.

Kjeldskov, J., Skov, M. B., Als, B. S., & Hoegh, R. T. (2004). Is it worth the hassle? Exploring the added value of evaluating the usability of context-aware mobile systems in the field. *Lecture Notes in Computer Science*, 61-73.

Mantyjarvi, J., Himberg, J., & Seppanen, T. (2001). *Recognizing human motion with multiple acceleration sensors*.

March, S. T., & Smith, G. F. (1995). Design and natural science research on information technology. *Decision Support Systems, 15*(4), 251-266.

Mayagoitia, R. E., Nene, A. V., & Veltink, P. H. (2002). Accelerometer and rate gyroscope measurement of kinematics: an inexpensive alternative to optical motion analysis systems. *J Biomech, 35*(4), 537-542.

McIntosh, E. (Ed.) (1964a) The Concise Oxford Dictionary of Current English (Fifth ed.). Oxford: Clarendon Press.

McIntosh, E. (Ed.) (1964b) The Concise Oxford Dictionary of Current English (Fifth ed.). Oxford: Oxford University Press.

McIntosh, E. (Ed.) (1964c) The Concise Oxford Dictionary of Current English (Fifth ed.). Oxford: Oxford University Press.

McIntosh, E. (Ed.) (1964d) The Concise Oxford Dictionary of Current English (Fifth ed.). Oxford: Clarendon Press.

MEMSense LLC. (2009). *MEMSense Wireless IMU*. Retrieved 24 August 2009, from http://www.memsense.com/?gclid=CPOfoPL61J0CFRcjawodPEDdqw

Michahelles, F., & Schiele, B. (2005). Sensing and Monitoring Professional Skiers. *IEEE Pervasive Computing, 4*(3), 40-46.

MicroStrain Inc. (2009). *Inertia-Link*®. Retrieved 24 August, 2009, from http://www.microstrain.com/inertia-link.aspx?gclid=CKn20u_61J0CFSn6agodwk0ZrQ

Minnen, D., Starner, T., Essa, I., & Isbell, C. (2006a). Discovering Characteristic Actions from On-Body Sensor Data. *Wearable Computers, 2006 10th IEEE International Symposium on*, 11-18.

Minnen, D., Starner, T., Essa, I., & Isbell, C. (2006b, October). *Improving Activity Discovery with Automatic Neighborhood Estimation.* Paper presented at the International Symposium on Wearable Computers.

Parker, P. M. (2009). *Heuristic*. Retrieved August, 2009, from http://www.websters-online-dictionary.org/definition/heuristic

Pascoe, J. (1998). *Adding Generic Contextual Capabilities to Wearable Computers.* Paper presented at the 2nd International Symposium on Wearable Computers, Pittsburgh, Pennsylvania, USA. http://kar.kent.ac.uk/17486/

Peffers, K. E. N., Tuunanen, T., Rothenberger, M. A., & Chatterjee, S. (2007). A Design Science Research Methodology for Information Systems Research. *Journal of Management Information Systems, 24*(3), 45-77.

Randell, C., & Muller, H. (2000). *Context awareness by analysing accelerometer data.* Paper presented at the The Fourth International Symposium on Wearable Computers.

Ravi, N., Dandekar, N., Mysore, P., & Littman, M. (2005). *Activity recognition from accelerometer data.* Paper presented at the Seventeenth Conference on Innovative Applications of Artificial Intelligence (IAAI). Retrieved 11 October 2007, from http://paul.rutgers.edu/~nravi/accelerometer.pdf

Schilit, B., Adams, N., & Want, R. (1994). *Context-aware computing applications.* Paper presented at the IEEE workshop on mobile computing systems and applications.

Schmidt, A., Aidoo, K. A., Takaluoma, A., Tuomela, U., Van Laerhoven, K., & Van de Velde, W. (1999). *Advanced Interaction in Context.* Paper presented at the 1st international symposium on Handheld and Ubiquitous Computing.

Smith, R. M., & Loschner, C. (2002). Biomechanics feedback for rowing. *Journal of Sports Sciences, 20*(10), 783-791.

Starner, T. (2001). The Challenges Of Wearable Computing: Part 1 & 2. *IEEE Micro, 21*(4), 54-67.

Stiefmeier, T., Lombriser, C., Roggen, D., Junker, H., Ogris, G., & Tröster, G. (2006). *Event-based activity tracking in work environments.* Paper presented at the Proceedings of the 3rd International Forum on Applied Wearable Computing (IFAWC), Bremen, Germany.

Swedish Sports Confederation. (2002). *Sports in Sweden*: Swedish Sports Confederation.

van Aalst, I., Kazakov, D., & McLean, G. (2003a). *SPARC Facts 1997-2001.*

van Aalst, I., Kazakov, D., & McLean, G. (2003b). *SPARC Facts Equestrian*.

Van Laerhoven, K., & Cakmakci, O. (2000). *What shall we teach our pants*.

Van Laerhoven, K., Schmidt, A., & Gellersen, H. W. (2002). *Multi-sensor context aware clothing.* Paper presented at the 6th International Symposium on Wearable Computers (ISWC 2002), Seattle, WA, USA. http://csdl.computer.org/comp/proceedings/iswc/2002/1816/00/18160049abs.htm

Verplaetse, C. (1996). Inertial proprioceptive devices: self-motion-sensing toys and tools. *IBM Systems Journal, 35*(3), 639-650.

Weiser, M. (1993). Some computer science issues in ubiquitous computing. *Communications of the ACM, 36*(7), 75-84.

Westeyn, T., Brashear, H., Atrash, A., & Starner, T. (2003). *Georgia tech gesture toolkit: Supporting experiments in gesture recognition.* Paper presented at the 5th International conference on Multimodal interfaces.

Wikipedia. (2009, 30 January). *Definition of English Riding*. Retrieved October 13th, 2009, from http://en.wikipedia.org/

Wynekoop, J. L., & Conger, S. (1990). A review of computer aided software engineering research methods. *The Information Systems Research Arena of the 90's: Challenges, Perceptions, and Alternative Approaches, 1*, 129-154.

Xsens Technologies B.V. (2009). *Xsens Inertial Motion Capture*. Retrieved 28 August 2009, from http://www.xsens.com/en/general/mvn

Zappi, P., Stiefmeier, T., Farella, E., Roggen, D., Benini, L., & Troster, G. (2007). Activity recognition from on-body sensors by classifier fusion: sensor scalability and robustness. *Proceedings of ISSNIP*.

Zinnen, A., & Schiele, B. (2008). *A new Approach to Enable Gesture Recognition in Continuous Data Streams.* Paper presented at the ISWC '08. International Symposium on Wearable Computers, 2008.

Appendix 1 – Mounting a horse

Mounting is the term used to describe when a rider gets on a horse. There are a number of different equestrian disciplines and some have their own mounting techniques. Disciplines such as Mounted Games, Vaulting and stunt riding often employ techniques that allow a rider to mount while the horse is moving, however most riders will (by choice) mount while the horse is standing still. Mounting a still horse can be quite different from mounting a moving horse.

A horse can be ridden fully tacked up (the horse wears a saddle) or bareback (no saddle). Most horses are ridden fully tacked up. The use of a saddle can significantly affect how a rider mounts a horse. The saddle design can also affect how a rider mounts. In particular a rider who uses a side-saddle has a significantly different technique for mounting. Riders who use a Western saddles have a different technique as a result of the Western saddle having a "horn" where the European saddle does not. Most riders outside of the US and Canada use European saddles.

Most riders get on a horse in a similar way. Assuming that the horse has an traditional European style saddle on, along with reins then the following describes a typical mounting technique. The rider stops the horse, stands on the left side of the horse either facing the horse or facing the horses rear, gathers the reins in their left hand (this normally entails lifting the left hand) and steadies the left hand by either resting it on the horse's neck or by holding part of the horse's mane (on the neck). Then either puts their left foot in the left-hand stirrup (sometimes using the right hand to steady the stirrup so the foot will go in easily) or gets a "leg up" from another person.

They then put their right hand on either the rear of the saddle or the front of the saddle (Pommel) to steady themselves, then lift themselves up on their left leg high enough to put the right leg over the saddle. At the same time taking the right hand off the saddle (so their leg can get over), lifting and turning the right arm so that it is up by the horses neck (often picking up the reins with the right hand), at the same time the left arm turns. Once the rider is up at a height where they can swing their right leg over the horse's back, the other movements, particularly the arm movements happen quite quickly, generating quite strong acceleration forces.

The rider settles their weight into the saddle, puts the right foot into the right stirrup and then gathers up the reins at the correct length with both hands. The rider may put their right foot into the right stirrup before completely settling their weight into the saddle.

A sequence of pictures showing a rider mounting

Gather the reins

Steady the stirrup

Left leg in stirrup

Right hand on cantle

Body lifted, right hand prior to going forward

Weight in saddle

Mounting seen from the left of the horse

Left leg in stirrup

Left hand on wither, right on saddle

Lifting body, balance on both hands

Right knee by back of saddle

Right knee over saddle, right hand has moved quickly forward

Weight in saddle, both hands gather the reins

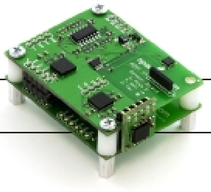
Mounting seen from the right of the horse

Appendix 2 – Sparkfun IMU 6 Degrees of Freedom V4

sparkfun ELECTRONICS

website: sparkfun.com
6175 LONGBOW DRIVE, SUITE 200
BOULDER, COLORADO USA
zip code: 80301
[303] 284.0979 [GENERAL] P
443.0048 F

2008.04.22



IMU 6 Degrees of Freedom v4 Data Sheet

1 Overview

The 6DOF v3 gets a make-over!

The 6DOF v4 Inertial Measurement Unit (IMU) is the newest SparkFun IMU offering, bringing the best features of the v3, plus a few new functions inspired by customer feedback and suggestions.

The v4 provides 3 axes of acceleration data, 3 axes of gyroscopic data, and 3 axes of magnetic data. Each independent channel is user selectable, as is the sampling frequency. The device can also report in ASCII or binary format, and can work over a Bluetooth link or a TTL hardline. Control is provided through an LPC2138 ARM7 processor with plenty of extra memory for custom code development. Additionally, the code has been ported to the WinARM development platform. With the freely available source code, you can be doing your own development in minutes!

The IMU 6-DOF v4 uses these sensors:

- Freescale MMA7260Q triple-axis accelerometer, settable to 1.5 g, 2 g, 4 g or 6 g sensitivity
- 2 InvenSense IDG300 500 degree/second gyros
- Honeywell HMC1052L and HMC1051Z magnetic sensors

All sensor readings are available through any terminal program in either ASCII or binary format, or with the improved 6DOF v4 IMU Mixer demo application (source code also available). Additionally, all sensors are internally temperature compensated.

2 Electrical Specs

- Input voltage: 4.2V to 7V DC
- Current consumption: less that 150mA
- Frequency response:
  - Magnetic sensors: 312Hz
  - IDG300 Gyros: 120Hz
  - MMA7260Q Accelerometer:
    - 350Hz, X and Y axes
    - 150Hz, Z axis

For a full description of the sensor specifications, please see the respective manufacturer's data sheets (available at www.Sparkfun.com).

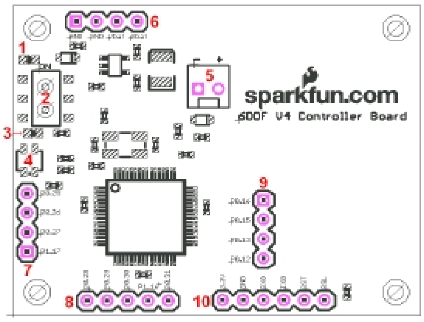
3 Hardware Overview

Like the v3, the v4 is a double-decker unit with the controller board on the bottom and the sensor board on the top. Each board has its own 3.3V regulator in order to better separate the digital and analog circuits.

3.1 Controller Board

There are a few things that the user may want to familiarize themselves with regarding the controller board.

Figure 1: Controller Board



1) Power indicator LED
2) Power switch
3) Bluetooth connection indicator LED
4) Tri-color status LED
5) Power connector
6) Power port for sensor board, switched from controller board
7) Magnetic sense lines
8) Accelerometer sense lines
9) Gyro sense lines
10) Programming port and TTL serial line

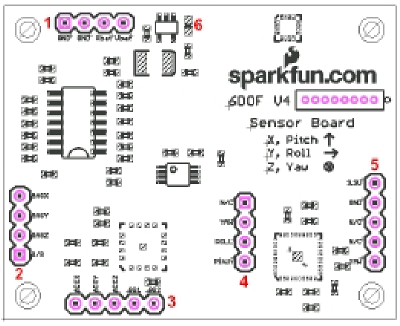
To aid in custom development, we've indicated the individual port numbers of the LPC2138 processor to which the user has access. All ADC lines are 0V to 3.3V, 10-bit. For a more in depth description of the LPC2138's capabilities, please see the LPC2138 User's manual.

3.2 Sensor Board

There are a few things that the user may want to familiarize themselves with regarding the controller board.

As stated previously, the sensor board uses Honeywell HMC1052L and HMC1051Z magnetic sensors. We've also included set/reset circuitry (used for realigning each sensor's magnetic domains

Figure 2: Sensor Board



1) Power port
2) Magnetic sense lines, plus ser/reset line
3) Acceleration sense lines, plus range set lines
4) Gyro sense lines
5) Vertical-mount gyro port
6) Power indicator LED

before each measurement), and each channel of the magnetic sensors has a high-gain differential amplifier as suggested by the HMC105X documentation. Supporting components have been kept at a distance from the sensors so as to increase the accuracy of the measurements.

The MMA7260Q accelerometer and the IDG300 gyros have each been set up per their manufacturer's recommendations, i.e. internal clock suppression filters on their outputs. These sensors are also internally temperature compensated.

All of the sensor lines have been indicated on the PCB should the user wish to use the 6DOF v4 sensor board with another control system, and all analog outputs are 0V to 3.3V.

4 Setup

When you first power up the 6DOF v4, you will see the power indicator LEDs on both the controller board and the sensor board light up. You will also see the tri-color status LED flash a few times. During normal sampling operations, the status LED will toggle red-blue-green, each color for 64 sample frames. When in the configuration menu, all colors will be on. If the device is not in the configuration menu and not sampling, the 6DOF is in its idle state and the status LED will be off (see the section on the configuration menu auto run mode for more details on this).

The 6DOF v4 comes pre-configured to run over Bluetooth. But if you haven't got a Bluetooth module…

4.1 Hard line connection

We've provided a back-door to get into the configuration over the hard line, but first the user needs to establish a hardware connection. The easiest way is to use one of our LPC programming adapters PGM-00714 or PGM-08650, but the user will still need to either solder a female header or the programming adapter itself to the 6DOF v4. We suggest using a header, but if you should choose to solder directly take care to get the orientation correct.. All of the signal lines are printed on the respective PCB's, so all you need to do is line them up.

If you should choose another means of hardware connection, you will need to know that the 6DOF v4 controller board TX and RX lines are 0 to 3.3V, not 5V, and certainly not RS-232. If you connect the controller board directly to an RS-232 line, you will likely damage the board.

From this point, we will assume that the user has provided for the hardware connection and we'll continue with the setup. Load your battery pack and plug it in to the 6DOF (or otherwise apply power to the device). Start with your 6DOF off but connected to your serial line. Open up a terminal program (Hyperterminal, Teraterm, etc) to the port to which you're connected with settings of 115,200 baud, 8 data bits, one stop bit, no parity or flow control. Now simultaneously hold down the spacebar on your keyboard and turn the 6DOF on. You should see the configuration menu come up (it will likely scroll past a few times since the keyboard repeats). Release the spacebar and choose option 6 to toggle the output port to "serial TTL". Cycle power for the setting to take effect.

4.2 Bluetooth connection

Generally speaking, a Bluetooth discovery will show the 6DOF v4 as "Firefly" with a random MAC. If you're using a Bluetooth device other than what is available from SparkFun, connect to the 6DOF v4 according to that manufacturer's directions as a serial port.

If you're using one of the Roving Networks Bluetooth devices available through SparkFun, you can directly open a serial port to the local device and issue discovery and connection commands without the interference of third-party Bluetooth drivers or other supporting software.

The first thing to do is to load your battery pack, plug it into your 6DOF v4 and turn it on. Assuming the user has a Roving Networks Bluetooth dongle (like the BlueDongle-RN-USB), the setup is very simple. Plug in your dongle and open a terminal program to the correct port, set to the same settings mentioned previously (115,200 baud, etc.). Issue the command "$$$<enter>" and the dongle will answer back with "CMD?". Then enter the command "I<enter>" and the dongle will go off and search for other Bluetooth devices for a few seconds. When it's done, it will report to you how many devices it found and give you their names and MAC addresses. The 6DOF v4 will show up as "Firefly" with a random MAC address. Now enter the command "C,<MAC address><enter>", where <MAC address> is that of the 6DOF v4, and the dongle will answer back with

"Trying". The dongle won't report the successful connection with text in the terminal window, but you'll see the connection indicator LED light up on both the 6DOF and the dongle. Now you're connected and ready to run.

4.3 6DOF v4 Mixer demo application

For a demonstration of the 6DOF v4's operation, the user can run the 6DOF v4 Mixer program. With the 6DOF powered up and connected in its idle state, close any terminal programs, open the 6DOF's serial port and start the mixer application. Select the port number to which the 6DOF is connected, set the frequency and sensitivity, hit the start button and you're off and running.

The mixer program requires that all channels are active. If you have any trouble getting the program to work right, check that all channels are active in the configuration menu.

5 Using a Terminal and the Configuration Menu

Once the novelty of the mixer program wears off, the user may want to do something slightly more useful with the v4, like attach it to something and log a file with a terminal program. What follows is a description of the configuration menu as well as a functional description of the v4's operation.

5.1 Operation from the Idle State

Upon reset and in its default configuration, the v4 will check to see if it has been configured for "auto run" mode (more on that later). If it's not in auto run mode, it goes into an idle state waiting for input. Normally this idle state serves as the start up state for the mixer application. In this state, the following inputs have the following effects:

1) "%", ASCII 37, sets the accelerometer to 1.5 g sensitivity
2) "&", ASCII 38, sets the accelerometer sensitivity to 2 g
3) " ' " (apostrophe), ASCII 39, sets the accelerometer sensitivity to 4 g
4) " (", ASCII 40, sets the accelerometer sensitivity to 6 g
5) ") ", ASCII 41, sets the sample frequency to 50Hz
6) " * ", ASCII 42, sets the sample frequency to 100Hz
7) "+", ASCII 43, sets the sample frequency to 150Hz
8) " , ", ASCII 44, sets the sample frequency to 200Hz
9) " - ", ASCII 45, sets the sample frequency to 250Hz
10) " . ", ASCII 46, sets the sample frequency to 300Hz
11) "#", ASCII 35, starts the unit running in binary mode with all channels active
12) " " (space), ASCII 32, stops the unit and returns it to the idle state (issuing another ASCII 32 will bring up the configuration menu)

Operation from this idle state will always be in binary output mode, but the user may select which channels are active. Also, configuration from this state as done in the mixer application will not be saved in memory, whereas settings from the actual configuration menu will be saved to memory for future use. At the same time, all but the active channel settings saved in memory have no effect on operation from the idle state. It should be noted that the primary purpose of this idle state and mode of operation is to more easily interact with the v4 mixer demonstration application, but there's no reason that a user's own application couldn't use it for a quick setup. It should also be noted that the 300Hz sampling rate is not available from the mixer app's selection, the reason being that the Bluetooth begins to exhibit latency when streaming data into it at somewhere between 250Hz and 300Hz with all channels active. But the 300Hz option is available from the idle state in case the user wishes to try it. Of course, operation from the configuration menu has no maximum setting (more on that later).

5.2 Operation from the Configuration Menu

To use the v4 from a terminal program, start up your program of choice (115,200 baud, hardware flow control, 8 data bits, one stop bit, no parity), plug in your Blue Dongle and power up your v4. When the devices connect, the Blue Dongle will report the connection established back to you. The v4 is now in the aforementioned idle state. Pressing the spacebar will bring up the configuration menu (STAT0 and STAT1 will come on as well), and here's what you'll see:

```
6DOF v4 setup, version 1.0

    1)   View/edit active channel
         list
    2)   Change output mode,
         curerntly binary
    3)   Set Auto run mode,
         curerntly off
    4)   Set accelerometer
         sensitivity, currently 1.5 g
    5)   Set output frequency,
         currently 100
    6)   Change output port,
         currently Bluetooth
    9)   Save settings and run unit
```

5.3 Active Channel List

Pressing "1" will bring up the active channel list:

```
    1)   Magneto X = on
    2)   Magneto Y = on
    3)   Magneto Z = on
    4)   Accel X = on
    5)   Accel Y = on
    6)   Accel Z = on
    7)   Pitch = on
    8)   Roll = on
    9)   Yaw = on
Press the number of the channel you wish to
change,or press x to exit.
```

To change a channel from active to inactive (or the reverse), just press the number of the channel you wish to change. It's a toggling function; pressing a number will bring up the full list again, but with the channel you wished to change in its opposite state. Press a few numbers and get a feel for it. Pressing "x" gets you back to the main menu.

5.4 Output Mode

Pressing "2" from the main menu will toggle the output mode from binary to ASCII and back again. What are these output modes, you ask?

In both output modes, the data from all active channels is framed by an "A" (ASCII 65) at the start and a "Z" (ASCII 90) at the end. Also in both modes, each channel is reported in exactly the sequence shown in the active channel list, with the addition of a sample count that immediately follows the "A" and precedes the first active measurement, which is to say:

1) Count
2) Mag X
3) Mag Y
4) Mag Z
5) Accel X
6) Accel Y
7) Accel Z
8) Pitch
9) Roll
10) Yaw

The count is two bytes that comes as MSB-LSB, and will range from 0 to 32767. If any of the channels are selected as inactive, that data is omitted from the frame and subsequent data moves up in the report sequence.

In binary mode, each active channel report comes as 2 bytes: MSB and LSB, in that sequence, and they will always be between 0 and 1023 because we're reading from 10-bit ADC's. The width of the data frame in binary mode will be 4 bytes ("A", "Z", and count are always present) plus 2 bytes for each active measurement. So for all channels active the data frame will be 22 bytes wide.

In ASCII mode, the count and active measurements are reported in ASCII so it's easier to read with a terminal program, plus all measurements and the count are delimited with TAB characters (ASCII 9) as well as a carriage return and line feed at the end of the data frame. This makes data capture and importation into a spreadsheet a relatively simple matter.

5.5 Auto Run Mode

Pressing "3" from the main menu will toggle the auto run setting. If you intend to use the v4 in ASCII mode, set this to "on". If the auto run feature is off, the v4 will always run from it's primary idle state, which means that it will always wait for a "#" to begin sampling and it will always run in binary mode.

One feature of auto run mode is that if the setting is active the v4 will begin sampling immediately upon power up, or after establishment of a Bluetooth connection if the Bluetooth is active. Pressing the spacebar will bring up the configuration menu again.

5.6 Setting the Accelerometer Sensitivity

Pressing "4" from the main menu will bring up the following submenu:

```
Set to:
   1) 1.5g
   2) 2g
   3) 4g
   4) 6g
```

Just press the number which corresponds to your choice and the v4 will revert to the main menu with the sensitivity changed.

5.7 Setting the Output Frequency

Pressing "5" from the main menu will allow you to change the sample frequency. Simply press "i" to increase or "d" to decrease, or "x" to revert to the main menu.

The minimum frequency setting is 10Hz, and there is no maximum setting. This allows the user to experiment with smaller data frames and higher sampling rates.

5.8 Setting the output port

Pressing "6" will allow you to toggle the output port, either Bluetooth or serial TTL. After selecting this option, you will be prompted to cycle power for this setting to become active.

5.9 Save Settings and Run Unit

Pressing "9" from the main menu will save the current settings to flash and exit the configuration menu. If the auto run feature has been activated the unit will begin running immediately. If it has not been set, the unit will revert to the initial idle state and wait for additional input.

6 Bandwidth Considerations and Firmware

The 6DOF v4 does not have any filtering in firmware, though there is enough memory left in the LPC2138 flash program space to implement some filtering. The internally set output bandwidth of the MMA7260Q accelerometer is 350Hz for the X and Y axes, and 150Hz for the Z axis. There are also additional single pole low pass filters to reduce switching noise from the sensor with poles set at 1591Hz (recommended by Freescale). The internally set output bandwidth for the IDG300 gyro sensors is 120Hz, along with single pole low pass filters at 96Hz (recommended by InvenSense). The HMC1052L and HMC1051Z magnetic sensors don't have internal filtering, but each axis has an external single pole low pass filter set at 319Hz. Of course, it's a good idea for the user to consider these numbers when developing an application to ensure that the proper filtering is in place for whatever sampling rate is selected.

Appendix 3 - On-site Check List   Version 2.1

☐ Introduce myself and brief explanation of what will happen; show equipment.

☐ Hand over Information Sheet & Consent form(s); allow time to read, ask questions then sign.

☐ Hand over waist belt to be put on; explain either back or front.

☐ If first rider for the day take an unused, pre-tested USB battery pack, place it in a holder and ask them to put it on. Assist if needed.

☐ Give them the wrist strap to put on, assist if required.

☐ Place the sensor case on the wrist trap (using the Velcro fastener) so that it is reasonably square on their wrist with the cable hole facing upwards when the wrist is unpronate. Plug the USB power cable into the battery pack.

☐ Use the free strap to collect together the extra cable length and put it under the strap so that it doesn't flap around.

☐ Turn the battery pack on.

☐ If first rider for the day take the iPaq and power it on using the button on the top right. Ignore any error messages about the external battery pack being low on power and dismiss such messages by touching the “x”.

☐ Go to Start → Settings on the iPaq, click on Buttons (ensure no buttons are assigned to any function); click on Lock (ensure that both button options are disabled when in Standby). Click OK twice to return to the main screen.

☐ Go into Calendar and ensure that no events will force a pop-up notification during the session with the rider.

☐ Go to the main screen and turn Bluetooth on

☐ Go to Bluetooth Manager and make a connection to the FireFly-D99F: SPP by holding the pointer on the icon until a blue circle appears and then choose → Connect; ensure that the icon changes to indicate a successful connection in both directions. Click on the “x” to close this screen.

☐ Click → Start → ZTERM (you may have to scroll to the bottom). If the screen immediately shows the sensor readout but it is not scrolling then reset the iPaq. Bluetooth should remain on (check) but you will need to reconnect to the FireFly. Re-start ZTERM.

☐ Choose the Sensor1 profile. When ZTERM starts, if the screen is scrolling with sensor readings then use the keyboard to press the space bar; if the screen is not scrolling, bring up the keyboard and press the space bar, in both cases a menu should appear.

☐ Click → Action → Log to file; enter the file name (YYYYMMDD99 where 99 is a sequence number starting with 01 that is incremented for each rider that day) and give it a .txt extension. Change the Type from Log Files to Text Files using the drop down. Choose Main Memory as the location (default). Click → OK.

☐ Press the space bar again so that the menu is repeated (this saves a copy of the settings for this session into the saved text file. IMPORTANT Now press the 9 key and visually check that the sensor readings are scrolling down the page. Close the key board BUT DO NOT CLOSE THE SCREEN BY CLICKING ON THE “x”.

☐ Carefully close the cover of the iPaq, show the rider what the readings look like and then carefully place the iPaq into the waist belt being careful not to press on the touch sensitive screen or on any buttons.

☐ Ensure that the video has a blank tape in it that is not set to read-only. Start the video and wait for the tape to settle (red icon goes away); press record and wait for the record icon to show.

☐ Ensure that the video is pointed at the rider, ask the rider to wave their arm with the sensor on it vigorously up and down then ask them to say their name (and horses name?).

☐ Proceed to video the preparations and riding session dealing with anything else that arises.

Appendix 4 - Tips for Organisers

Hej, thank you very much for organising riders for my study. I have found that the following tips help everyone to be organised and to have an enjoyable time.

- **I can only record one rider at a time** and so if more than one rider will be riding at the same time then please tell all riders that I will be recording the riding session of the volunteer and if there is an instructor involved then please also tell the instructor that I will be attending.

- **Transportation** – I don't have access to a car and so I will usually arrive by train or bus. I need to transport quite a lot of heavy equipment and so I use a suitcase with wheels so that I don't have to struggle lifting the equipment. Riding halls and arena are rarely situated alongside bus stops or train stations and so I need to be picked up from the closest public transport drop off point, please. I also don't know Sweden very well yet and so it helps me if you can email me with details of the recommended public transport operators in your area and the recommended stops.

- **Communications and formal permission (15 minutes)** – If a rider has not ridden during a session with me before then we need some extra time before getting on their horse when they can read the description of the study, sign the permission form and talk about what will happen during the session. It takes about 15 minutes per rider and so please allow time for this before riding and before the rider gets their horse ready.

- **Younger riders** - Riders aged under 18 must have their parents permission and signature on a form before they can take part in a recorded session with me. As parents are often not at the riding hall, this requirement usually means that a rider aged under 18 must take the permission form home and have it signed before the day organised for the recording session. Riders aged under 14 are not permitted to take part in the study even if they have their parents permission.

- **Getting ready (10-15 minutes)** – I need somewhere flat where I can put my laptop computer and other equipment while we get the rider ready for the session. The rider needs to put on my sensor equipment and I need to start the equipment. This is easiest done in a room away from the horses so that I can concentrate on starting the equipment correctly, however, I have sometimes done this from the seat of a car if a room is not available. If possible I like to have a power plug for my laptop computer although it will usually retain enough power from its battery to handle the equipment set up requirements.

- **Preparing to ride (10-15 minutes)** – I want to record the rider as they prepare to ride and so the riders should be told not to pre-prepare their horse and riding equipment.

- **Riding time (35-55 minutes)** - My video tapes can record a maximum of 80 minutes and so if possible, a riding session should be shorter than one hour. A riding session between 40 and 45 minutes long is usually ideal.

- **Where to ride** – The camera can record both inside and outside but it doesn't handle transitions from shadows to bright light very well and so if riding inside on a bright day the light from windows interferes with the camera and often results in a poor picture. On bright sunny days it is better to ride outside if that is possible. Conversely, the equipment can easily be damaged by water and so if it is likely to rain then it is safest to ride inside please. The camera works best within a range 10 to 25 meters but can record shorter and longer distances with some loss of picture quality. Riders often ride on a circle or ellipse and so I try to position myself so that I am an even distance away from where the rider will ride.

- **After the ride (8-12 minutes)** – I want to continue to record the rider for a short time after they finish riding, while they put their horse away and take off the saddle and tack.

- **Taking the sensor equipment off (5-8 minutes)** – The sensor equipment is of a prototype nature and can lose data if it is switched off or unknowingly unplugged while it is being taken off. It is best if I take the equipment off the rider rather than having the rider take it off themselves. This takes between 5-8 minutes to do.

- **Time between riders (20-25 minutes)** – I need time between riders to save the data from the first rider before preparing the equipment for the next rider. The data is really important and so it can take up to 25 minutes to ensure that the data is correctly saved and to prepare the equipment for the next rider.

- **Time to be comfortable (15-20 minutes)** – I use special equipment to help me hold the camera for long periods without straining myself but it is still very tiring for me to hold the camera and to concentrate for up to 80 minutes at a time and so I need some time myself especially if there are three or more riders on a day. It is helpful if I can get a glass of water or a cup of tea to drink between sessions and of course that means that I also need to take time for a toilet stop between sessions. Please help me to be comfortable.

The above time requirements mean that I can usually only handle one rider every two hours for first time participants or one rider every 105 minutes for riders who have had a prior recording session. Please don't organise for riders to start earlier than this as this puts pressure on the preparation time and this has often lead to valuable data being lost. The ideal situation that I prefer to use unless there are severe time constraints is to allow two hours for each rider and that way every one enjoys the sessions much more and they are very productive for me.

This also means that effectively, I can not handle more than five riders per day and even trying to handle four riders within one session at the same riding venue is a major struggle for me to complete without any problems.

Thank you

Doug Hunt

Appendix 5 - Tips for Riders who organise themselves

Hej, thank you very much for agreeing to be one of the riders for my study. I have found that the following tips help everyone to be organised and to have an enjoyable time.

- **I can only record one rider at a time** and so if you are planning to ride with a group of other riders then please tell them that we will be recording your riding session and if you normally have an instructor then please also tell your instructor that I will be attending.

- **Transportation** – I don't have access to a car and so I will usually arrive by train or bus. I need to transport quite a lot of heavy equipment and so I use a suitcase with wheels so that I don't have to struggle lifting the equipment. Riding halls and arenas are rarely situated alongside bus stops or train stations and so I need to be picked up from the closest public transport drop off point, please. I also don't know Sweden very well yet and so it helps me if you can email me with details of the recommended public transport operators in your area and the recommended stops.

- **Communications and formal permission (15 minutes)** – We need to allow for some extra time, the first time that you ride during a session with me. Please allow an extra 15 minutes before getting on your horse so that you can read the description of the study, sign the permission form and talk about what will happen during the session.

- **Younger riders** - Riders aged under 18 must have their parents permission and signature on a form before they can take part in a recorded session with me. As parents are often not at the riding hall, this requirement means that a rider aged under 18 must take the permission form home and have it signed before the day organised for the recording session. Riders aged under 14 are not permitted to take part in the study even if they have their parents permission.

- **Getting ready (10-15 minutes)** – I need somewhere flat where I can put my laptop computer and other equipment while we get you ready for the session. You need to put on my sensor equipment and I need to start the equipment. This is easiest done in a room away from the horses so that I can concentrate on starting the equipment correctly, however, I have sometimes done this from the seat of a car if a room is not available. If possible I like to have a power plug for my laptop computer although it will usually retain enough power from its battery to handle the equipment set up requirements if no power plug is available.

- **Preparing to ride (10-15 minutes)** – I want to record you as you prepare to ride and so please don't pre-prepare your horse and riding equipment.

- **Riding time (35-55 minutes)** - My video tapes can record a maximum of 80 minutes and so if possible, a riding session should be shorter than one hour. A riding session between 40 and 45 minutes long is usually ideal.

- **Where to ride** – The camera can record both inside and outside but it doesn't handle going from shadows to bright light very well and so if you are riding inside on a bright day then the light from windows can interfere with the camera and often results in a poor picture. On bright sunny days it is usually better to ride outside if that is possible. Conversely, the equipment can easily be damaged by water and so if it is likely to rain then it is safest to ride inside please. The camera works best within a range 10 to 25 meters but can record shorter and longer distances with some loss of picture quality. Riders often ride on a circle or ellipse and so I try to position myself so that I am an even distance away from where you will ride. You are free to ride anywhere as I will follow you and you should do the things that you normally do during a riding session, please don't do special things for me.

- **After the ride (8-12 minutes)** – I want to continue to record you for a short time after you finish riding, while you put your horse away and take off the saddle and tack.

- **Taking the sensor equipment off (5-8 minutes**) – The sensor equipment is of a prototype nature and can lose data if it is switched off or unknowingly unplugged while it is being taken off. It is best if I take the equipment off you rather than having you take it off yourself. This takes between 5-8 minutes to do.

- **Time after riding (20-25 minutes)** – I need time after you finish riding to save the data. The data is really important to me and so it can take up to 25 minutes to ensure that the data is correctly saved. I like to save the data straight away so that I know that it is safe, this means that I will stay at the venue during this time and so please allow for this time in your schedule. It is helpful if I can get a glass of water or a cup of tea to drink during this time.

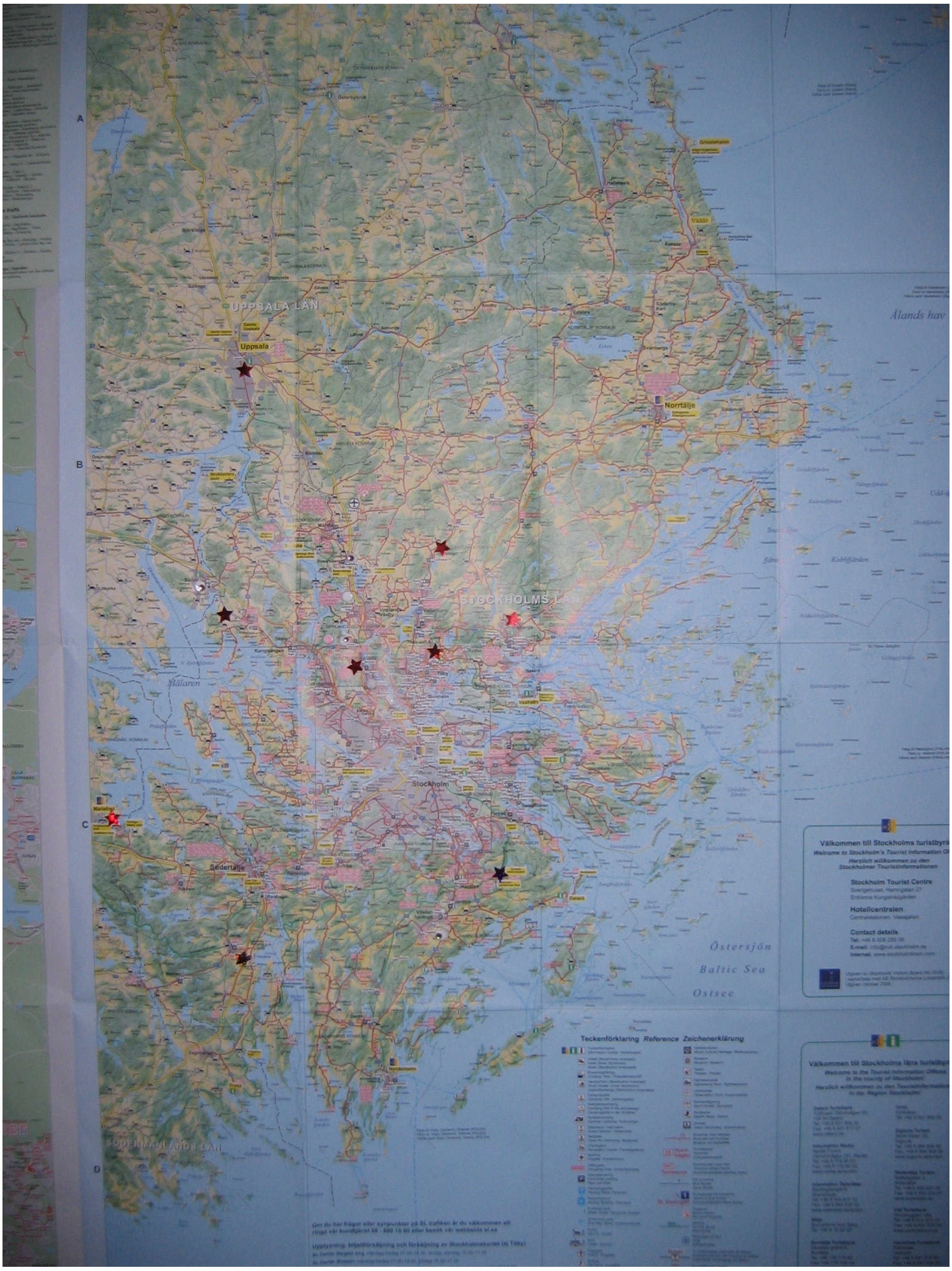
The above time requirements mean that the first time that you ride with me will take around two hours and on the next two times, it will take around an hour and forty five (1:45) minutes. Please don't organise your schedule assuming less time than this as this puts pressure on me and this has sometimes lead to valuable data being lost. To be safe and comfortable you may like to allow two hours for every session and that way we both enjoy the sessions much more and they are very productive for me.

Thank you.

Doug Hunt

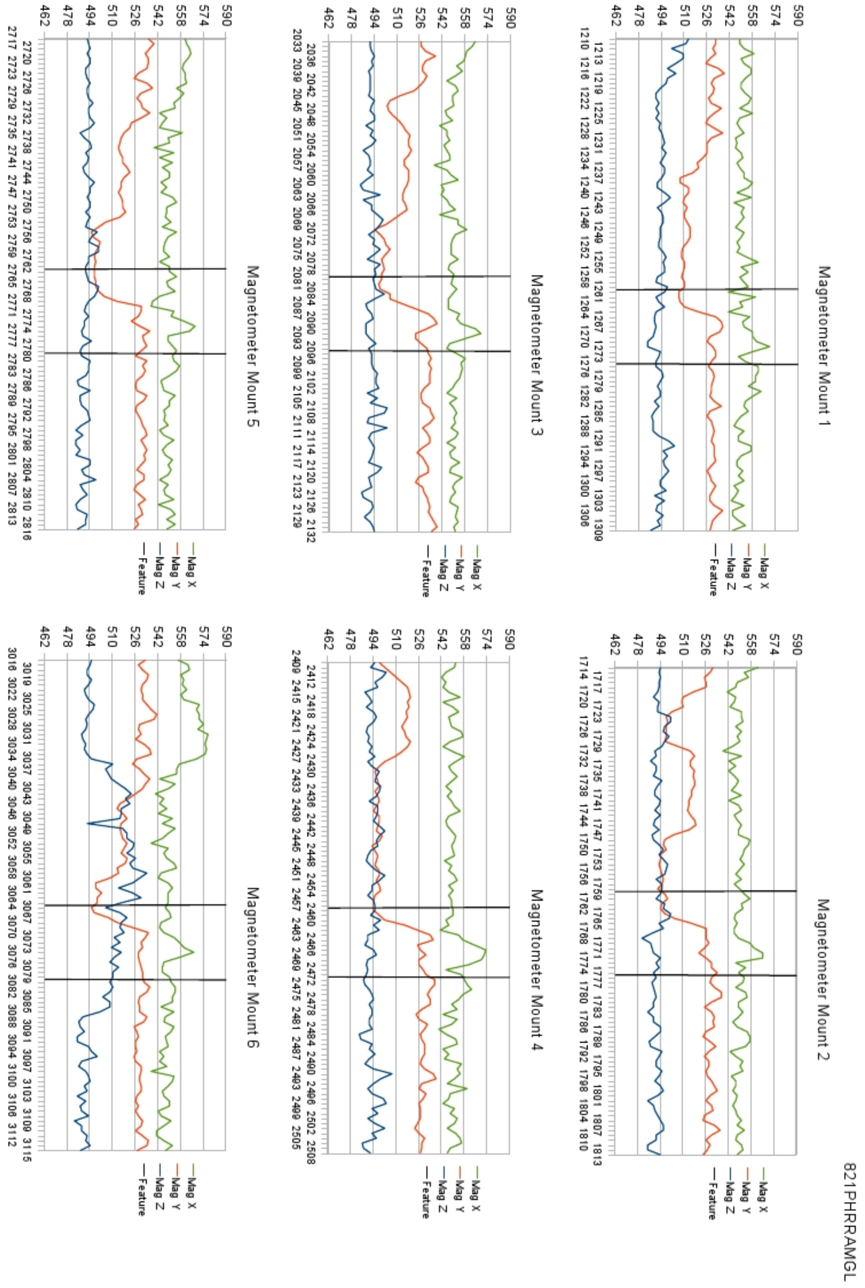
Appendix 6 – Transportation & Scheduling Map

The map below is of the outer areas of Stockholm and surrounding cities. Places where data collection sessions were scheduled are shown by stick-on stars.



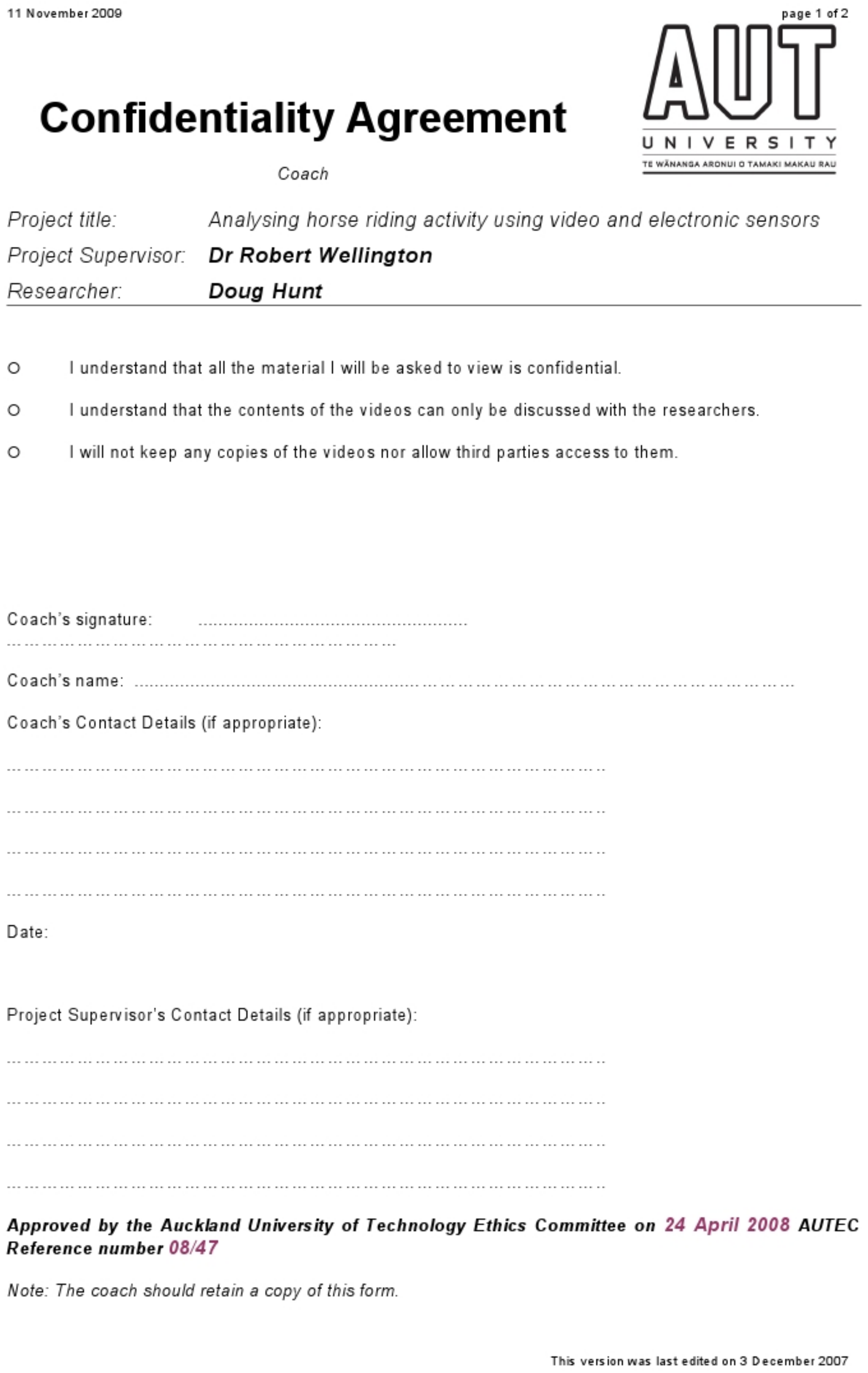
Appendix 7 – Additional Sensor Output Graphs

Magnetometer graphs for the six datasets used for recognition method training.



Magnetometer graphs were not used because they vary depending on geographic location and orientation.

Appendix 7 – Ethics forms



11 November 2009

page 1 of 2

Confidentiality Agreement

Coach

Project title:	*Analysing horse riding activity using video and electronic sensors*
Project Supervisor:	***Dr Robert Wellington***
Researcher:	***Doug Hunt***

○ I understand that all the material I will be asked to view is confidential.

○ I understand that the contents of the videos can only be discussed with the researchers.

○ I will not keep any copies of the videos nor allow third parties access to them.

Coach's signature: ....
……………………………………………………………

Coach's name: ....……………………………………………………………

Coach's Contact Details (if appropriate):

………………………………………………………………………………………

………………………………………………………………………………………

………………………………………………………………………………………

………………………………………………………………………………………

Date:

Project Supervisor's Contact Details (if appropriate):

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Approved by the Auckland University of Technology Ethics Committee on 24 April 2008 AUTEC Reference number 08/47

Note: The coach should retain a copy of this form.

This version was last edited on 3 December 2007

Confidentiality Agreement

Research Assistants & Project Staff

Project title: *Analysing horse riding activity using video and electronic sensors*
Project Supervisor: ***Dr Robert Wellington***
Researcher: ***Doug Hunt***

○ I understand that all the material I will be asked to work with is confidential.

○ I understand that the contents of the Consent Forms and videos can only be discussed with the researchers.

○ I will not keep any copies of the information nor allow third parties access to them.

Intermediary's signature: ....……………………………………………

Intermediary's name: ....
……………………………………………………………

Intermediary's Contact Details (if appropriate):

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

Date:

Project Supervisor's Contact Details (if appropriate):

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Approved by the Auckland University of Technology Ethics Committee on 24 April 2008 AUTEC Reference number 08/47

Note: The Intermediary should retain a copy of this form.

This version was last edited on 3 December 2007

Konfidentiell överenskommelse

KTH Informations- och
kommunikationsteknik

Instruktör

Projekttitel: *Analysering av hästridningsaktivitet med hjälp av video och elektroniska sensorer*

Handledare: ***Dr Robert Wellington***

Forskare: ***Doug Hunt***

○ Jag förstår att allt material jag ska titta på är konfidentionellt.

○ Jag förstår att innehållet I videorna kan bara får bli diskuterat med forskarna i projektet.

○ Jag kommer inte att behålla kopior av videor eller låta tredje part ta del av dem.

Instruktörens underskrift :...

Instruktörens namn :...

Instruktörens kontaktinformation (I förekommande fall):

……………………………………………………………………………………

……………………………………………………………………………………

……………………………………………………………………………………

……………………………………………………………………………………

Datum:

Handledarens kontaktinformation (I förekommande fall):

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OBS: Instruktören ska behålla en kopia av denna blankett.

Approved by the Auckland University of Technology Ethics Committee on 24 April 2008 AUTEC Reference number 08/47

This version was last edited on 3 December 2007

KTH Informations- och
kommunikationsteknik

Konfidentiell överenskommelse

Forskarassistenter och projektanställda

Projekttitel:	*Analys av aktivitet under hästridning med hjälp av video och elektroniska sensorer*
Handledare:	***Dr Robert Wellington***
Forskare:	***Doug Hunt***

○ Jag förstår att allt material jag ska arbeta med är konfidentionellt.

○ Jag förstår att innehållet i medgivandeblanketten och videorna kan bara bli diskuterat med forskarna i projektet.

○ Jag kommer inte att behålla kopior av information eller låta tredje part ta del av dem.

Förmedlarens namnteckning: ……………………………………………………………………………

Förmedlarens namn: ……………………………………………………
……………………………………………………………

Förmedlarens kontaktinformation (i förekommande fall):

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Datum:

Handledarens kontaktinformation (I förekommande fall):

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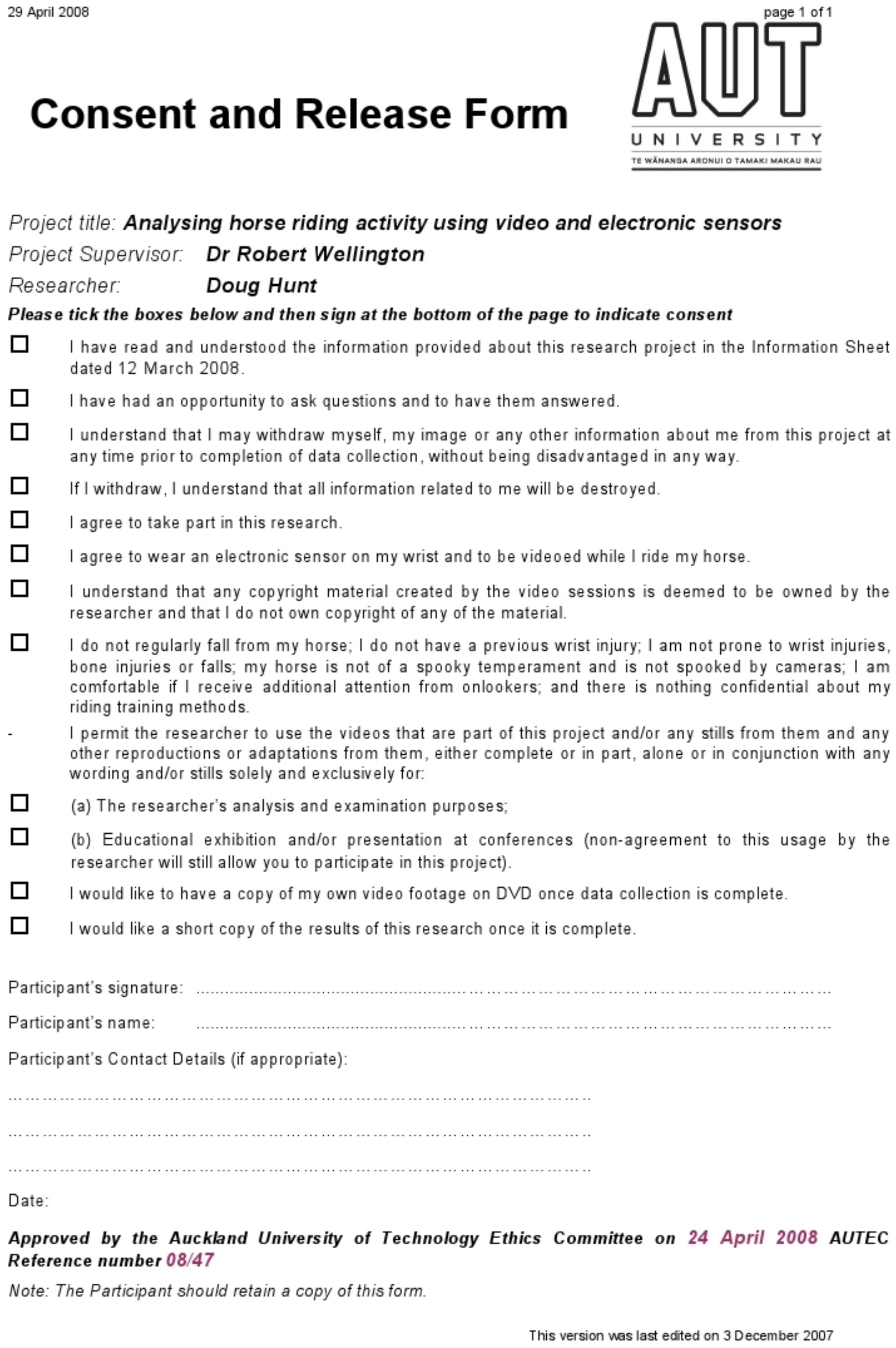
…………………………………………………………………………………………

OBS: Förmedlaren ska behålla en kopia av blanketten.

Approved by the Auckland University of Technology Ethics Committee on 24 April 2008 AUTEC Reference number 08/47

This version was last edited on 3 December 2007



29 April 2008

page 1 of 1

Consent and Release Form

Project title: ***Analysing horse riding activity using video and electronic sensors***

Project Supervisor: ***Dr Robert Wellington***

Researcher: ***Doug Hunt***

Please tick the boxes below and then sign at the bottom of the page to indicate consent

☐ I have read and understood the information provided about this research project in the Information Sheet dated 12 March 2008.

☐ I have had an opportunity to ask questions and to have them answered.

☐ I understand that I may withdraw myself, my image or any other information about me from this project at any time prior to completion of data collection, without being disadvantaged in any way.

☐ If I withdraw, I understand that all information related to me will be destroyed.

☐ I agree to take part in this research.

☐ I agree to wear an electronic sensor on my wrist and to be videoed while I ride my horse.

☐ I understand that any copyright material created by the video sessions is deemed to be owned by the researcher and that I do not own copyright of any of the material.

☐ I do not regularly fall from my horse; I do not have a previous wrist injury; I am not prone to wrist injuries, bone injuries or falls; my horse is not of a spooky temperament and is not spooked by cameras; I am comfortable if I receive additional attention from onlookers; and there is nothing confidential about my riding training methods.

- I permit the researcher to use the videos that are part of this project and/or any stills from them and any other reproductions or adaptations from them, either complete or in part, alone or in conjunction with any wording and/or stills solely and exclusively for:

☐ (a) The researcher's analysis and examination purposes;

☐ (b) Educational exhibition and/or presentation at conferences (non-agreement to this usage by the researcher will still allow you to participate in this project).

☐ I would like to have a copy of my own video footage on DVD once data collection is complete.

☐ I would like a short copy of the results of this research once it is complete.

Participant's signature: ....…………………………………………………………

Participant's name: ....…………………………………………………………

Participant's Contact Details (if appropriate):

……………………………………………………………………………………………..

……………………………………………………………………………………………..

……………………………………………………………………………………………..

Date:

Approved by the Auckland University of Technology Ethics Committee on 24 April 2008 AUTEC Reference number 08/47

Note: The Participant should retain a copy of this form.

This version was last edited on 3 December 2007

29 April 2008 page 1 of 1

KTH Informations- och kommunikationsteknik

Medgivande och publiceringsblankett

Projekttitel: *Analysering av hästridningsaktivitet med hjälp av video och elektroniska sensorer*

Handledarer: ***Dr Robert Wellington***

Forskare: ***Doug Hunt***

Var vänlig kryssa i rutorna nedan och skriv under denna blankett för medgivande

☐ Jag har läst och förstått informationen om detta forskningsprojekt I Informationshäftets 5 sidor daterat 12 Mars 2008.

☐ Jag har haft tillfälle att ställa frågor och få dem besvarade.

☐ Jag har förstått att jag kan utträda, ta bort mina bilder och annan information om mig från projektet när som helst före avslutande av datainsamling, utan att vara missgynnad på något sätt.

☐ Om jag utträder, förstår jag att all information relaterad till mig förstörs.

☐ Jag medger mitt deltagande I denna forskning.

☐ Jag medger att bära en elektronisk sensor på vristen och att bli videofilmad under hästritt.

☐ Jag förstår att copyrighten för materialet i projektet anses vara ägt av forskaren och jag äger ingen copyright på något av materialet.

☐ Jag brukar inte falla från min häst vanligtvis; jag har inga tidigare skador på vristerna; Jag är inte benägen att få vristskador, skelettskador eller att ramla; min häst har inget underligt temperament och blir inte rädd för kameror; jag blir inte störd om jag får mycket uppmärksamhet från åskådare; och det är ingenting konfidentionellt med min ridträningsmetod.

- Jag tillåter forskaren att använda videofilmerna I projektet och/eller bilder från dem och alla andra återgivande eller bearbetningar från dem, antingen komplett eller i delar:

☐ (a) Forskarens analyser och undersökningssyfte;

☐ (b) Undervisning och/eller presentation på konferens (non-agreement till sånt användande av forskaren gör att du fortfarande kan medverka i projektet).

☐ Jag vill ha en kopia av mina egen videoupptagning på dvd när all data är sammanställd.

☐ Jag vill ha en kort resumé av resultatet när forskningen är komplett.

Medverkandens namnteckning: ....………………………………………………………

Medverkandens namn: ....…………………………………………………………

Medverkandens kontaktinformation (i förekommande fall):

………………………………………………………………………………………..

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………………………………………………………………………………………..

Datum:

OBS! Den medverkande ska behålla en kopia.

Approved by the Auckland University of Technology Ethics Committee on *24 April 2008*, AUTEC Reference number *08/47*.

This version was last edited on 3 December 2007

Riding Research Invitation

KTH Informations- och kommunikationsteknik

An Invitation

Riders are invited to take part in a project where the results may help in designing devices that will help to more easily learn classical riding techniques, especially correct classical riding posture. I am a Masters student at AUT University in New Zealand and I am working with Professor Mark Smith of the Wireless@KTH group at KTH in Kista.

What is the purpose of this research?

The purpose of this research is to see if an electronic sensor being worn by a rider can tell when the rider is mounted on a horse and if the horse and rider are moving or standing still. If this is possible then this information may be used to make training devices to help riders learn to ride faster & with better posture.

Who may take part?

I am looking for riders in the Stockholm area who are interested in helping with this research. Riders may be from Dressage, Show Jumping & Horse Trials. Riders may be learner riders or expert riders and may be young people or adults although a rider must be aged 14 or older to take part in the research and children must have their parents' permission.

What will happen in this research?

Riders will wear a small electronic sensor device on their wrists before, during and after riding their horse during a typical training session and will also be videoed. Riders will do the things that they normally do during a training session such as grooming their horse, tacking up, riding and afterwards dismounting, untacking and grooming their horse. The objective is to try to capture on video and through the sensor the normal activities of a typical rider during a training session.

The device is small and light so that it should not affect the rider. The device does not give off any sound and a similar device has previously been worn by other riders without problems.

Here is a photo of a similar device being worn by a rider in New Zealand.

Up to three sessions per rider will be videoed. Afterwards riders may come to the laboratory in Kista to view their own videos and may help analyse the videos if they wish. The research team and a riding coach are the only other people who will see the videos. Once the research is finished riders may have a copy of their own video records if you want them.

There is no cost involved in taking part in this research other than the rider's own time.

For further information please contact the researcher:

Doug Hunt, e-mail: dphunt@kth.se phone: +46 700 44 12 04

web: http://ridingcontext.googlepages.com/home

This document was last edited on 23 April 2008

Inbjudan till forskning om ridning

KTH Informations- och kommunikationsteknik

Invitation

Ryttare är inviterade att medverka i ett projekt där resultaten kan hjälpa till att designa apparater som gör att man enklare kan lära sig klassiska ridtekniker, speciellt klassisk ridhållning. Jag är en Mastersstudent på AUT University, Nya Zealand och jag jobbar med Professor Mark Smith från Wireless@KTH gruppen på KTH i Kista.

Vad är syftet med detta projekt?

Syftet med detta projekt är att testa och se om en enda elektronisk sensor, buren av en ryttare verkligen kan exakt känna medan ryttaren är i sadeln eller inte, och om i sadeln, om häst eller ryttare rör sig eller står still. Om detta är möjligt kan denna information användas till att göra hjälpmedel som hjälper ryttare lära sig fortare och med bättre hållning.

Vem kan vara med?

Jag söker ryttare från Stockholmsområdet som kan vara intresserade att hjälpa till med denna forskning, Det kan vara från dressyr, showhoppning eller andra sorters ridning. Ryttarna kan vara nybörjare eller proffsryttare, unga eller gamla, men måste vara 14 år eller äldre för att kunna medverka i denna forskning och barn måste ha förälders tillstånd.

Vad händer sedan i denna forskning?

Ryttarna ska bära en liten elektronisk sensor runt vristen före, efter och en kort tid efter ridning med din häst under en typiskt vanlig session och kommer också att bli videofilmade. Ryttarna ska göra det som är normalt att göra under en träningssession, som att rykta din häst, betsla och sitta upp, rida till träningsområdet, justera betsel när du sitter upp och efteråt likadant. Målet är att försöka filma och genom sensorn fånga normala aktiviteter för en ryttare under en träningssession.

Apparaten är liten och lätt så den ska inte påverka ryttaren. Den ger inget ljud ifrån sig och liknande apparater har använts nyligen av andra ryttare utan problem.

Här är ett foto på en liknande apparat buren av en ryttare i New Zealand.

Upp till tre sessioner per ryttare kommer att bli videofilmade. Efteråt kommer ryttarna att få komma till laboratoriet i Kista och se sina egna videor och hjälpa mig analysera dem om de vill. Forskningsteamet och en ridtränare är de enda personer som kommer att se dessa filmer. När forskningen är färdig kan ryttarna få en egen kopia av videon om de så önskar.

Den enda kostnaden för de som deltar i detta projekt är den egna tiden man lägger ner .

För mer information kontakta forskaren:

Doug Hunt, e-mail: dphunt@kth.se Tel: 070 0 44 12 04

web: http://ridingcontext.googlepages.com/home

This document was last edited on 23 April 2008

Deltagar-information

KTH Informations- och kommunikationsteknik

Senast ändrad

12 Mars 2008

Projekttittel

Analysering av hästridningsaktivitet med hjälp av video och elektroniska sensorer

Invitation

Du är inviterad att delta i ett projekt där resultaten kan hjälpa till att designa hjälpmedel som kan hjälpa ryttare mer lättinlärd klassiska ridtekniker, speciellt korrekt klassisk ridhållning. Jag är en mastersstudent från AUT universitetet i Nya Zeeland och jag arbetar med Professor Mark Smith på Wireless@KTH gruppen, KTH i Kista, Stockholm. Detta forskningsprojektet ger mig en chans att slutföra min Mastersexamen. Ditt deltagande i projektet är fullständigt frivilligt och du kan när som helst dra dig ur utan några konsekvenser för dig.

Vad är syftet med detta projekt

Syftet med detta projekt är att testa och se om en enda elektronisk sensor, buren av en ryttare verkligen kan exakt känna medan ryttaren är i sadeln eller inte, och om i sadeln, om häst eller ryttare rör sig eller står still.

Om projektet kan känna av dessa två saker (I sadeln eller inte och röra sig eller står still) från sensorns avläsning på ett pålitligt och samstämmigt sätt, så kan denna information bli använd i framtiden till att effektivisera träningsredskap för folk med aspekten av korrekt klassisk ridteknik.

Slutsatserna i detta projekt kommer att skrivas som en del av min Mastersuppsats och kommer att publiceras på mitt universitet. Det är också möjligt att en kortare version av slutsatserna kommer att publiceras in en skoltidning och/eller en publikation fokuserad på ridsport och eller generell sportträning och den kortare versionen kommer du att få vid begäran.

Hur blev jag utvald att delta i detta project?

Du blev utvald med den s.k Snowball-tekniken. Det är, jag kontaktade en person som jag känner inom ridsport och den personen antingen föreslog dig eller föreslog någon som föreslog ditt namn som möjlig deltagare.

Vad händer sedan med denna forskning?

Om du accepterar min invitation till att delta, så kommer du att bli tillfrågad om att bära en liten elektronisk sensor runt vristen (vilken som är fördelaktigast) före, efter och en kort tid efter ridning med din häst under en typiskt vanlig session. Du kommer också att bli videofilmad medan du bär denna apparat.

Under denna tid som du bär apparaten, kommer du att bli ombedd att göra saker som är typiska under en vanlig session. Du kommer inte bli ombedd om hur du ska göra (utom att bära apparaten och att stanna inom synhåll för kameran). Du ska göra normala saker som du brukar göra före ridningen (som att rykta din häst, betsla och sitta upp); under ritt (som att rida till träningsområdet, justera betsel när du sitter upp, värma upp, annan sorts ritt och uppvärmning; du kan även stanna och prata med någon om du brukar göra det normalt sett i denna situation); och efter ritten (som att sitta av, betsla av och rykta din häst). Målet är att fånga på videon och genom sensorn, den normala och eller typiska aktiviteten hos en ryttare (du) under en träningssession med din häst.

This version was last edited on 3 December 2007

Apparaten är liten och lätt nog för att inte påverka din ridning i någon som helst märkbar väg, men, om du någon gång känner dig obekväm när du bär apparaten, kan du ta av den och jag kan fortsätta med videofilmningen. Om du av någon annan anledning känner dig obekväm under sessionen kan du sluta och när som helst säga till att vi ska avsluta videofilmningen. Till exempel, jag kommer att se till att kameran är tillräckligt långt bort från dig så att det inte ska påverka din häst, men om det av någon anledning skulle påverka din häst med kameran igång, stanna genast och jag avbryter filmandet. Apparaten som du bär ger inget ljud ifrån sig och det är osannolikt att den kan kännas av din häst och en väldigt snarlik apparat har använts av både nybörjare och proffsryttare utan påverkan på deras hästar.

Här är ett fotot av en väldigt snarlik apparat buren av en ryttare.

Om du är nöjd med första sessionen, kommer du att bli inbjuden till två efterföljande sessioner, helst på samma häst, så jag kan lyckas få fram olika data från dig som kan vara jämförbara men från olika sessioner. De två påföljande sessionerna behöver inte innehålla exakt samma aktiviteter och det kan faktiskt vara användbart om det är så ditt normala sätt att göra under träning ser ut.

Vid något tillfälle under de följande 8 veckorna efter dina sessioner med filmning, kommer du att bli inviterad att se videofilmer från dina sessioner på vårt laboratorium på KTH i Kista, Stockholm. Du kommer inte tillåtas se någon annans video och ingen annan än projektanställda som jag själv forskarassistenter och en erfaren ridtränare, kommer att titta på dina data. Instruktören och all projektanställda har skrivit på ett medgivande om att hålla allt konfidentionellt och kommer inte att diskutera någonting om projektet utom för att skydda din identitet.

Om du så vill, medan du tittar på din video kan du ytterligare hjälpa mig med att markera de tillfällen när du sitter av eller på, och de tillfällen när du och din häst rör er eller står still. Denna extrauppgift är helt frivillig och kommer att ta cirka 30 minuter/videofilmad session, så tre sessioner kommer att ta cirka en och en halv timme för markering.

Jag kommer att ge dig dina egna inspelningar att ta med på dvd om du vill ha dem.

Vad är svårigheter och risker?

- **Viktobehag** – Apparaten är så lätt, men väger cirka 100g, och du bär den på din vrist och det kan om man bär den en längre period kännas obekvämt .

- **Extra skador om du faller** – Om du faller från din häst under tiden du bär apparaten, kan det extra omfånget på din vrist göra att du kan skada dig själv på ett sätt som du inte skulle göra utan den. Med tanke på låg vikt, litet omfång och plastmaterial så är den konstruerad så att extra skador inte ska vara någon risk.

- **Din häst blir skrämd** – Det finns en risk att din häst skräms av kameran eller mig.

- **Obekväm uppmärksamhet** – Under sessionen kommer du att ha en ovanlig apparat på din vrist och samtidigt bli filmad, resultatet kan bli att andra människor i området kan titta och undra vad du gör. Den extra uppmärksamheten kan få dig att känna dig obekväm.

- **Anonymitetsförlust** – Folk som tittar på videorna från dina sessioner kan känna igen dig eller din häst.

Hur kan man minska svårigheterna och riskerna?

- **Viktobehag** – En normal session håller på mellan 40 och 50 minuter och det resulterar i, enligt min erfarenhet, att är det mycket osannolikt att känna obehag av vikten. Skulle det ske så kan du när som helst sluta och ta bort apparaten.
- **Extra skador om du faller** – Om du regelbundet faller från din häst; om du haft vristproblem och eller har läggning för vristskador, skelettskador eller faller, ska du inte delta i detta projekt. Om du tror att du ska falla under sessionen eller så ska du ta bort apparaten och stoppa sessionen.
- **Din häst blir skrämd**- Det finns en risk att din häst har ett känsligt temperament och skrämts av kameror tidigare och då ska du inte delta med den hästen. Om du vill delta så kommer jag att sköta kameran och jag har en lång erfarenhet av hästar. Jag kommer att vara extra uppmärksam på din hästs reaktioner under sessionen. Om jag märker att kameran påverkar din häst kommer jag att avsluta genast. Du kan stoppa sessionen när som helst.
- **Obekväm uppmärksamhet** – Om du är en blyg person eller någon som känner sig obekväm med extra uppmärksamhet bör du inte delta i detta projekt. Under sessionen kommer jag att be andra människor att stanna utanför upptagningsområdet medan jag arbetar. Om du deltar och känner dig obekväm kan du alltid stoppa sessionen när som helst.
- **Anonymitetsförlust** – Om något i din träning är konfidentionellt så ska du inte delta i detta projekt. Ytterligare, om du deltar i detta projekt kan alla som är tillåtna att se din video under analys måste ha skrivit på ett medgivande om att hålla all information konfidentionell. Efter att ha sett dina egna videor kommer jag att fråga om du är beredd att jag visar dina data (eller delar av) för andra människor vid sådana tillfällen som konferenser där jag håller en presentation om projektet. Du är sedan vara fri att tillåta mig att visa dina videor och data eller att begära att dina videor ska vara konfidentiella. Jag kommer att respektera ditt beslut.

Du och din hästs säkerhet är det absolute viktigaste och går alltid före aktiviteter i projektet. Om någonting annat känns obekvämt under ren session säg bara stopp.

Vad är fördelarna?

En fördel med deltagande i projektet är att du medverkar i ett projekt som kan göra nytta för ryttare I framtiden och det hjälper mig att göra min Mastersavhandling. Hur som helst, om projektet misslyckas med att hitta ett sätt att urskilja sitta upp och sitta av och röra sig eller stå still så kanske det inte blir till någon nytta i framtiden för ryttare.

En annan möjlig fördel är om du vill ha videorna från dina träningssessioner så kan det hjälpa dig i din träning, att behålla som minne av din häst och eller att visa för en potentiell köpare om du senare vill sälja din häst.

Min fördel som forskare, oavsett utfallet av projektet, är att jag kan skriva min avhandling och få min Mastersexamen i alla fall.

Hur skyddas mitt privatliv?

Alla som deltar i projektet måste skriva på medgivande om att hålla all information om konfidentionell innan de får tillåtelse att se några data om deltagare. Dessutom får bara videofilmerna visas om deltagaren har givit speciellt tillstånd för någon utanför projektets anställda. Sådana data (om den är tillåten) kan visas för folk som besöker konferenser där jag presenterar resultatet av projektet och eller kan visas för andra akademiker inklusive mina examinerare.

Var sådan data blir visad (med tillstånd) kommer du inte att bli speciellt identifierad men du eller din häst kan bli igenkänd.

All projektdata kommer att bli lagrad i universitetets servrar under och efter projektet och sådana lager har normala kommersiella datasäkerhetssystem. Dessa data kommer inte att vara tillgängliga för allmänheten under normala omständigheter.

Det är inte förekommande att videofilmerna som hör till detta projekt kommer att bli publicerat i någon åtkomlig form eller något datasystem med allmän åtkomst, men det skrivna resultatet av projektet i form av min avhandling kommer att publiceras i ett format och på sådant sätt som är allmänt åtkomligt för andra akademiker och allmänhet. Ingen personlig identifierbar information relaterad till dig kommer att publiceras i denna avhandling

Vad kostar det att delta I denna forskning?

Som deltagare är dina enda kostnader tiden du lägger ner och eventuell restid till mitt universitet för att se videofilmerna. Jag förmodar att det tar mellan en och fem timmar (plus eventuell restid) att delta i detta projekt och faktiska tiden beroende på hur många sessioner du har medgett att delta i för detta projekt (max 3 stycken) och längden på filmerna för att se dina egna videor.

Jag föredrar att en deltagare är beredd att delta i alla tre sessionerna och tittar och markerar sina egna videofilmer, I detta fall förutsätter jag att tiden du behöver lägga ner är fyra och en halv timme samt restid.

Vad har jag för möjligheter att överväga invitationen?

Du får 5 dagar att fundera och ställa frågor som du kan ha innan du bestämmer om du vill delta eller inte.

Hur gör jag för att ge mitt medgivande om att delta i denna forskning?

Du måste fylla i en blankett för medgivande och returnera den till mig innan du kan var med i detta projekt. En medgivandeblankett finns bifogad med denna invitation och ett frankerat kuvert med returadress bifogad.

När jag fått blanketten kommer jag kontakta dig för att bestämma en tid för din första session.

Kommer jag att få feedback på resultatet av denna forskning?

Ja du kommer att få möjlighet att se dina egna videofilmer och om du skriver på din medgivandeblankett att du vill bli informerad om resultatet i detta projekt när det är slutfört, så kommer jag att kontakta dig och skicka en kortare version av resultatet. Dessutom, om du inte skrivit att du vill ha denna information men sedan ändrar dig, så hör gärna av dig och jag kommer gärna att dela med mig av informationen.

Vad gör jag om jag har funderingar gällande denna forskning?

Eventuella funderingar om vad detta projekt är bör snarast höra av sig till projektets handledare, Dr Robert Wellington, e-mail: robert.wellington@aut.ac.nz , phone: +64 9 921 9999 anknytning 5432, eller till min svenska handledare, Professor Mark Smith e-mail: msmith@kth.se tele 08-7904485

Funderingar rörande ledningen för detta project bör anmälas till the Executive Secretary, AUTEC, Madeline Banda, *madeline.banda@aut.ac.nz* , +64 9 921 9999 ext 8044.

Vem kontaktar jag för för mer information om detta projekt?

Forskarens kontaktinformation:

Doug Hunt, e-mail: hjk6380@aut.ac.nz Tele: 070-04412004 i Sverige eller +64 9 921 9999 anknytning 8359 i Nya Zealand

Projektets handledares kontaktinformation:

Dr Robert Wellington, e-mail: robert.wellington@aut.ac.nz ,Tel:. +64 9 921 9999 anknytning 5432.

Professor Mark Smith, e-mail msmith@kth.se, Tel: 08-7904485

Approved by the Auckland University of Technology Ethics Committee on *24 April 2008*, AUTEC Reference number *08/47*.

Participant Information Sheet

Date Information Sheet Produced:

12 March 2008

Project Title

Analysing horse riding activity using video and electronic sensors

An Invitation

You are invited to take part in a project where the results may help in designing devices that will help riders to more easily learn classical riding techniques, especially correct classical riding posture. I am a Masters student at AUT University, New Zealand and I am working with Professor Mark Smith of the Wireless@KTH group at KTH is Kista. This research project will allow me to complete my Masters degree. Your participation in this project is completely voluntary and you may withdraw your participation at any time with no adverse consequences for you.

What is the purpose of this research?

The purpose of this research is to test to see if an electronic sensor being worn by a rider can accurately sense when the rider is unmounted or mounted and when mounted, if the horse and rider are moving or standing still.

If the project can detect these two things (mounted/unmounted and moving/not moving) from the sensor readings in a reliable and consistent way then this information could be used in future to make more effective training devices for riders for some aspects of correct classical riding technique.

The findings from this project will be written up as part of my Masters thesis and will be published at my university. It is also possible that a shorter version of the findings might also be published in a scholarly journal and/or a publication focussed on equestrian sports and/or general sports training and this shorter version would be available to you on request.

How was I chosen for this invitation?

You were chosen using what is called the Snowball technique. That is, I contacted a person that I know within the equestrian community and that person either suggested your name to me or suggested another person who subsequently suggested your name to me as a possible participant.

What will happen in this research?

If you accept my invitation to participate then you will be asked to wear a small electronic sensor device on your wrist (possibly on both wrists) before, during and for a short time after riding your horse during a typical training session. You will also be videoed while you are wearing the device.

During the time that you wear the device you will be asked to do the things that you typically do during a normal training session. You will not be told what to do (other than being asked to wear the device and to try to stay within range of the video camera). You should do the normal things that you would do before riding (such as grooming your horse, tacking it up and mounting); during riding (such as riding to your training area, adjusting your tack while mounted, warming up, other riding and warming down; you might even stop to chat to a friend if that is what you normally do or any other activity that is normal for you in this situation); and after riding (such as dismounting, untacking and grooming your horse). The objective is to try to capture on video and through the sensor the normal and/or typical activities of a typical rider (you) during a training session with your horse.

The device is small enough and light enough that it should not affect your riding in any appreciable way, however, if at any time you feel uncomfortable wearing the device then you may take it off and I will discontinue the video recording. If for any other reason you become uncomfortable during the session then you may discontinue it at any time and ask for the videoing to be stopped. For example I will position the camera far enough away from you that it should not affect your horse but if for some reason your horse is affected by me working the camera then please stop immediately and I will withdraw. The device that you wear does not give off any sound and so it is highly unlikely to be noticed by your horse and a very similar device has been worn previously by both novice and expert riders without any affect on their horses.

Here is a photo of a very similar device being worn by a rider in New Zealand.

If you are happy with the first session then you will be invited to participate in two more subsequent sessions, preferably on the same horse so that I can obtain sets of data from you that will be comparable but from different sessions. The two subsequent sessions need not involve the same exact activities and in fact some variety of activities would be useful if this is consistent with your normal practise while training.

At some point in the following 8 weeks after your sessions have been recorded you will also be invited to view the video data from your sessions at our laboratory at KTH University in Kista, Stockholm. You will not be permitted to view anyone else's video data and no one else other than project staff such as myself, research assistants and an experienced equestrian coach will view your data. The coach and all project staff will have previously agreed to keep all data confidential and so will not discuss anything from the project except in a manner that protects your identity.

If you wish, while you are viewing your own video data you can further assist me by marking your video at the points where you mount and unmount your horse and at the points where you and your horse are moving or standing still. This additional task is completely voluntary and if you agree to do it would take around 30 minutes per videoed session and so three sessions would take around one and a half hours to mark.

I will give you your own video records to take away on a DVD if you want them.

What are the discomforts and risks?

- **Weight discomfort** - The electronic device is quite light, but it does add approximately 100 grams to the wrist that you wear it on and over a prolonged period its weight may become uncomfortable.
- **Additional injuries should you fall** - If you fell from your horse while wearing the device then the extra bulk on your wrist might possibly mean that you injure yourself in a way that would not have happened if you weren't wearing the device. Given its light weight, small bulk and the plastic materials its case is constructed of the possibility of additional injuries seems slight.
- **Your horse takes fright** - There is a possibility that your horse might spook at the video camera or me.
- **Attention discomfort** - During the session you will have an unusual device on your wrist and you will be being videoed, as a result other people within the area may notice and stare at you or wonder what you are doing. This extra attention may make you feel uncomfortable.
- **Loss of anonymity** – People who view the videos of your sessions may recognise you or your horse.

How will these discomforts and risks be alleviated?

- **Weight discomfort** - A normal session is expected to last between 40 and 50 minutes and as a result, my experience is that you are highly unlikely to feel discomfort from the weight of the device over this period. However, should you feel discomfort of any sort then you may stop the session and remove the device at any time.
- **Additional injuries should you fall** - If you regularly fall from your horse; if you have had a previous wrist related injury and/or you know of any reason why you might be prone to wrist injuries, bone injuries or falls then you should not participate in this project. If during a session you think that you might fall and you have the opportunity to do so then you should remove the device and stop the session.
- **Your horse takes fright** - If your horse is of a spooky temperament or if it has spooked at cameras before then you should not participate in this project on that horse. If you do participate then I will operate the camera and I have a good general understanding of horses. I will be extra sensitive to how your horse is reacting during the session. If I feel that the camera is affecting your horse adversely then I will withdraw. You may stop the session at any time.
- **Attention discomfort** - If you are a shy person or someone who feels uncomfortable at additional attention then you should not participate in this project. During a session I will post a sign asking other people to stay back from the area where we are working. If you participate and subsequently feel uncomfortable then you may stop the session at any time.
- **Loss of anonymity** - If there is anything about your training sessions that is confidential then you should not participate in this project. In addition, if you participate in this project then anyone who is permitted to view your video data during analysis will have agreed to keep all information confidential. After you have viewed your own video data I will ask you if you are prepared to allow me to show your video data (or parts of it) to other people at such events as a conference where I may be giving a presentation on the project. You are then free to permit me to show your video data or to require me to keep your video data confidential. I will honour your request on this.

Your and your horse's safety are of the utmost importance and always takes precedence over the activities of the project. If anything else has you feeling uncomfortable during a session then please stop.

What are the benefits?

One benefit to you as a project participant is that you will get to contribute to a project that may benefit riders in the future and that will assist me to complete my Masters thesis. However, if the project fails to find a way of distinguishing mounted from unmounted and moving from not moving then there may not be any future benefit for riders.

Another possible benefit for you is that if you request the videos of your training sessions then you could use those to assist with your own training, to keep as a memento of your horse and/or to show to a potential buyer if you later sell your horse.

I will benefit as a researcher regardless of the outcome of the project as I will be able to write my thesis and complete my Masters degree in any case.

How will my privacy be protected?

All project staff that participate in this project are required to agree to keep participant information confidential before they are permitted to view any participant data. In addition only the video data of participants who have given prior specific permission will be shown to anyone outside the project staff. Such data (where permitted) may be shown to people attending conferences where I present the results of the project and/or may be shown to other academics including my examiners.

Where such data is shown (with permission) you will not be specifically identified but you and/or your horse may be recognised.

All project data will be stored in the university's computerised storage facilities during and after the project and such facilities have normal commercial data security measures. This data will not be available to the general public under normal circumstances.

It is not anticipated that the video data associated with this project will be published in any generally accessible form or on any generally accessible computer system but the written outcomes of the project in the form of my thesis will be published in a format and in a way that will be generally accessible to other academics and members of the public. No personally identifiable information relating to you will be published within this thesis.

What are the costs of participating in this research?

As a participant your only costs are the time that you put into this project and any transport costs associated with travelling to my university to view your video data. I anticipate that it will take between one and five hours of your time (plus any travel time) to participate in this project and the actual amount of time will vary depending on how many sessions you agree to take part in (a maximum of three) and the length of time needed to view your own video data.

My preference is that as a participant you would be prepared to take part in all three sessions and the viewing and marking of your own video data. In this case I expect that the time you would need to allocate is four and a half hours plus travel time.

What opportunity do I have to consider this invitation?

You will be given five days to consider this invitation and to ask any questions that you might have before deciding if you will participate or not.

How do I agree to participate in this research?

You will need to complete a consent form and return it to me before you can take part in this project. A consent form is attached to this invitation and it has a return address and a stamped, self-addressed envelope attached.

Once I receive your consent form I will contact you to schedule a mutually agreeable time for us to do your first session.

Will I receive feedback on the results of this research?

Yes you will have the opportunity to view your own video data and if you indicate on the consent form that you want to be informed of the results of the project then once the project is complete I will contact you and send you a short copy of the results. In addition, if you initially indicate that you don't want to receive this information and then subsequently change your mind then please contact me and I will happily share this information with you.

What do I do if I have concerns about this research?

Any concerns regarding the nature of this project should be notified in the first instance to the Project Supervisor, Dr Robert Wellington, email: robert.wellington@aut.ac.nz , phone: +64 9 921 9999 extension 5432, or to my Swedish supervisor, Professor Mark Smith email: msmith@kth.se phone +46 8 790 44 85.

Concerns regarding the conduct of the research should be notified to the Executive Secretary, AUTEC, Madeline Banda, *madeline.banda@aut.ac.nz* , +64 9 921 9999 ext 8044.

Whom do I contact for further information about this research?

Researcher Contact Details:

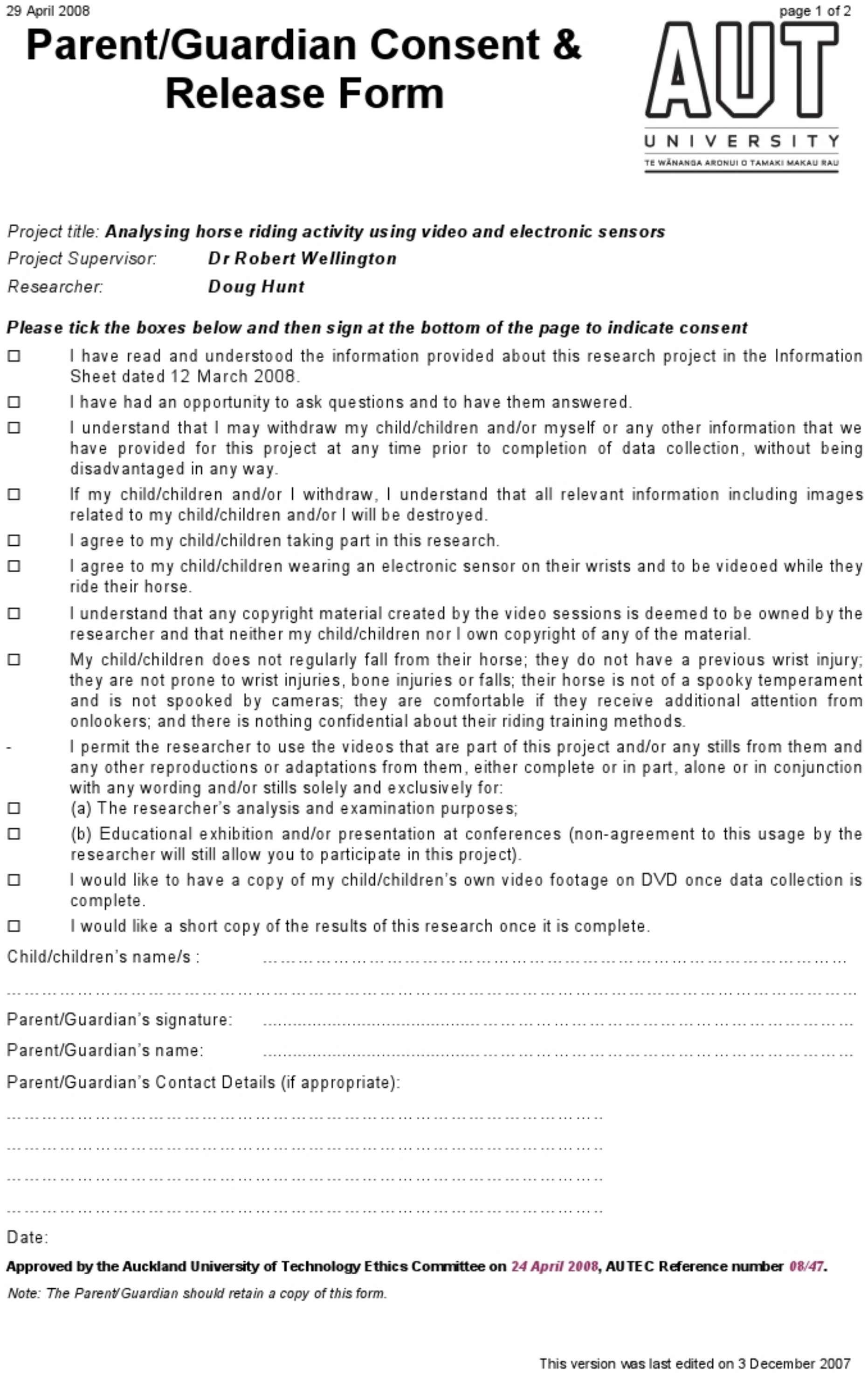
Doug Hunt, e-mail: hjk6380@aut.ac.nz , or phone: +46 700 44 12 04 in Sweden or +64 9 921 9999 extension 8359 in New Zealand.

Project Supervisor Contact Details:

Dr Robert Wellington, e-mail: robert.wellington@aut.ac.nz , phone: +64 9 921 9999 extension 5432.

Professor Mark Smith, e-mail msmith@kth.se phone: +46 8 790 44 85.

Approved by the Auckland University of Technology Ethics Committee on *24 April 2008*, AUTEC Reference number *08/47*.



29 April 2008

page 1 of 2

Parent/Guardian Consent & Release Form

Project title: ***Analysing horse riding activity using video and electronic sensors***

Project Supervisor: ***Dr Robert Wellington***

Researcher: ***Doug Hunt***

Please tick the boxes below and then sign at the bottom of the page to indicate consent

☐ I have read and understood the information provided about this research project in the Information Sheet dated 12 March 2008.

☐ I have had an opportunity to ask questions and to have them answered.

☐ I understand that I may withdraw my child/children and/or myself or any other information that we have provided for this project at any time prior to completion of data collection, without being disadvantaged in any way.

☐ If my child/children and/or I withdraw, I understand that all relevant information including images related to my child/children and/or I will be destroyed.

☐ I agree to my child/children taking part in this research.

☐ I agree to my child/children wearing an electronic sensor on their wrists and to be videoed while they ride their horse.

☐ I understand that any copyright material created by the video sessions is deemed to be owned by the researcher and that neither my child/children nor I own copyright of any of the material.

☐ My child/children does not regularly fall from their horse; they do not have a previous wrist injury; they are not prone to wrist injuries, bone injuries or falls; their horse is not of a spooky temperament and is not spooked by cameras; they are comfortable if they receive additional attention from onlookers; and there is nothing confidential about their riding training methods.

\- I permit the researcher to use the videos that are part of this project and/or any stills from them and any other reproductions or adaptations from them, either complete or in part, alone or in conjunction with any wording and/or stills solely and exclusively for:

☐ (a) The researcher's analysis and examination purposes;

☐ (b) Educational exhibition and/or presentation at conferences (non-agreement to this usage by the researcher will still allow you to participate in this project).

☐ I would like to have a copy of my child/children's own video footage on DVD once data collection is complete.

☐ I would like a short copy of the results of this research once it is complete.

Child/children's name/s : ……………………………………………………………………………………

……

Parent/Guardian's signature: ……………………………………………………………………………

Parent/Guardian's name: ……………………………………………………………………………

Parent/Guardian's Contact Details (if appropriate):

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Date:

Approved by the Auckland University of Technology Ethics Committee on *24 April 2008*, AUTEC Reference number *08/47*.

Note: The Parent/Guardian should retain a copy of this form.

This version was last edited on 3 December 2007

Assent & Release Form

AUT
UNIVERSITY
TE WĀNANGA ARONUI O TAMAKI MAKAU RAU

Project title: ***Analysing horse riding activity using video and electronic sensors***
Project Supervisor: ***Dr Robert Wellington***
Researcher: ***Doug Hunt***

Please tick the boxes below and then sign at the bottom of the page to indicate consent

☐ I have read and understood the sheet telling me what will happen in this study and why it is important.

☐ I have been able to ask questions and to have them answered.

☐ I understand that I will wear a device on my wrists and be videoed while I ride.

☐ I understand that while the information is being collected, I can stop being part of this study whenever I want and that it is perfectly ok for me to do this.

☐ If I stop being part of the study, I understand that all information about me, including the recordings or any part of them that include me, will be destroyed.

☐ I agree to take part in this research.

☐ I do not often fall from my horse; I do not have a previous wrist injury; my horse is not spooky and is not frightened by cameras; I am not shy.

☐ I would like to have a copy of my own video footage on DVD once data collection is complete.

☐ I would like a short copy of the results of this research once it is complete.

Participant's signature: ....………………………………………………………

Participant's name: ....………………………………………………………

Participant Contact Details (if appropriate):

………………………………………………………………………………………..

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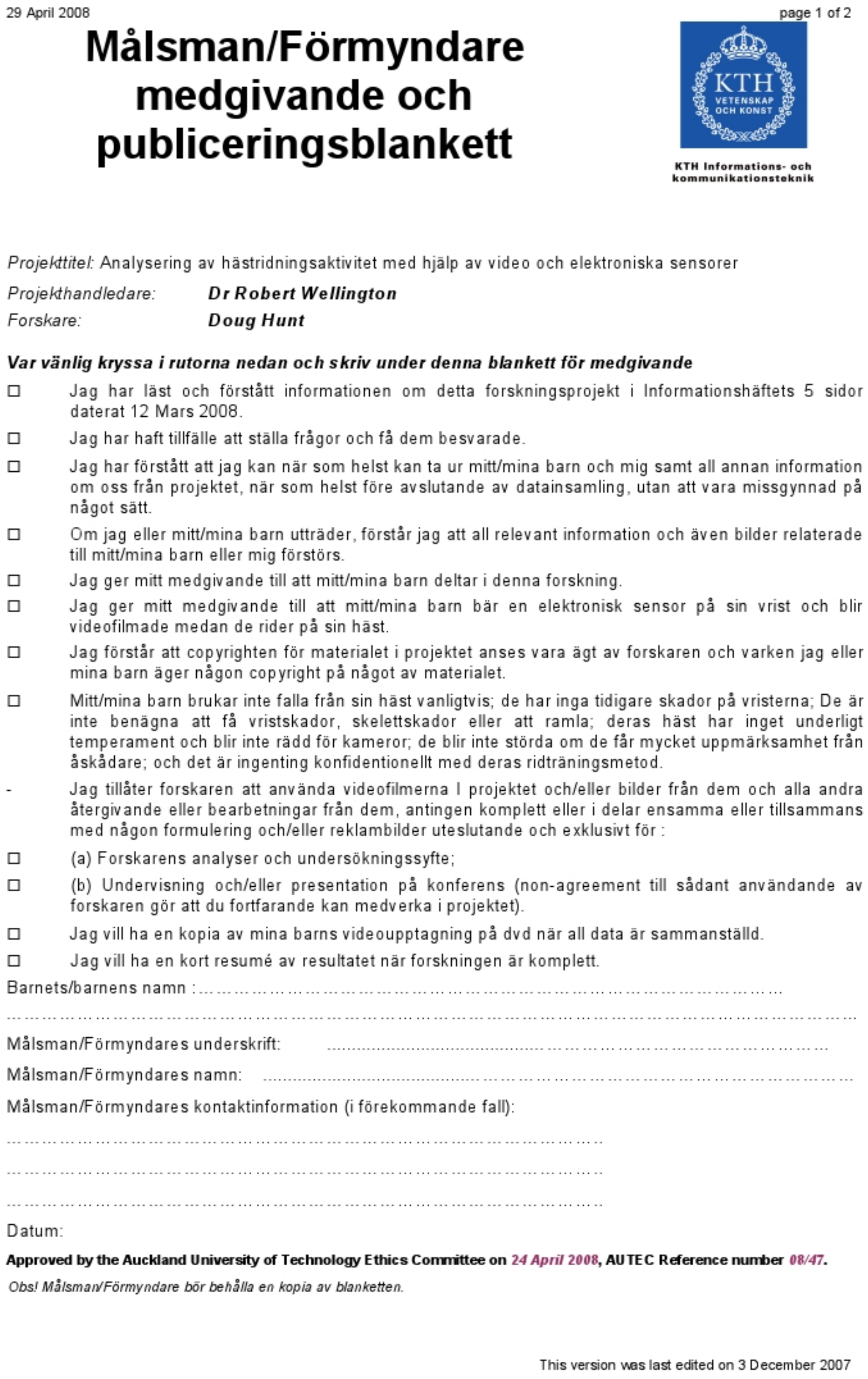
Date:

Approved by the Auckland University of Technology Ethics Committee on *24 April 2008*, AUTEC Reference number *08/47*.

Note: The Participant should retain a copy of this form.

This version was last edited on 3 December 2007



29 April 2008 page 1 of 2

Målsman/Förmyndare medgivande och publiceringsblankett

KTH Informations- och kommunikationsteknik

Projekttitel: Analysering av hästridningsaktivitet med hjälp av video och elektroniska sensorer

Projekthandledare: ***Dr Robert Wellington***

Forskare: ***Doug Hunt***

Var vänlig kryssa i rutorna nedan och skriv under denna blankett för medgivande

☐ Jag har läst och förstått informationen om detta forskningsprojekt i Informationshäftets 5 sidor daterat 12 Mars 2008.

☐ Jag har haft tillfälle att ställa frågor och få dem besvarade.

☐ Jag har förstått att jag kan när som helst kan ta ur mitt/mina barn och mig samt all annan information om oss från projektet, när som helst före avslutande av datainsamling, utan att vara missgynnad på något sätt.

☐ Om jag eller mitt/mina barn utträder, förstår jag att all relevant information och även bilder relaterade till mitt/mina barn eller mig förstörs.

☐ Jag ger mitt medgivande till att mitt/mina barn deltar i denna forskning.

☐ Jag ger mitt medgivande till att mitt/mina barn bär en elektronisk sensor på sin vrist och blir videofilmade medan de rider på sin häst.

☐ Jag förstår att copyrighten för materialet i projektet anses vara ägt av forskaren och varken jag eller mina barn äger någon copyright på något av materialet.

☐ Mitt/mina barn brukar inte falla från sin häst vanligtvis; de har inga tidigare skador på vristerna; De är inte benägna att få vristskador, skelettskador eller att ramla; deras häst har inget underligt temperament och blir inte rädd för kameror; de blir inte störda om de får mycket uppmärksamhet från åskådare; och det är ingenting konfidentionellt med deras ridträningsmetod.

\- Jag tillåter forskaren att använda videofilmerna I projektet och/eller bilder från dem och alla andra återgivande eller bearbetningar från dem, antingen komplett eller i delar ensamma eller tillsammans med någon formulering och/eller reklambilder uteslutande och exklusivt för :

☐ (a) Forskarens analyser och undersökningssyfte;

☐ (b) Undervisning och/eller presentation på konferens (non-agreement till sådant användande av forskaren gör att du fortfarande kan medverka i projektet).

☐ Jag vill ha en kopia av mina barns videoupptagning på dvd när all data är sammanställd.

☐ Jag vill ha en kort resumé av resultatet när forskningen är komplett.

Barnets/barnens namn :……………………………………………………………………………………

……

Målsman/Förmyndares underskrift: ………………………………………………………………

Målsman/Förmyndares namn: ……………………………………………………………………

Målsman/Förmyndares kontaktinformation (i förekommande fall):

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Datum:

Approved by the Auckland University of Technology Ethics Committee on *24 April 2008*, AUTEC Reference number *08/47*.

Obs! Målsman/Förmyndare bör behålla en kopia av blanketten.

This version was last edited on 3 December 2007

Samtycke och publiceringsblankett

KTH Informations- och kommunikationsteknik

Projekttitel: Analysering av hästridningsaktivitet med hjälp av video och elektroniska sensorer

Projekthandledare: ***Dr Robert Wellington***
Forskarer: ***Doug Hunt***

Var vänlig kryssa i rutorna nedan och skriv under denna blankett för medgivande

☐ Jag har läst och förstått blanketten som talar om vad som kommer att hända under studien och varför det är viktigt

☐ Jag har haft tillfälle att ställa frågor och få dem besvarade.

☐ Jag förstår att jag ska ha apparaten på min vrist och bli videofilmad medan jag rider.

☐ Jag förstår att medan sammanställning pågår, kan jag när som helst sluta att delta I studien och det är inga problem.

☐ Om jag slutar delta I studien förstår jag att all data om mig inklusive filmerna eller någon del av dem som inkluderar mig, kommer att förstöras.

☐ Jag ger mitt medgivande att delta I denna forskning.

☐ Jag faller inte vanligtvis från min häst, har inte haft vristskador, min häst har inget underligt temperament och är inte rädd för kameror, jag är inte blyg.

☐ Jag vill ha en kopia av mina egen videoupptagning på dvd när all data är sammanställd.

☐ I Jag vill ha en kort resumé av resultatet när forskningen är komplett.

Deltagarens underskrift: ……………………………………………………………………………

Deltagarens namne: ……………………………………………………………………………

Deltagarens kontaktinformation (i förekommande fall):

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……………………………………………………………………………

Datum:

Approved by the Auckland University of Technology Ethics Committee on *24 April 2008*, AUTEC Reference number *08/47*.

OBS! Deltagaren bör behålla en kopia av blanketten

This version was last edited on 3 December 2007