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**Department of
Computer Science**



UNIVERSITY OF
BATH

Technical Report

Undergraduate Dissertation: Advanced Golf Tutor

Richard Clive Percy

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Advanced Golf Tutor

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Batchelor of Science in Computer Science with Honours

The University of Bath

May 2007

Advanced Golf Tutor

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DECLARATION

This dissertation is submitted to the University of Bath in accordance with the requirements of the degree of Bachelor of Science in the Department of Computer Science. No portion of the work in this dissertation has been submitted in support of an application for any other degree or qualification of this or any other university or institution of learning. Except where specifically acknowledged, it is the work of the author.

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Abstract

Golf is a highly technical sport and as such golfers regularly seek lessons from professionals and qualified coaches. The golf swing lasts a very short time and so often coaching occurs with the aid of video systems. Many of these existing systems have little grounding in HCI and as such experience usability issues. In addition, much research has been performed into the psychology of coaching but very little has been implemented into golf coaching systems.

This project changes the way feedback is received by both the pupil and the golf professional with the aim of creating a system that will increase pupil learning. In addition the system aims to be highly usable, so not to hinder the coaching progress.

Evaluation of the system has indicated no major usability issues and has shown that learning can occur with the system. Details of further testing to assess any learning benefits are discussed as are improvements to the system, and issues raised in the participatory design of a coaching system

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1 Introduction

Golf is a sport played worldwide, with millions of people playing the sport every week. One of the many attractions to golf is the important role that technique plays in a successful round. As such, instruction and lessons from recognised golf professionals or coaches play a vital role in the development of a golfer's skill. Professionals will teach pupils on both a group and individual basis; in addition pupils spending many hours practising individually on a driving range, as well as playing golf.

Golf professionals, like coaches from other sports, are increasingly using technology to aid their coaching of pupils, and increasing pupil learning and performance. However, many of the computer based systems are created either by computer scientists, with very little coaching experience, or by coaches who have not had the necessary grounding in computer science theory. This project aims to fill this gap, building upon knowledge of modern coaching techniques and utilising knowledge from human computer interaction.

1.1 Overview

This project considers developments in psychology, coaching, biomechanics and human computer interaction and aims to utilise these principles in the development of an effective coaching system. Human computer interaction is must be considered, as a badly designed system may not allow a golf professional to coach effectively, as well as possibly discouraging them from utilising aspects of a system that may aid development of the pupil's skills. In addition it is important to consider the computer literacy of the golf professional, as golf professionals often have limited exposure to technology because of their nature of work.

The designed system targets the way knowledge of results (KR) is supplied to both the professional and the pupil. The system not only gives increased and more accurate knowledge of results than a lesson not utilising technology, it aims to utilise summary KR which has been shown to increase performance. By utilising these principles it is believed that the pupil will learn quicker and more effectively.

However, as this project only has a limited time frame, the system will not aim to test this learning principle, as a golf swing will take many months to show consistent improvement. However, testing and evaluation occurred during the project, notably testing the usability of the system and evaluating whether the system offers the ability for a pupil to learn. In addition the issues associated with longitudinal testing have been considered and discussed in the project.

1.2 Organisation

This dissertation begins with a review of the latest literature in coaching, golf biomechanics and human computer interaction in chapter 2. This section additionally discusses how the research could be applied to golf. Chapter 3 details

the requirements for a golf coaching system which were developed with the aid of a golf professional. Chapter 3 additionally details the key aspects that can be learnt from in chapter 2. Chapter 4 applies the requirements generated in the previous chapter and considers potential system designs, followed by designs for the end system which were developed with the aid of a golf professional. Chapter 5 discusses the key areas of the implementation, looking at areas that caused difficulties or are particularly important to the development of the end system. Chapter 6 of the system evaluates the implementation in terms of usability and learning, indicating issues raised by potential users and how these problems could be resolved. Chapter 7 concludes the project, summarising issues raised throughout the dissertation, including critiques of the methodology used in the development of the system and issues that need further research. Finally, the section concludes with possible future applications of the system, other implementations of theory in coaching system and finally guidelines for future coaching system development.

2 Literature Review

2.1 Introduction

In recent years extensive research has been undertaken in the field of coaching and improving performance in all sports, at all levels. This can be linked to the general increase in sports based research and the growth of the leisure industry. The level of growth is also reflected in the golf industry, with US\$3.2 billion dollars being spent on US golf club memberships in the 1990s (Farrally et al, 2003). In addition to purely sports based research, research from other disciplines is now being applied to sport, particularly in the field of psychology (e.g. work by Newell). Top players now realise the improved results that can be obtained by practising aspects of sports psychology, these include more consistent performance under pressure and increased 'mental strength'.

Improved technology has enabled greater biomechanical research and a reduction in cost of equipment has seen analysis equipment become available to the average golfer and golf professional. Golf professionals are now able to provide video analysis to club players, which not only aid the player, but additionally increase golf professional profits through additional charging for video based lessons.

In the following review the latest coaching practices and the psychology of learning are outlined and this research is then applied the golf coaching domain. Additionally, how recent biomechanical research can be utilised by a coach with a computerised video system will be explained. The section is concluded with an explanation of how the biomechanical, psychological and coaching practices can be delivered effectively to both the coach and pupil through a usable system founded on sound Human Computer Interaction (HCI) principles.

2.2 Coaching

Coaching can be divided into two main sections, information given to the pupil before practising a skill, and information given to the pupil after they have practised the skill. The pre-practice information will usually be a visual demonstration and/or a verbal description of the skill. The post-practice information will generally include feedback information on the way the user performed the skill.

A classical view of the distinction between pre and post practice information can be linked to the way representations of motor movements are stored in memory proposed by Schmidt and Adams. Adams (1971) and Schmidt (1975) propose that learning results in the development of either actual memory traces or schemas (Schmidt's abstractions of the movement). These representations initiate the movement and evaluate its effectiveness once the action has been performed. The development of these schemas underpins learning.

2.2.1 Explicit and Implicit Learning

Gentile (1998) differentiated learning into explicit and implicit processes. The explicit processes are directed towards goal attainment, and allowing the learner to develop appropriate mapping with the task. Implicit processes develop the appropriate force-generation patterns that allow efficient and effective movement within the skill. The two processes are said to be interdependent, however it has been discovered that they develop at different rates with the explicit process developing the quicker.

The structure of the learning means the demonstrations of explicit processes tend to shape the movement, however these demonstrations are often insufficient to generate the required implicit knowledge. Often coaches use analogies to compare areas of a skill to a skill that the learner already has knowledge of, a common example of this is the initial movement of a golf swing is analogous to the passing of a rugby ball. Using existing skills to improve the implicit knowledge of a new skill encompasses the work done on memory traces and schemas by using connectionism to indicate a link between the new skill schema and the existing skill schema. As a coach will aim to develop the pupil's explicit and implicit skills, the system must allow the coach to develop these processes.

2.2.2 Open and Closed Skills

When performing a motor skill two metrics for measuring the success of the task are apparent: achieving the goal and how well the movement was performed. These metrics lead to the classification of closed and open skills. Closed skills are those that view the goal of the task and how the goal is achieved with equal performance, whereas in an open skill a goal may be achieved in many different ways. Golf itself is an open skill as the aim of golf is to achieve as low a possible score and this can be done with a differing number of shot types and using differing swings. The individual skills in golf are themselves open skills. It is possible to see this by simply observing the different techniques top professional golfers use to perform the same shot. However, when coaching golf a professional will often model the pupil's golf swing into a closed skill, for example changing the pupil's swing plane. The modelling process involves the user becoming detached from the goal of hitting a good shot and is instead focused on making a specific movement. This is often termed "goal confusion" (Gentile, 1972; Whitting and den Brinker, 1982).

When treating an aspect of a golf swing as a closed skill, often a professional will give their pupil a template to follow. Following a template has been shown to increase the consistency of the performance of the skill (Newell et al, 1990). However, the performance increase is not replicated if the same technique of copying a template is applied to an open skill. Gentile (1972) indicated that the consistency gained from following a template is not always desirable in an ever-changing environment, something as occurs in golf. For this reason pupils are instructed to practise after a lesson in order to "get used to" or develop a "feeling" for the skill.

The implications of the different coaching techniques for open and closed skills for a coaching system are significant. The system must allow modelling of the swing as both an open and closed skill, implying the need for analysis of the swing in its entirety and in parts.

2.2.3 The Role of Images and Models

The image or template that the pupil receives can play an important role in the success of skill acquisition. Any golf coaching system must allow the pupil to develop this image, or refine an existing template. The development of the image may have specific areas reinforced by the coach and as such should additionally support this. The role of the image can be demonstrated simply with an example of a pupil who does not have the physical ability to reproduce the model. Without the physical ability, pupils trying to copy, they will never manage to imitate the model and hence never achieve the goal (the goal is assumed to be replicating the model, and replication is a closed skill).

Models can be presented in multiple ways, "expert models" occur when an expert is used as the basis for a skill. However these expert models are not the only type of model a learner can follow, "learning models" are models that emphasise important aspects of the skill rather than demonstrating how to perform the skill perfectly. Pupils following these learning models have shown equally good performance in post acquisition tests, as those who have observed expert models. According to Hodges et al (2002), when watching the learning model the pupils are more involved in the problem-solving process and so concerned with goal attainment rather than mimicking a model - ideal for open skills.

A pupil following a learning model is experimenting; working out what works, and what does not, and in an open skill such as golf, this can prove very useful to the end user, particularly when performance is sub-optimal. Vereijken (1991) argued that discovery learning, the type of learning that occurs when a pupil follows a learning model, could work positively by encouraging the discovery of a solution suited to the individual. There is an increased chance that this solution is optimal for the individual leading to increased performance.

However, a given learning model will not necessarily be effective for all learners, it must be in context and relevant to the learner and their ability. For example, a learning model aimed at a beginner may not be suitable for an expert as the pupil may already have mastered part of the skill the learning model is teaching; hence the model will provide no new information. Newell (1981: 537) summarised the issue of relevance "When the information to be conveyed through demonstration is redundant, there is, by definition no information transmitted to the learner" (Newell 1981: 537).

Models are an integral part of coaching and learning and as such they must be supported in a coaching system. Additionally it is possible for a coach to form a learning model from an expert model through highlighting and annotating the expert model. Any computer based system must have the capability to allow this model transformation.

2.2.4 Learning

When dealing with a perceptual skill with complex requirements, such as judging shot distance in golf, if the details of the movement are explicitly instructed, degradation in performance is observed. The degradation is also observed when the learner is exposed to a specific piece of information relating to task success, as the pupil may miss other important information, focusing solely on the information that

he thinks will bring him task success. The cognitive demands of the task experienced by the learner will be interrupted, causing poorer learning.

Learning can be divided into three phases: cognitive, associative and autonomous (Fits & Posner, 1967). The cognitive phase is important during the early stages of skill acquisition and involves the pupil understanding the action/movement that is going to be performed. The associative phase of learning concerns gaining the feeling of the correct movement, then the autonomous phase makes the process subconscious. Research however has only been performed with information processing skills, not the complex motor skills that are found in the golf swing; however, it is believed that the theory will scale as it has been attributed to transferring skills to new domains. Higgins (1991) indicated the importance of understanding by stating that training not learning occurs when someone else's solution is not fully understood by the pupil.

One of the main aims of coaching is the development of skills that are repeatable and consistent under pressure, that is making the skill autonomous, something that has been iterated by top athletes, swing coaches and sports psychologists (e.g. Clarke, D and Morris, K, 2005; Rotella B, 1995). The development of consistency concerns not only skill technique but the pupil's belief about their technique. Implicit and explicit learning affects this consistency. Masters (1992) and Hardy et al (1996) tested the value of implicit knowledge in a golf-putting task. The experiment consisted of three groups: two taught groups, one who received implicit tuition and one who received explicit tuition, both groups had practice interleaved with their tuition; and a third control group who received no tuition and simply practised. During practice, all groups improved, with the implicit improving slower than the other two. The participants were then placed under pressure in a test environment resulting in the explicit and control groups' performance deteriorating. In contrast the implicit learning group's level of performance was much higher and the participants showed an improvement during testing. Following these findings, Masters (1992) hypothesised that automatically produced actions and procedures governed by lower-level systems become controlled by higher-order sub-systems and hence performance breaks down when reinvested with explicit knowledge. Under pressure, performers have a tendency to analyse and internalise the action, concentrating on the mechanics (Masters et al, 1993) and this is the same concept that Rotella (1995) speaks of when he talks about "trusting". The results of the findings do not have new implications for a coaching system, rather they emphasise the importance of implicit knowledge in development of autonomous learning, further justifying the need for methods of implicit knowledge to be included in the system.

Wulf et al (1998, 1999) have shown that a focus on mechanics can also be a problem in the coaching phase - when the attention is focused on the limbs rather than the affects of the action, the effect on acquisition was detrimental. This is extremely important for golf where the player's action is often analysed in minute detail, meaning it is important for the coach to force the player to focus on the larger goal. The problem of focusing on limb movement can occur when following an expert model without the guidance of a coach. The pupil may watch the model and say "His hands do X" and hence try to replicate this hand movement, neglecting another movement the expert makes. However, the pupil should try to follow the club movement and replicate the club position and movement, therefore the pupil is more

likely to produce the correct sequence of actions. The findings imply the need for the system to be able to generate club path details when analysing the swing.

2.2.5 Feedback: Knowledge of Results

After having practised a pre-practice model, learners move into the post-practice or feedback stage. Feedback has been the subject of extensive research, in general and specific to the sport domain. Feedback research concerns how a pupil will obtain the knowledge after performing a task and how they process the obtained knowledge. Knowledge of Results (KR) is known as the post-response error information a learner receives and Knowledge of Movement Production is the learner knowing that he/she performed a specific movement. However, KR and Knowledge of Movement Production tend to be used synonymously as they share the same theoretical background and convey the same information (Guadagnoli, 2002). An example of the synonymous use is “you twisted your foot”, should the actor not mean to twist their foot when performing the action, the instruction is considered both KR and knowledge of movement production.

KR has two major effects on the learner receiving it; first, it tends to have a motivating effect with the learner exerting more effort towards the task and/or has more positive feelings towards the task. The second effect of KR is the information property, which is considered one of the important uses for KR. Many performers cannot adequately evaluate errors on their own and so need to have the information provided to them about the task. This information will be in relation to error from the goal, or sometimes about the errors in movement production, it could even guide the pupil on how to correct the error. However, until the pupil has developed a mental representation of the skill and knowledge of the movement production to correctly perform the skill, they must be provided with information that is the basis of an appropriate mental representation from some other source. This information can be provided by a coach or more recently obtained from videos (Guadagnoli et al, 2002). Any system must allow the coach to highlight errors, allowing the pupil to visualise their mistakes. Such visualisations may involve a comparison to a model, either expert or learning.

Golfers often try to provide themselves with their own KR whilst they are practising or playing. However, the way a golfer analyses the swing for a shot is unclear. Obviously it is possible for a golfer to see the shot shape and where the ball finished but golfers have more “feel” than this. In addition to seeing the shot, it is possible for a golfer to work out where they have hit the golf ball on the face of the golf club through feeling the club twist. It is also believed that sound plays an important role in this “feeling” (Morrice, 2005) but the research on the role of club acoustics on sound is limited and would need further research if it were to be considered beyond a minor feedback method. The accurate feedback the golfer receives is limited to the end goal and it is very difficult for a golfer to deduce more than how they hit the ball correctly. If they are hitting the ball badly they will seek increased level of KR so they are able to build up a model of their current skill to compare it to their model of a correct swing, hence a coaching system should aid the pupil in the development of reference KR.

2.2.6 Delivery of Knowledge of Results

The level of feedback and the way knowledge of results are presented to pupils is an area that has been studied greatly, probably due to the belief that KR is difficult to use. This apparent difficulty could be to do with confusion about the potential performance characteristic that a particular KR refers to or that often performance has been shown to degrade after receiving KR (Schmidt et al, 1989). There are three main ways KR tends to be given to the pupil: immediate, delayed (summary) and a combination of both. Immediate KR is given to pupil after each practice of the skill whereas delayed is given after a number of practices and the information is presented as a summary of the pupil's performance over these practices. It would be desirable for a system to support both delayed and immediate KR techniques.

The level of KR given to the learner has been shown to have an optimal level based upon the relative complexity of the task, defined as the complexity of the task relative to the skill of the learner performing the skill. This is the same reasoning as the level of the model given to the pupil, with expert players requiring feedback that is more precise. During coaching KR does not have to be related to the entire open skill of the golf swing, it can be related to part of the skill that the coach has identified as incorrect and has asked the pupil to model as a closed skill.

Lavery (1962, 1964) employed experiments to see the learning benefits of learners provided with summary KR, immediate KR and both. Lavery set up a simple motor skills test with three groups and provided one group with delayed (summary) KR after twenty trials, one group with immediate KR after each trial and one group with both. When the pupils were in the acquisition phase, those receiving summary KR performed worst with more errors than the other two groups. However, when the participants were tested in trials where no KR was provided the summary group performed at a consistent level, whereas the immediate and both exhibited considerable losses in performance to such an extent that the summary group were now more effective than the other two groups. Lavery's work is significant for golf coaching in particular as the testing was performed in a no KR environment. As indicated earlier the KR that a golfer will receive during a game is limited, more so in the amateur game than in the professional game as the rules of golf state that you are not allowed to receive advice during the game, with the exception of advice from your caddy. Most amateurs do not have caddies, or if they do, the caddy is unlikely to understand the game sufficiently to provide effective KR. As the golfer will receive minimal KR during golf, the coaching system must not cause the pupil to become dependent on KR.

A guidance hypothesis for KR has been formulated with initial work done by Annett and Holding and later the hypothesis was made more formal by Salmoni et al (Schmidt et al, 1989). The hypothesis assumes that KR provides information on how to solve the movement problem; hence, KR provides strong guidance where KR is present, making performance very effective in acquisition. This guidance is very important for the acquisition of a skill as it allows the learner to be directed towards a correct movement schema. The hypothesis however goes further than speculating on the guiding property of KR, reasoning that the learner gains a reliance on the KR and the learner then fails to process other factors, which could relate to skill success. A similar effect is observed when a learner of an open skill tries to copy an expert model without engaging in learning and the learner struggles in a changing

environment. Summary KR, however, lacks the strong guiding property of immediate KR and so the user must engage in further aspects of the problem solving, similar to the effect when a novice pupil follows a learning model. To avoid guiding the pupil, any system must allow summary KR to be developed.

The length of summary KR can vary which can have an effect on the retention of information. If the summary is too short it provides too much guidance during acquisition, whereas too long encourages processing of movement information but does not provide the guidance to drive for the solution to the movement. The properties of summary KR led Schmidt et al (1989) to hypothesise that there must be an optimum summary-KR length. Their work showed that increased length in the early acquisition phase when immediate KR was still present degraded performance. However retention was found to be optimal when 15-trial summary KR was used and they believe the optimum solution lies between 15 trials and the 20 trials set out by Lavery (1962). Nevertheless, Schmidt et al discuss that although these are optimal for learning it is necessary for the learner to have some KR for a given performance so that they can modify errors in the movement and hence develop the understanding of the movement required in open-skills, such as the golf swing. Schmidt et al's discussion is vital for a coaching system as it suggests open skills need both guiding and summary KR to become fully developed.

It is possible to hypothesise about the role practice plays in an environment where KR has been provided. Summary KR leads to the acquisition of the capability to process and detect your own errors (Schmidt & White, 1972; Schmidt et al, 1987), and immediate KR does not allow for the acquisition of the error knowledge, the role of practice after a skills coaching is of greater importance with immediate KR than summary KR. Practice sessions are widely used in golf and considered essential to maintain and improve performance for both amateurs and professionals alike. The practice of a professional golfer can involve hitting 1,000 golf balls per day and so this practice allows them to develop their implicit skills from the explicit instructions and integrate closed skills into the open skill of the swing.

2.2.7 Knowledge of Results in the Golf Domain

Experimentation carried out on the different methods of providing KR was performed by Guadagnoli et al (2002) who compared feedback given to three groups of golfers. One group received verbal tuition from a PGA professional observing their swings, one group received video-based tuition from the same PGA professional, and the final group was self-guided. The golfers were assessed on a distance and accuracy basis and each golfer received a 90-minute training session on each of four days; each of these training sessions was separated by one day and outside of the training sessions, the golfers neither played nor practised. The groups were given pre-tests to check their ability and all groups performed equally. However, the method has its flaws, a small error in a good swing can produce worse results than several small errors correcting themselves in a bad swing, but with the large groups (10) and random assignment this should have negated any bias.

The pupils had two post-tests, the first 48 hours after the last training session and the second two weeks after the first post-test. During the two weeks between the post-tests, the participants played and practised as much as they wished (exit interviews

suggested that this was no different to their usual practice routine). The results showed the self-guided group experienced no real improvement in consistency over the three tests, whereas both the instructed groups showed greater variability in the first post-test than they did in the pre-test. However, in the final post-test the instructed groups showed a significant decrease in variance of shots, in particular distance variance. The video group performed the best of the three groups in the second post-test both in absolute and relative terms, halving their original variance in distance of shot.

The results suggest that the more precise KR that can be gained from a video allows a player to make a greater change in the mechanical action of the skill. It is possible to hypothesise that a computer-based system provides greater KR for the learner. The additional KR could be provided through a number of areas, firstly by allowing the coach to identify areas of the swing that needs improving in greater detail. Video aids the coach to identify areas that are not possible to identify with the naked eye due to visual illusions, a phenomenon found by Pelz (2000) with his analysis of the putting stroke (a “pure inline stroke” putting stroke can appear to have a “swinging door” effect). Computer based systems allow the pupil to gain a greater understanding of the model of the movement, specifically by allowing the user to compare their model on a screen with their internal representation, and in addition with an expert or learning model. The increased detail found in a computer based system allow for greater analysis with freezing of the video to view specific areas, and split screen viewing, enabling the swing to be viewed simultaneously from multiple angles.

The research performed by Guadagnoli et al (2002) additionally indicates that when detailed KR is provided practice is necessary afterwards to gain knowledge of the skill. This hypothesis also supports the work done by (Shadmehr and Holcomb, 1997) who say that practice helps develop the internal model.

2.2.8 Summary

The work carried out on coaching has lead to a number of conflicting findings, firstly the precision of feedback that a learner receives and secondly the details in models. However, the theme that is reflected throughout the research indicates the importance of varying levels of feedback and demonstrations or models. Different people learn at different speeds and in different ways and so the information conveyed to them must be relevant. Additionally, learners receiving specific movement information must practise that movement, as performance in a practice does not mean the learner has not absorbed the information provided.

However, even if the learning of the movement is optimal, the information provided to the pupil about movement production must be sufficient to effectively guide the pupil; biomechanics of the golf swing can provide the information.

2.3 Biomechanics

There exists no particular swing for any single golfer but all players must have a single swing (Egret et al, 2003). The ‘ideal’ golf swing however can be characterised

within a set of biomechanical parameters such that the golfer increases the performance and reduces the risk and severity of injury. These advantages are what drive a golfer to receive tuition from a professional golf coach who will be able to modify the golfer's swing so it is closer to the idealised swing.

The golf swing has been studied in terms of kinematics, kinetics in two dimensions, dynamics of weight transfer, electromyographic analysis and mathematical modelling (Egret et al, 2003) in pursuit of the idealised parameters. Using a high-speed video camera at a variety of angles has been shown to be sufficient to allow analysis of the biomechanical parameters of a movement. All details of the biomechanical analysis are for a right handed golfer. Should these principles need to be applied to a left-handed golfer, right and left can simply be reversed.

2.3.1 Set-up

The setup of the golf swing establishes the golfer's static and dynamic balance and so must be analysed by the coach (Hume et al, 2005). It is common knowledge amongst golfers that a bad setup position will often cause a bad swing. Pelz (2000) indicates the sub-conscious reactions initiated by bad alignment cause an abnormal and inconsistent stroke. Alignment is essential, and any tutoring system must allow the golf professional to indicate this explicitly to the pupil.

The grip is another fundamental of the golf swing. The grip a golfer has on the golf club is the golfer's only point of contact with the club allowing the golfer to effectively control the angle of the club face. A grip can be termed weak, strong, or neutral depending on hand position and a professional must be able to analyse the hand position in detail seeing the position of each of the digits.

The golfer's body additionally must be aligned such that the knees are flexed 20-25° and the trunk flexed 45° to the hips, known as the spinal angle. The shoulders should be tilted approximately 16° to the right due the grip position (Hume et al, 2005). It is possible to see from this position that even the static setup position requires a lot of detail and several two dimensional images. The implications of this are two fold; firstly, any system must support the ability to freeze a moving image and secondly, the system must have the detail necessary to analyse the setup position from all necessary angles. Figure 2-1 describes the optimal viewing positions for analysing the setup.

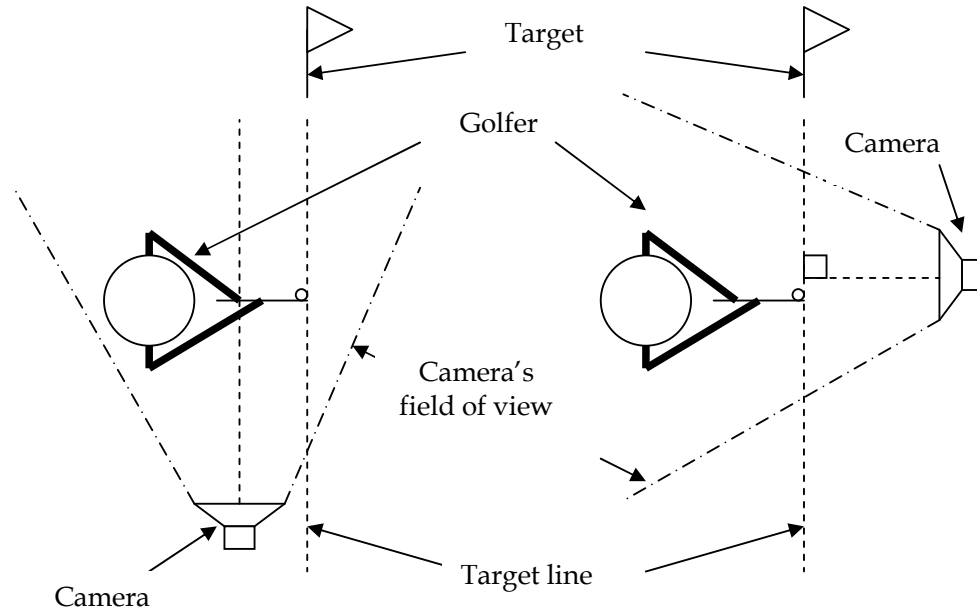


Figure 2-1 - The optimal camera positions to analyse setup positions (parallel and perpendicular to the target line)

2.3.2 Backswing

The backswing is the phase of the golf swing that follows the setup and ideally positions the club in a position such that the golfer can return the club to the ball with maximum velocity and accuracy. The golfer will initially rotate the trunk and arms to the right, positioning the club parallel to the target line at waist height with the arms extended fully. The extension of the arms allows maximal width, a key component of the golf swing (Hume et al, 2005).

The trunk continues to rotate and the arms continue upwards until the shoulders have completely rotated. During this rotation, the right knee will flex slightly and additionally the hips begin to rotate. The difference in rotation between the hips and shoulders is termed the X-factor and it has been shown by McLean (1992) that when the X-factor is maximised distance of the shot is increased, and as such golf professionals analyse the X-factor in a pupil's swing, such that a coaching system must support such analysis.

Furthermore, the position of the club at the top of the swing is believed to influence the distance and accuracy of shots greatly. The swing plane is defined as the angle of the butt of the shaft in relation to the ball and is indicated in Figure 2-2. Swing plane is one of the most difficult concepts for pupils to understand as many movements (any of the setup or backswing movements) can influence it, so a system would desirably aid this learning. Additionally, when a golfer is swinging at high speed it is difficult for a professional to analyse their swing plane, so slow motion analysis of the swing would aid the professional.

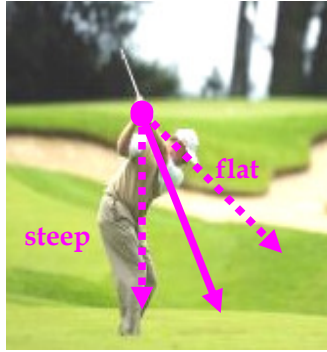


Figure 2-2 Diagram showing swing plane (solid line), and the areas classed as too steep and too flat (Image courtesy of www.ernieels.com)

The golf backswing is a very complex sequence of movements performed at a high-speed that can be difficult for a professional to analyse so any system would aid them in this analysis. The complex nature of the movements also is difficult to interpret for the pupil, such that a coaching system should aid their learning and interpretation of the swing.

2.3.3 Downswing

The purpose of the downswing is to return the club head to the golf ball with maximal velocity and on the correct plane. For elite golfers the transition from top of the backswing to impact is 0.23 seconds (Hume et al, 2005). The plane of this downswing is very difficult to analyse with the naked eye due to the speed the club is travelling. Any system created must allow for analysis of the down swing in slow motion.

The downswing is a sequence of “unwinding” motions, with the hips and shoulders rotating towards the left. The wrists remain cocked until the arms are horizontal, where they uncock in the final acceleration phase into the golf ball and impact position. The wrist cock has been shown to be greater at the horizontal position in the better player (Hume et al, 2005). This important area of the swing has only been recently analysed due to the advent of slow motion images and videos and is not visible during normal viewing. Analysing the wrist cock would need to be incorporated into any coaching system, therefore slow motion analysis is necessary.

2.3.4 Equipment

The equipment used to analyse biomechanics ranges greatly, however since the 1980s most kinematic analysis has been done using high-speed video (Hamilton and Luttgens, 2002). Traditional PAL videos in the UK have an effective frame rate of 25 frames per second, whereas high-speed cameras have a frame rate of hundreds of frames per second (Knudson and Morrison, 2002). Modern digital video cameras have the ability to record at around 60 frames per second, allowing for more detailed data capture than a standard PAL camera.

However, higher frame rates will not be displayed on a standard television, the television will only be able to display 25 frames per second. Computer systems are frequently used for biomechanical analysis, as they are able to support the higher frame rate and allow for analysis in more detail. According to Hamilton et al (2002)

coaches and pupils find benefits in the freezing of video, whilst Knudson et al (2002) recognises the advantages of split screen viewing, allowing the pupil to view several different angles and create a mental three dimensional image of the swing. The advantage of digital video and the improved coaching toolkit give important justification for biomechanical analysis on a computer system.

Optoelectronics are being more commonly used in biomechanical analysis, specifically in golf. The pupil has reflectors attached to specific points on their body; multiple cameras then capture the swing. The reflective points are used as references for construction of a three dimensional model of the pupil's golf swing. An example of this is the MAT-T System by Adidas-TaylorMade. The equipment for this system is expensive; it requires multiple video cameras, which are synchronised and a lab to stop light interference. The high cost means an optoelectronic system would be beyond the means of the typical club golf professional. Lab settings have the additional problem of not allowing the user to view the result of a specific swing in the correct environment and so not allow the user to receive appropriate feedback.

In conclusion, the most cost effective equipment for a golf professional is a computer system with a digital video camera. The advantages of a system are many fold over the naked eye, whilst some of the optoelectronic systems can model the system in three dimensions, this three dimensional representation may be too abstract for the pupil to effectively learn.

The advantages from biomechanical knowledge allow the professional to coach the pupil to the maximum of the pupil's ability. However, it is important that the coach is able to communicate this information to the pupil, and that the pupil is able to comprehend the information received. The chance of the communication being successful is maximised if the principles of human computer interaction are followed.

2.4 Human Computer Interaction

According to Sutcliffe (2000) the mission of Human Computer Interaction is transferring knowledge from cognitive sciences such as psychology and sociology into the design of computer systems. The transferring of skills should allow for a highly usable system, but for a truly usable system, the user needs to be considered throughout the design process.

Initially a designer must consider how the user will interact with the system, not only the physical interaction with the system but the environment in which the user will interact with the system.

2.4.1 Application of Cognitive Science to HCI

Cognitive science theories can predict how a user will interact with a system, however these theories are complex. Sutcliffe (2000) believes that this is one of the major problems in HCI, the transfer of these skills. Many cognitive theories are so complex that they can only be implemented by large teams for example the EPIC

model (Kieras and Meyer, 1997) provides an architecture of perceptual and cognitive processors that predict the user's attention. This model was created on a small scale for a simple user interface; however the more this model was scaled the more complex it became. This indicates the difficulty of implementing cognitive science, especially when conveying cognitive theory to designers who are non-experts.

Cognitive science however has only been able to be partially transferred to HCI. Cognitive phenomena can be implicitly specified in requirements for interactions, a method that will be implemented for this project. Psychological results may also be presented as principles or constraints relating to cut down theory. This is often presented in the form of models.

2.4.2 Interaction Models

User interaction with computers has been modelled greatly in order to understand the way that the user and system interact. Models advise on a set of generic design properties that guide the designer towards a usable system. The model will consider the domain, the user's field of expertise; the tasks, the method of manipulation; and the user's goals.

An early model, that is both clean and intuitive was proposed by Norman (1986) called the execution-evaluation cycle. The process contains two major phases (execution and evaluation) and seven subdivisions. The subdivisions specify how the user establishes their goal, how the user formulates what action to take, and how the user perceives the result of their action. If a system reflects the user's goals, it is considered successful. Dix et al (1998) defined the gulf of execution as the difference between the user's formulation of actions and the actions that the system allows. Efficiency can be measured in terms of the gulf of execution, the smaller the gulf is, the more efficient the interaction. Additionally, the gulf of evaluation is the distance between the system state and the user's expectation. The system's efficiency can be described in terms of the gulf of evaluation, the more readily a user can evaluate the system in terms of their goals, the more effective the system is. An effective system is essential for a golf coach; an ineffective coaching system may cause ineffective coaching and pupils not learning effectively. Effectively learning for pupils is essential as pupils who do not feel they are effectively learning are likely to seek another coach.

Norman's model does not include the system and the system's input and output explicitly. Adowd and Beale created a model with Norman's model a base, which explicitly incorporated the system and its inputs called the Interaction Framework. The models inclusion of both user and system perspectives on input and output allows designers to consider the system without the expertise of a cognitive background. The framework defines the information presentation, input performances, the users observation of outputs and the users articulation of the input. The articulation of user input contains the translation of the user's goals into the input language. The translation is dependent on the input allowed and the input methods.

Models have the significant advantage of allowing the designer to create a highly user centred design, an area of high importance in a people centric business such as

golf. However, in a golf environment the interaction is constantly changing due to the changing environment.

2.4.3 Interaction Space

Interaction in golf is a dynamic area, often there is a classroom in addition to the outdoor teaching area, however due to space restrictions the classroom may not be always be the ideal working environment.

The physical environment can affect interaction and any design must take into consideration where the system will be used. Factors include the position of the system, the lighting, time of day, noise and the temperature, all of which can fluctuate in a golf environment. Time of day is important as golf professionals will often teach for long periods of time, so any system must not place an excessive demand on concentration or strain the eyes. Large clear symbols would reduce eye strain whilst clear, accessible commands would allow for minimal cognitive demands.

The other aspect of the physical environment that changes is the number of people interacting with the system. Typically, a golf professional will have a single lesson or a group of 6 to 10 pupils. In individual lessons, interaction will involve the golf professional communicating the ideas to the pupil with conversation on the pupil's understanding. Group lessons however involve a much larger interaction area, with a golf professional demonstrating and highlighting concepts and pupils asking for clarification in a more structured manner. Golf professional's will often ask pupils for their understanding of concept and then demonstrate the concept subject to the pupils' understanding. Any coaching should take into account the variety of interaction methods, so not to hinder the way a professional coach currently interacts with their pupil.

The study of the physical characteristics of interaction including the interaction space is termed ergonomics. Dix et al (1998) indicated its similar yet distinct relation to HCI, with the primary focus of ergonomics on user performance and how the system's user interface aids or detracts from the user's performance in the environment. User performance is essential in the coaching environment when the coach is the user, performance being a metric for coach success and as we have no control over the physical environment we must concern ourselves with our input and output methods.

The arrangement of the controls and displays of the system can be considered in ergonomics as these affect the physical interaction with the system. Examples of bad ergonomics include two keys next to each other with opposite meanings for example "save and quit" and "quit without saving". Functional controls should be arranged with other functionally related controls; sequentially related controls should be ordered sequentially; and frequently used controls should be easily accessible. Observation of golf professionals has shown that controls frequently used for one professional will not be identical to those used by another, meaning that any system should allow for customisation and personalisation of the control system.

2.4.4 Interaction Methods

Numerous interaction methods exist for interacting with a system, however only a number of them would be relevant for an interactive coaching system. Methods such as command-line can be dismissed due to their complex and involved nature, hence not being suited to a novice user such as the golf professional. Natural language methods can also be dismissed due to their ambiguity in a field where precision is essential. Inflexible methods including form-filling and query dialogs are not suited to a coaching system, as they may restrict the coach, not allowing them to coach effectively.

The only appropriate interfaces are WIMP (Windows, Icons, Menus and Pointers), Point and Click and 3D. The simplistic nature of Point and Click interfaces make it advantageous for coaching, however as data is likely to be entered and stored it is likely to be too limited. Three dimensional interfaces are often too complex, particularly as projection and lighting can distort important aspects of the coaching. WIMP interfaces have the advantage of being the common interface technique for the majority of computer users, specifically in non-expert systems and as such the coach would be familiar with the system. WIMP interfaces require consistency and careful design to make them usable, an ideal system would utilise the Point & Click paradigm for the majority of the interaction.

2.4.5 Feedback and Presentation of Information

All interaction requires feedback, specifically for novices, who may not understand the process. The level and timing of feedback is important, constant feedback of the system state is theoretically ideal, however constant interruptions can distract the user from their goal and slow their process down. According to Fitt's Law the time and accuracy of pointing, and hence the time of the process is dependent on target size and distance. Accuracy in the system is additionally important in the ever changing environment; concentration is unlikely to be optimal at all times indicating large clear buttons would be advantageous for the coaching system.

The importance of clear presentation can be seen in psychology with the Gestalt principle of perceptual organisation. The principles indicate the human perception of collective objects are organised. The principles are proximity, tendency to group near objects; similarity, tendency to group elements that share similar shape; closure, tendency to organise collective elements to form a single object; area, tendency to group objects to create the smallest possible figure; symmetry, tendency to see symmetric elements as part of the same shape; and continuity, tendency to group elements into continuous contours or repeating patterns.

Groupings of objects can be tested for "pop-out" items, where an item is spatially related, yet it appears to pop-out from the other objects (May, 1997). The presence of the pop-out item will mean that the item will be processed and become the pragmatic subject. This processing occurs even if the user only wishes to process the group surrounding the item. Thus, any system must be checked for pop-out items. Items can pop-out for numerous reasons: size, shape and colour to name a few. However, the pop-out feature can be used effectively, for example in highlighting a command in a menu system.

Often elements are grouped together to reduce complexity and follow theories of ergonomics. Following the Gestalt principles will aid to create clear groupings rather than ambiguous groupings. Mullet and Sano (1995) suggested that the presence of clear groupings can be checked using a “squint test”. The user squints to see if they can see any groupings. Clear groupings are important in a coaching system used in ever-changing environments, aiding the coach in sub-optimal conditions.

Consistency in the layout of the system helps the user interpret state and methods. Familiarity can also be built by this consistency; however, familiarity is not advantageous in all situations. Familiar terms may aid one person but hinder another person due to misinterpretation. Such misinterpretations can occur with icons, realistic icons can cause confusion between instances of an object and their meaning. Road signs are an example of unambiguous information and their clear design should be replicated in any coaching system, thus providing clear affordances for the user and increasing usability.

2.4.6 Usability Paradigms

Usability paradigms indicate methods of making a system more usable (Dix et al, 1998), such that the given sections should be considered throughout design. The paradigms are learnability, flexibility and robustness.

Learnability is defined as the ease of learning effective interaction and the time it takes to achieve maximal performance. Dix et al (1998) divide the process into; predictability, ability for the user to determine future events based on passed actions; synthesizability, the user’s ability to assess the effect of past operations on the current system state; familiarity, ability for the user’s knowledge and other real world experiences can be applied to the system; generalisability, the ability to extend current knowledge to other areas; and consistency, the similarity of inputs and outputs as experienced in similar situations. Learnability is essential in a golf coaching environment as a professional coach may not have time to learn a complex system, the reasons for this being two-fold: firstly, the pay structure is per lesson rather than hourly so when not coaching the professional is not making money; secondly, it is not possible for the coach to learn during lessons as this may degrade their performance.

The flexibility of a system, defined by Dix et al (1998) is the multiplicity of ways the end-user and system exchange information. This can be subdivided into dialog initiative, allowing the user freedom from artificial constraints on the input dialog imposed by the system; multithreading, ability of the system to support multiple tasks simultaneously; task migratability, the ability to pass task control between the user and the system; substitutivity, allowing equivalent inputs and outputs to be substituted for each other; and customisability, the ability for the user to modify the system interface. A flexible system is essential for a golf coaching system. Each golf professional is likely to have different experiences of computer systems as well as differing opinions on coaching meaning a task may be performed in a different way, as such the system must be flexible so to not restrict the coach. However, it is unlikely that the system will need to support task migratability, the majority of tasks are system or user specific.

Robustness are features that support the successful achievement of goals. Dix et al (1998) divide robustness into observability, the ability of the user to evaluate system state; recoverability, the ability of the user to recover once an error has recovered; responsiveness, the user's perception of the rate of communication with the system; and task conformance, the degree of conformance between the system and what the user wants to, and the way they wish to perform it. Robustness is important in a system as a novice's confidence level rises if the system state is observable and recoverable. Responsiveness and task conformance increase the user's contentment with the system and so the professional will show greater motivation to use the system.

2.4.7 Implementing our Knowledge

Having established the principles behind HCI and the cognitive theories it is necessary to look at ways of implementing these into designs. Paradigms and principles are useful for the designer; however it does not give concrete methods for incorporating these in designs. Bellotti (1993) suggested that modellers from Artificial Intelligence and Software Engineering background would be able to contribute to design solutions; the different perspectives contributing different design solutions that summarise the design issues and modelling recommendations. Unfortunately, Bellotti did not suggest how the domain knowledge could be exchanged so limited work in this field has been done. Frameworks and principles however have emerged such as the "Ergonomics requirements for office systems visual display terminal" (ISO, 1997). However, much of the work done does not implement the cognitive psychology in sufficient detail for it to be useful (Sutcliffe, 2000).

The task-artefact cycle was proposed by Carroll as an alternative method of implementing psychological knowledge. Artefacts, tasks and claims are key to Carroll's theory. Claims are proposed to be a bridging representation between the theory and design providing advice for designers about a specific scenario; this situated nature is the main weakness of claims. Claims strength lie in their theoretical grounding and consequently provide important knowledge to system design. Artefacts embody the claim's knowledge in a strict scenario and contain features that theoretically enhance usability and the user centric analysis of requirements. Schemas of claims knowledge have further enhanced Carroll's original design. A claims description schema (Sutcliffe and Carroll, 1998) includes the claim with additional information relating to the claim (see Figure 2-3). Although no claims for a golf coaching system exist, it would be possible to implement modified versions to encompass the theory implemented and the trade-offs.

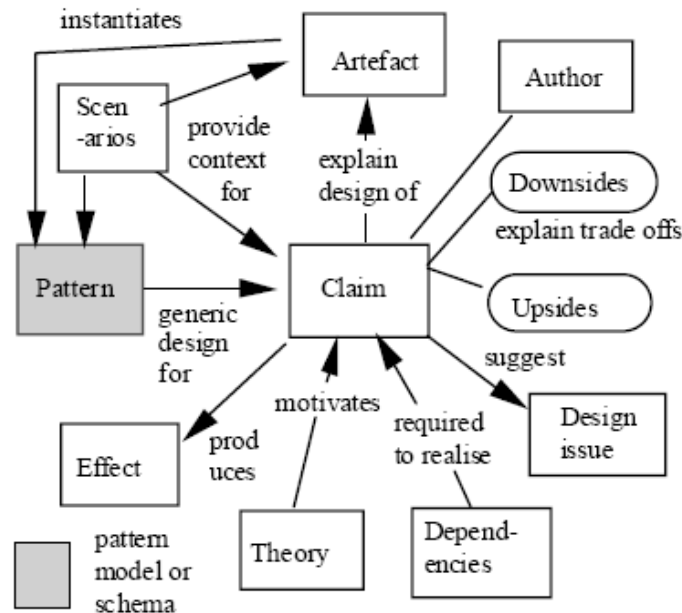


Figure 2-3 Sutcliffe and Carroll's (1998) claims description schema from Sutcliffe (2000)

2.4.8 Designing with the User

Having established the principles of implementing knowledge into usable systems for designers it is important for designers to follow models to produce a usable design. Interactive design is critical, setting the user as stakeholder throughout. Preece et al (2002) divide interaction design into four sections: identifying user and system needs and establishing the requirements, developing alternative designs, building interactive versions of the designs, and evaluating the designs.

Having the user as a stakeholder in the system means that requirements include the user's needs, rather than an interpretation of them. Involving users in the creation of design allows the user to identify potential problems and issues with the design and implementation of the requirements. Again testing interactive designs and evaluating them allows identification of potential issues with the system. Changes to working styles are more likely to be accepted by the user if they have a stake in the system.

Scenario based designs allow for impacts of technology to be analysed, predicting how the new technology will affect the user. These scenarios allow the user to see the effect of the system before it is built. User interaction scenarios are used to describe the interaction between the user and the system and are useful for clarifying system interaction. They can be formulated through evaluation of existing systems, including non-computer based systems. This method is ideal for a domain such as the coaching system; existing coaching principles can be written as scenarios, as well as scenarios from existing systems. The fundamentals in the coaching system could be expanded to include claims descriptions before the creation of system designs.

2.4.9 Evaluating Usability

Having designed a usable system, a design will need to test their claims. This is done throughout the design, specifically in iterative design; and after implementation. The evaluation process can take two paths; analysis or empirical study. During the design process formative evaluation occurs where prototypes or system versions are evaluated with the goals of improving the design and discovering the necessary process to improve the design. Summative evaluation is aimed to define measures of quality in the system; does it meet the system goals, and is it better than any previous product. Summative evaluation generally occurs at the end of the process; however, Rosson et al (2002) claim it can be used throughout the design process as a check point. Both of these evaluation techniques are important to the development of a usable system, and will be used.

Scriven (1967) defines two classes of evaluation; intrinsic (analytical) and payoff (empirical). The analytical methods produce interpretations about the usability of the product, but not results; the empirical methods study the user using the system, consequentially giving results, however the evaluator is required to have a good understanding of the system. Scriven (1967) proposed a mixed evaluation solution, termed mediated evaluation. Mediated evaluation uses analytical evaluation during the design to source potential problem areas; using these results to shape the empirical evaluations. Mediated evaluation allows the creation of a customised test plan and will be used.

2.4.10 Analytical Methods

Many analytical methods exist for usability evaluation can be used to evaluate the usability of the system. Often a usability inspection will be performed. A usability expert will examine or work with a system to identify potential problems with the system. To aid the inspector, Nielsen (1994) suggested 10 guidelines against which the system being evaluated could be tested. Nielsen called this heuristic evaluation.

Walkthroughs are another common technique for usability evaluation, Polson's (1992) cognitive walkthrough analyses the user's goals, expectations and reactions to individual tasks; the tasks must be accurately defined to ensure appropriate evaluation coverage. Think-aloud walkthroughs where the user communicates their goals and thoughts to the evaluator give a good insight into the usability of the presentation. However by communicating the ideas the user may use the system in a differing way.

Models can also be used in usability evaluation to represent the user's goals and knowledge, a classic example of this is GOMS (goals, operations, methods and selection) analysis. A GOMS model is created from the user's goals, the user's current intentions, the method they plan to use to achieve the goal and any selections they may have to make. The model then has human performance data applied to it in order to calculate the time to complete the user's goal. This is a very useful method and complex and as such would be beyond the scope of this project.

2.4.11 Empirical Evaluation

Validity when performing evaluation is essential; it defines how results obtained from experiments are going to relate to the environment that the system is going to be used in. Hypotheses from experiments with low validity are unlikely to transpose well into the target domain.

Laboratory testing is a common method of empirical evaluation, participants are given the system to use, and observational data is collected including data calculated by the system, recording the user's interaction with the system. The method allows controlled experiments to investigate specific problems or test hypotheses. However, these controlled experiments may not be representative of the use of the final system and may have limited coverage. Often lab experiments can have differences in the users, environment and prototype leading to invalid results that are skewed or misleading.

Field studies evaluate the real users in their natural environment and as such they ensure validity of results, and so do not suffer from the validity problems of laboratory or controlled experiments. Field study results are extensive and qualitative but can be difficult to summarise and interpret. To gain the extensive results a longitudinal study must be performed, which will ensure full coverage and allow analysis of the severity of the problems but unfortunately humans often reconstruct usability issues rather than recall issues, meaning errors are often difficult to pin-point. Smaller studies can be used, however although these results will be valid they may not have the full coverage to analyse severity. Field study, in the form of a longitudinal study will not be possible in my system due to the product not being fully implemented; however a smaller scale study will be implemented.

However, there exists an extensive range of usability evaluation techniques that are available to use. I do not feel I am able to indicate the methods that will be used at this stage due to the specialities of each method. Nevertheless, it is possible to predict the use of both empirical and analytical methods.

2.4.12 Summary

Human Computer Interaction highlights the importance of designing the system and making the design user-centric including the user as a stake holder to enable the creation of a user based system. The use of claims will provide a theoretical background to the implementation and allow for the implementation of the coaching theory.

2.5 Conclusion

Extensive research carried out on learning will provide the theoretical background to this project. Learning will prove to be important in both the coaching in the system and the design. Important recommendations can be drawn from the application of results and feedback supplied to the pupil. The pupil will provide stakeholder analysis for the feedback they receive, not only from the coach, but from the system. The variety of ways that feedback can be provided in allows for development of a diverse system that will have to cater for the variety of coaches.

The usability of the system is important due to the non-technical nature of golf professionals; the HCI research has indicated that the system must be flexible, robust and easy to learn to enable effective coaching. This can be achieved through incorporating coaches throughout the design and creation stage, making sure the system is applicable in its domain. The effectiveness of the system will be defined by its usability, specifically in regards to flexibility reflecting the different methods used by different coaches; these methods will be defined in the next section, the requirements for the system.

3 Requirements

3.1 Introduction

According to Preece et al (2002) the reason for gathering and establishing requirements is twofold. Firstly, it allows the developer to understand the users' work and environment, and additionally understand how the system will allow the users to achieve their goals. Secondly, the requirements form a set of principles and guidelines that the system can be designed around. As design is an iterative process, these requirements are likely to change, however they must be relatively stable in order to allow the design to be built successfully upon them.

It is important that the requirements process is performed thoroughly throughout the system lifecycle. Reports (e.g. Taylor, 2000) have suggested that requirements issues feature highly in the causes of IT project failures, with "unclear objectives and requirements" being cited most frequently as the reason for failure. Badly defined requirements can cause hindrance to the user trying to use the product, resulting in loss of productivity. This must not happen in the time critical task that is a golf lesson. To ensure that the system requirements are well defined, the established model formulated by Preece et al (2002) has been followed.

The requirements for the system were established using a variety of methods and sources. Notably, sources for the requirements analysis came from interviews, conversations and informal discussions with my local golf professional, who was able to provide information relating to his 25 years worth of experience coaching golf. In addition, conversations with local golfers gave grounding in the area. Finally, any areas that were not covered by the other sources were completed using personal knowledge and experience, having personally coached golf for five years and played and received tuition for over 10 years. Additionally, literature sources are used to form the HCI based requirements and for requirements relating to new coaching practices that are not implemented.

The section begins by using scenario based analyse to examine the typical format of a golf lesson, both when technology is and is not used. This is followed by an analysis of how video systems can be used to locate and highlight errors within the golf swing. Finally the section concludes with a list of the requirements for the system detailing the rationale behind the requirement, and the priority of requirement for success of the system.

3.2 Scenario based analysis

Scenarios based analysis considers common scenarios that occur in the work place. These scenarios allow the developer to understand what occurs in the existing system, and analyse where any system could fit in, as well as where the system would become a hindrance. The following scenarios were described using my personal knowledge and experience, and then additions and corrections were made with the aid of the golf professional.

3.2.1 Analysis of the standard lesson format

The standard lesson a type of lesson that the professional will teach to the pupil without using any type of technological aid. The professional will use his knowledge and experience to identify errors, and then explain these faults using demonstrations and descriptions. The full details of the system flow are detailed in Figure A-1.

The lesson format has been analysed to indicate areas where technology could be used in the system, to supplement and support the coach. It is noticeable that the standard lesson format can be supplemented with technology in a number of areas without drastically changing the format of the lessons. If the format of the lesson changes greatly, both the coach and pupil may become uneasy at the change, meaning less effective teaching occurs. Additionally, users are likely to resist great change to their way of work. The idea of the computer system is to aid the coach and pupil, not replace the coach and allow golf to become self-taught.

The following list highlights areas of the system where technology could be used. The list is ordered by when the pupil or coach would first experience the technology in the lesson. In addition the list details the section of the lesson flow (see Figure A-1) the technology would appear.

1. **Golf Professional asking the pupil for his thoughts about his game.** A system could record data about the pupil's game. This could be in the form of a scorecard for the rounds of golf the pupil has played, with details of where shots were hit. A simple scorecard would not be detailed enough on its own, as a par on a golf course can be achieved in many different ways! This information could however be in the format of multimedia such as video of the pupil practising their golf or playing a round of golf. This analysis would be useful, as the pupil may not truly reflect their performance because of modesty, boastfulness, or focusing on narrow aspects of the game. Having improved information allows the golf professional to analyse the pupil's swing in context.
2. **Golf Professional watches the pupil hit between three and five shots.** A system that records the swing of the pupil allows analysis of the swing in increased detail. This could be in the form of a video or 3-Dimensional model.
3. **Golf Professional analyses the pupil's swing.** This is linked with the concept of using multimedia methods to capture the pupil's swing. Research performed in the literature review indicated the advantages of using videos for analysis.
4. **Golf Professional discusses with the pupil their faults.** A Golf Professional will be able to use a multimedia system to indicate where in the pupil's swing the faults occur. Research indicated in the literature review suggests this added visualisation and increased knowledge of results aids learning.
5. **Golf Professional indicates methods of fixing the swing.** The system could provide learning models or demonstration of how to correct the fault. Research suggests that these methods aid learning
6. **Pupil attempts to apply fixes.** The system could be used to record the student attempting to apply the fix. This would allow the pupil to see changes in their swing.
7. **Golf Professional watches the pupil hitting golf shots whilst trying to apply the fixes and refines the fixes.** The system could indicate to the golf

professional in greater detail how the pupil is trying to apply the fix. This would allow the professional to refine the fix in more detail.

8. **Golf Professional summarises the fixes.** The system could provide a permanent record of the pupil's lesson and their progress throughout the lesson. This means the pupil would be able to recall the lesson and the fixes supplied in detail. This will help stop confusion.

In some of these areas technology is already used in golf coaching, particularly the use of video cameras and video analysis software. A typical video lesson is detailed in the next section.

3.2.2 Analysis of Video / Computer System Lesson Format

The video lesson format is similar that of the standard lesson, with the only main difference occurring in swing analysis. A full flow diagram can be found as Figure A-2. The pupil's golf swing is recorded onto video, the golf professional then analyses the video and uses the video to demonstrate the pupil's swing faults. Purely video analysis is a relatively simple method and the following methods are typically used:

- Playing the video in slow-motion, full speed or freezing the video at a specific frame
- Using paper as a straight line to highlight movement
- Using paper to mask areas of the swing and focus on others
- Drawing on the television to indicate areas (this method is very rarely used due to damage to the television)

All of the methods used in the video analysis are available in the computer system, in the form of digitised tools for highlighting areas (e.g. drawing with the mouse). The video in the computer system is controlled using the same controls as on the video system (i.e. Play, Fast Forward, Pause, Step, etc.). Additional features are available in the computer system and these will be analysed in a later section.

The broad outline of the lesson format needs to be analysed in greater detail, in particular the use of the video or computer to analyse the swing. As has previously been identified, the features used in video system analysis are a subset of the features available in the computer system. The analysis phase can be linked to the following four sections of the lesson format:

1. Golf professional records four of the pupil's swings
2. Golf professional plays the pupil's golf swing back and analyses it
3. Golf professional highlights problem areas in the swing to the pupil on the video
4. Golf professional indicates methods of fixing the swing on the video

When analysing the system, only the standard, single video system was considered. This system is more commonly used than more elaborate systems such as MAT-T System by Taylor Made. This is due to the high cost of the elaborate systems, and with the majority of golf professionals being self employed, cost is a very important factor. The following details the use of video cameras in the capture of the pupil's swing and indicate in which phase of the lesson it occurs (see Figure A-2)

Golf Professional records the pupil's swing - The golf professional typically records the pupil's swing using just a single video camera and records it from two angles, one from directly behind the pupil (parallel to the target line), and one facing the pupil (perpendicular to the target line). These viewing angles allow the coach to view the entire swing, as demonstrated in the literature review.

The other three areas that are to be analysed need to be done so in more detail, such that an understanding of the different methods that are used by the system. This is the most important area, as this is the area where the coaching occurs. The area shall be analysed by taking scenarios of the most commonly occurring errors in the swing and how the professional analyses these errors, plus details of how this is performed in existing software, such as GASP.

By highlighting error the professional is using two psychological principles; firstly changing the goal of the swing into producing a correct swing, thus turning the open skill into a closed skill and secondly giving the pupil knowledge of results. The use of slow motion analysis means the pupil receives very accurate knowledge of results, something that better player relies on to improve performance and allows them to perform an improved evaluation of their newly defined closed skill.

Throughout the analysis process the professional may compare the pupil's swing with a professional, further highlighting the changes in the swing. This comparison can also be linked to the pupil's creation of a mental model, or template of the movement for the pupil; something Newell et al. (1990) indicated is beneficial to learning. In addition the professional's swing can be considered an expert or learning model for pupil, that is it develops a correct schema for the pupil to use as a reference.

3.2.3 Errors

This section defines swing errors that typically occur in a golf swing, each of which is broadly defined such that almost all errors fall into one of these categories. A pupil may have just one of these errors, or a combination of many. Often a single error will be the cause of many other errors, particularly in the setup. The errors are divided into two sections; swing errors, errors that occur in making the golf swing and setup errors, errors that occur before the golf swing begins.

Each error defined here includes the current method, or methods for analysing it, plus a description of the error itself. Any system that wishes to analyse the golf swing must as a minimum include the ability to analyse all of these errors.

3.2.3.1 Swing Errors - Swaying

Swaying occurs when the golfer's head moves away from the target during the backswing phase. Often the upper body is dragged with the head.

Angle viewed from: Perpendicular to the target line

Analysis tools used: Sway tool, Straight line, Circle

Sway tool: The sway tool consists of a circle surrounded by straight lines. The circle is placed over the pupil's head at setup, and the lines are resized so that they are over the outside edge of the shoulders. The width of the tool is changed, with the circle remaining central. This can cause problems when the head is not centrally placed between the shoulders, as one line cannot be aligned with the edge of the shoulders.



Figure 3-1 Use of the sway tool

The video is then played and the coach sees if the head moves from the circle (some head movement is allowed in the golf swing and the amount of movement allowed is at the professional's discretion the amount of movement allowed). The use of the shoulder lines allows the professional to see if the upper body has been 'dragged across'.

Circle: The circle is simply placed around the head at setup and the coach uses the circle as reference to spot any head movement. To allow analysis of upper body movement a vertical line placed on the rear shoulder is often used in conjunction with the circle.

Line: A vertical line is placed on the rear most ear, and can be used as a point of reference. Additional vertical lines can be placed on the rear most shoulder and front hip to indicate body movement.

3.2.3.2 Swing Errors - Changing Spine Angle

During a golf swing the golfer will change his spine angle, becoming more upright or bent-over.

Angle viewed from: Parallel to the target line

Analysis tools used: Straight Line

A straight line is drawn down the back to indicate the spine angle. This line is kept throughout the swing and the video played back in slow motion. Any deviation can be noticed and a new line can be drawn at the greatest deviation to indicate the change in spine angle.

3.2.3.3 Swing Errors - Hip and Shoulder Rotation

During a golf swing the golfer will rotate their hips and shoulders. There is a given range for this and the rotation is interdependent.

Angle viewed from: Both perpendicular and parallel to the target line

Analysis tools used: None

The swing is paused at the period of maximum rotation and the amount of rotation is observed. Due to the nature of a 2D image it is not possible to measure the angle in terms of degrees.

3.2.3.4 Swing Errors - Knee Straightening

During a backswing the golfer straightens their rear leg, causing over rotation.

Angle viewed from: Both perpendicular and parallel to the target line

Analysis tools used: Circle

A circle is used to highlight the fault and the image is paused indicating the straightened leg. Alternatively the knee is highlighted and the backswing played in slow motion to show the straightening.

3.2.3.5 Swing Errors - Club Face Angle

Throughout the swing the angle of the club should point in a specific direction. Rotation of the hands and arms can cause this to move

Angle viewed from: Parallel to the target line

Analysis tools used: Straight Line

A line is placed on the leading edge of the club to highlight the face angle, the golf professional determines if this angle is correct. The common places for analysis are at the halfway stage and the top of the backswing.

3.2.3.6 Swing Errors - Shaft Angle

At the top of the backswing the shaft of the golf club should be pointing at the target.

Angle viewed from: Parallel to the target line

Analysis tools used: Straight Lines / Arrow

The swing is paused at the top and a line/arrow is extended along the shaft towards the target. Perspective is important here as a swing shorter than parallel may have the correct shaft angle but appear to be pointing off target.



Figure 3-2 Analysing the shaft angle

3.2.3.7 Swing Errors - Wrist Hinge

This is the angle between the thumb and the forearm, like many other areas of the golf swing the amount of hinge is variable depending on swing technique.

Angle viewed from: Perpendicular to the target line

Analysis tools used: Angle Measurement

The swing is paused at specific intervals in the swing and the angle between the thumb and forearm of the top most hand on the club is taken. This is within a given range depending on the physiology of the player and their swing type.

3.2.3.8 Swing Errors - Impact Position

This is the position at impact and should broadly replicate the setup position.

Angle viewed from: Both perpendicular and parallel to the target line

Analysis tools used: Straight Lines / Arrow

The swing is paused at impact and the same tools as used in setup analysis are used to analyse the position.

3.2.3.9 Swing Errors - Swing Plane

This is the greatest analysed area of the golf swing and is the path that the club travels in. It can be defined by an arc made by the club head. The arc should fall within a given range, which is defined by a 'V' whose point is at the golf ball and is bisected by the shaft. The deviation from this plane is dependent on the coaching method used.

Angle viewed from: Perpendicular to the target line

Analysis tools used: Straight Lines / Club Tracker Tool

At setup a straight line is drawn up the shaft and two further lines are drawn either side of this, depending on the golf professional's view on the swing plane. The swing is then played in slow motion to see if the club stays on plane. It will then be possible to highlight when the club first went off plane, and where additional movement was necessary to bring the club back onto plane.

Should the club tracker be used, the swing is played in stages and the position of the head is marked to give an analysis of the plane. It can then be seen if this plane lies inside the swing plane defined by the 'V', and where it deviates from the 'V'.



Figure 3-3 - Analysing swing plane

3.2.3.10 Setup Errors - Spine Angle and Knee Flex

The pupil may have too much or too little flex in their knees or be too upright / bent over at the address position.

Angle viewed from: Parallel to the target line

Analysis tools used: Straight lines, Angle measurement

The angle is dependent on the player's physique. This means that the angle received is within a given region and as such requires interpretation by the professional. The use of the tools is identical with the angle tool simply measuring the angle between the two lines. One line is placed on the person's back, the second on their upper legs. The professional can then analyse the angle between these lines and see if it is in the correct region.

3.2.3.11 Setup Errors - Alignment

The pupil does not correctly align himself with the target. The areas that may not be aligned are club, feet, hips and shoulders

Angle viewed from: Parallel to the target line

Analysis tools used: Straight lines, Parallel lines.

Straight Lines: A line is drawn from the golf ball to the target to indicate the 'target line'. The clubface should be perpendicular to this if it is correctly aligned. Further lines are drawn across the hips / shoulders / feet to show alignment. If the pupil is correctly aligned, these lines would be parallel to the target line.



Figure 3-4 Analysing alignment

Parallel Lines: A line is drawn through the hips / shoulders / feet and then a parallel line is drawn through the golf ball to show where the pupil is aiming.

3.2.3.12 Setup Errors - Head Position, Weight Position

The pupil leans back or forward at setup causing incorrect weight distribution and / or head position.

Angle viewed from: Perpendicular to the target line

Analysis tools used: Straight lines

Lines are drawn across parallel with the trunk to indicate the vertical position of the trunk. Should these lines be too far from the vertical, this can indicate incorrect weight position. This can also indicate incorrect head position. Additionally, a vertical line can be drawn from the head to see if the head position is in the correct position in regards to the stance.

3.2.3.13 Setup Errors – Stance Width

The distance between the feet at setup has a direct impact on the golf swing

Angle viewed from: Perpendicular to the target line

Analysis tools used: Straight lines, parallel lines, sway tool

Lines are vertically drawn from either shoulder through the feet (using a simple straight line, sway tool or parallel lines). The width of stance can then be analysed in terms of shoulder width, however the stance width is also dependent on club and type of shot being played.



Figure 3-5 Analysing stance width

3.2.3.14 Setup Errors – Hand Position

The hands in the golf swing should be positioned ahead of the golf ball at address; the degree of this varies on coaching style.

Angle viewed from: Perpendicular to the target line

Analysis tools used: Straight lines

A vertical line is drawn from the front of the hands to indicate the position of the hands in relation to the golf ball.

3.2.3.15 Setup Errors – Incorrect Ball Position

The ball is positioned too far towards the front or back foot for the club.

Angle viewed from: Perpendicular to the target line

Analysis tools used: Straight lines, ruler

Ruler: A tool that has unit markings on it is placed with markings at both feet. The graduations can then be used to judge ball position.

Straight Lines: A straight line is drawn over the ball and on the inside of each foot; this then highlights the ball position in relation the feet.

3.2.3.16 Setup Errors - Grip

The hand position on the club is positioned too far in either the clockwise or anticlockwise direction. The greater the clockwise rotation of the top hand, the 'stronger' the grip is said to be.

Angle viewed from: Perpendicular to the target line

Analysis tools used: Arrow, Magnifying Glass

Arrow: When the hand is placed on the golf club the thumb and forefingers form a 'V-shape', with a designated direction that these should point (this is variable depending on teaching style and pupil's physiology). The 'V' is extended using the arrow to show where the V points.

Magnifying Glass: The magnifying glass tool is simply used to highlight the issue to the pupil by making the hands larger; this allows the number of knuckles visible to be counted. The number of knuckles visible on the 'top-hand' indicates the strength of the grip.

3.2.4 Errors using the tools

When using the above tools a common error has been highlighted - the placing of the drawing tools. The issue can be traced to two problems, the level of detail in the video and the accuracy in placing the drawing tool. The video quality is limited by the quality of the device capturing the video and the accuracy of the drawing tool is related to the pointer for placing the device, and in the case of a line, its thickness.

3.3 System Type

As requirement analysis and early design can overlap, in initial discussions with golf professional regarding different types of systems that could be used it was evident that there is more to a system for a golf professional than quality of the tuition the pupil receives. Golf Professionals need pupils 'through the door' in order to entice the pupil to use other services at the golf club. As the typical golf professional is self employed it is important that they find ways of making money. However, as the focus of this project is on implementing the research ideas identified in the literature review these business issues have a lower priority.

3.4 Requirements

The following list of requirements is generated from the preceding analysis and the literature review. Each of the requirements follow Preece et al.'s (2002) framework. All of the requirements have been given a priority between 1 and 5. 5 means "must be implemented" whilst 1 means "It would be nice to have". The priorities for the system were decided upon by analysing the emphasis the users placed on the requirements during the analysis phase, or the effect of the requirement on the learning process. Where there was a lack of clarity regarding the requirement priority, personal experience was used, or the golf professional was contacted.

3.4.1 Functional Requirements

The following requirements describe what the system should do.

ID: 1

Details: The system must allow the coach to communicate his ideas

Rationale: Effective learning will not be achieved if the system provides a barrier for the coach. Additionally the system will be less likely to be used.

Source: Lesson Analysis

Priority: 5

Priority Rationale: If the coach cannot communicate their ideas the lesson will fail

ID: 2

Details: The system must support the coach in identifying swing faults

Rationale: This will enable to coach to perform their task easier

Source: Error analysis

Priority: 4

Priority Rationale: A golf swing is fast and not all faults can be analysed using the naked eye

ID: 3

Details: The system must take input of the pupils swing

Rationale: To analyse the swing, the swing must be viewable

Source: Analysis of existing lesson format

Priority: 5

Priority Rationale: The system would be useless without this feature

ID: 4

Details: The system must allow the professional to highlight areas of the swing

Rationale: The pupil must know what area the coach is trying to explain

Source: Analysis of existing lesson format

Priority: 4

Priority Rationale: Effective learning only occurs with KR, and this is one way of providing effective KR

ID: 5

Details: The system must allow the coach to teach using explicit and implicit knowledge

Rationale: Both explicit and implicit knowledge have been shown to be key for learning

Source: Literature Review

Priority: 5

Priority Rationale: Without effective learning the lesson will not be effective

ID: 6

Details: The system must support learning models

Rationale: Learning models have been shown to support learning

Source: Existing Systems and literature review

Priority: 3

Priority Rationale: Learning models are one way of learning

ID: 7

Details: The system must allow swing comparisons

Rationale: Demonstrations are key to shaping the pupils understanding of skills

Source: Existing System and Literature review

Priority: 5

Priority Rationale: The professional indicated this was his most important aspect of his existing software

ID: 8

Details: The system must allow pupil's swings to be stored

Rationale: A record of previous performance allows the pupil to see progress

Source: Professional Request

Priority: 2

Priority Rationale: Viewing progress can aid development

ID: 9

Details: The system must allow feedback to be produced

Rationale: Feedback is key to pupil learning

Source: Literature review and existing system analysis

Priority: 5

Priority Rationale: Without feedback the pupil will not know how they are learning, or what they are doing wrong. In addition no feedback means the coach will not be aided with error identification

ID: 10

Details: The system must allow the swing to be analysed in detail

Rationale: The golf swing is very intricate and detailed KR can improve learning

Source: Golf professional and literature review

Priority: 5

Priority Rationale: Insufficient detail could cause errors in swing analysis

ID: 11

Details: Any system given to the user must be able to be used on both Windows and Macintosh machines

Rationale: The system must not exclude users as it could have a detrimental effect on the professional's earnings

Source: Professional's business desires

Priority: 2

Priority Rationale: Alienating customers will have a derogatory effect on the professional's business

ID: 12

Details: The system must allow for the swing to be played in slow motion and paused

Rationale: This will allow the coach to highlight areas of the swing for the pupil

Source: Existing system, analysis of lesson format and literature review

Priority: 4

Priority Rationale: Slow motion improves the level of detail that the system can be analysed in

ID: 13

Details: The system shall support a client database

Rationale: Professionals keep details of their clients for marketing purposes

Source: Professional comment

Priority: 1

Priority Rationale: Professional desire, not key to teaching

ID: 14

Details: The system shall give the pupil a method of viewing the video outside of the lesson

Rationale: Often pupils have difficulty in remembering lesson details

Source: Professional and user comments

Priority: 3

Priority Rationale: Some pupils will not learn effectively if they can't remember which aspects to change

ID: 15

Details: The system must allow a coach to model the golf swing as a closed skill

Rationale: Modelling an open skill as a closed skill has been shown to aid changing the technique of the swing

Source: Literature review, lesson format analysis and professional comments

Priority: 5

Priority Rationale: Common method used for coaching and a useful way of learning technique

ID: 16

Details: The system must allow knowledge of results to be given

Rationale: Knowledge of results have been shown to be key to learning

Source: Literature Review

Priority: 4

Priority Rationale: KR provides key guiding properties when learning

ID: 17

Details: The system must aid the user in developing their mental image of their golf swing

Rationale: Imagery has been shown to be key to learning

Source: Literature Review

Priority: 4

Priority Rationale: Imagery is key to learning

ID: 18

Details: The system must support the cognitive phase of learning

Rationale: The cognitive phase is a key part of learning

Source: Literature Review

Priority: 5

Priority Rationale: The cognitive phase is a key part of learning

ID: 19

Details: The system must not focus solely on golf swing mechanics

Rationale: Focusing on mechanics often causes the player to perform an incorrect movement

Source: Literature review

Priority: 3

Priority Rationale: Focusing on mechanics can have a derogatory effect of learning

ID: 20

Details: The system must aid the pupil in developing reference Knowledge of Results

Rationale: Immediate KR is not available on the golf course and so reference KR must be created

Source: Literature Review

Priority: 4

Priority Rationale: Studies have indicated that over reliance on immediate KR can hinder skill development

ID: 21

Details: The system must allow for analysis of setup

Rationale: The setup in the golf swing plays a key role in shaping the swing

Source: Lesson format analysis and literature review

Priority: 5

Priority Rationale: The setup is a key part of the swing

ID: 22

Details: The system must allow for analysis of the backswing

Rationale: The backswing is an import part of the swing

Source: Lesson format analysis and literature review

Priority: 5

Priority Rationale: The backswing is a key part of the swing

ID: 23

Details: The system must allow for analysis of the downswing

Source: Lesson format analysis and literature review

Rationale: The downswing is an import part of the swing

Priority: 5

Priority Rationale: The downswing is a key part of the swing

ID: 24

Details: The system must support analysis of the golf swing from both front and rear views

Source: Lesson format analysis and literature review

Rationale: Not all faults can be seen from one angle

Priority: 5

Priority Rationale: Analysis of the swing is a key aim of the system

ID: 25

Details: The system must support learning for a range of abilities

Rationale: Coaches teach pupils of all abilities

Source: Professional conversation and experience

Priority: 5

Priority Rationale: The system must not alienate users

3.4.2 Data Requirements

These requirements describe data type, size, amount, accuracy and validity

ID: 26

Details: The system must be able to run on non specialised hardware

Rationale: Minimising system cost

Source: Literature Review

Priority: 4

Priority Rationale: Professional's are self employed and as such have limited money

ID: 27

Details: The system must be able to run on a PC with 1 GB RAM

Rationale: Standard Specification for a new PC

Source: Internet based research

Priority: 4

Priority Rationale: Professional's are self employed and as such have limited money

ID: 28

Details: The system must be able to run on a PC with a 2.8GHz processor.

Rationale: Standard Specification for a new PC

Source: Internet based research

Priority: 4

Priority Rationale: Professional's are self employed and as such have limited money

ID: 29

Details: The data stored in the system must be kept in accordance with the Data Protection Act

Rationale: Legal Requirement

Source: Research

Priority: 5

Priority Rationale: Legal Requirement

ID: 30

Details: The data in the system must be easily backed up

Rationale: The data is important to the professional

Source: Golf professional

Priority: 3

Priority Rationale: Data is important to the golf professional

ID: 31

Details: Any internet based system must be able to run on a 512Kb broadband system.

Rationale: The standard broadband connection

Source: Research

Priority: 3

Priority Rationale: Professional's are self employed and as such have limited money

3.4.3 Environmental Requirements / Context of use

The following requirements describe the physical, social, organisational and technical use of the system

ID: 32

Details: The system must be usable for individual lessons

Rationale: Coaches mainly teach individual pupils

Source: Golf professional

Priority: 5

Priority Rationale: Coaches mainly teach individual pupils

ID: 33

Details: The system must be suitable for group coaching

Rationale: Coaches also teach group lessons, particularly children's lesson

Source: Lesson format analysis

Priority: 3

Priority Rationale: Golf professional's can teach group lessons

ID: 34

Details: The system must be able to be used in a standard golf club

Rationale: Professionals will not be able to afford expensive modifications to their club

Source: Golf professional

Priority: 4

Priority Rationale: Professional's are self employed and as such have limited money

ID: 35

Details: The system must be usable by several professionals

Rationale: Several teaching professionals often work at the same club

Source: Situation at professional's club

Priority: 3

Priority Rationale: All professionals must be supported

ID: 36

Details: The system must be usable in a driving range

Rationale: Golf lessons usually occur at a driving range

Source: Experience of situation at most golf clubs visited

Priority: 4

Priority Rationale: The location of lessons is unlikely to change

ID: 37

Details: The system must support the teaching of all ages

Rationale: Children (10+) to pensioners all play golf

Source: Situation at the professional's golf club

Priority: 4

Priority Rationale: Cannot alienate pupils

3.4.4 User Requirements

These requirements describe the characteristics of the intended users

ID: 38

Details: The coach must have detailed knowledge of the golf swing

Rationale: Golf swings are complex, individual movements that need to be analysed by a specialist

Source: Literature Review

Priority: 5

Priority Rationale: The system is designed to be complementary

ID: 39

Details: The user must have a basic knowledge of using a Microsoft Windows system

Rationale: Windows is the most common operating system and as such the product will be developed for the system

Source: Research

Priority: 4

Priority Rationale: A system designed for a complete novice would hinder all other users

ID: 40

Details: The user must be able to use a mouse

Rationale: Drawing tools require a mouse and the system will use a point and click interface

Source: Literature Review

Priority: 5

Priority Rationale: This is a primary input

ID: 41

Details: The user must be able to use a keyboard

Rationale: Data entry is required

Source: Literature Review

Priority: 5

Priority Rationale: This is a primary input

ID: 42

Details: The pupil must have basic knowledge of using a computer system

Rationale: The system requires pupil interaction

Source: Literature Review

Priority: 5

Priority Rationale: The system requires pupil interaction

ID: 42

Details: Both the coach and the pupil must have suitable vision to use a VDU

Rationale: The system will be displayed on a VDU

Source: Literature Review

Priority: 5

Priority Rationale: This system will be using visual representations

3.4.5 Usability requirements

These requirements describe the usability goals and measures to increase usability

ID: 43

Details: The system must be intuitive, allowing a coach with basic computing skills to use the basics of the system without training

Rationale: Golf Professionals often have had very little technological experience due to the nature of their jobs

Source: Literature Review

Priority: 4

Priority Rationale: This system must be usable from the beginning or the pupil will receive substandard lessons

ID: 44

Details: The system must present important information clearly

Rationale: Important information needs to be highlighted

Source: Literature Review

Priority: 4

Priority Rationale: Clear presentation of information prevents errors

ID: 45

Details: The system should comply with Nielsen's Heuristic Evaluation guidelines

Rationale: Usable systems increase user productivity and enjoyment

Source: Literature Review

Priority: 4

Priority Rationale: Systems that are difficult to use will decrease lesson quality

ID: 46

Details: The system should be usable without sound

Rationale: The system may be used outside on the golf course where sound could be distracting

Source: Golf professional

Priority: 2

Priority Rationale: Volume could be used at a minimum level

ID: 47

Details: The system should be usable in a group situation

Rationale: Group lessons occur

Source: Lesson Analysis

Priority: 4

Priority Rationale: Group lessons are often taught

ID: 48

Details: The system should minimise cognitive demands

Rationale: High cognitive demands over a long period (golf professionals can work 15hour days) will have a detrimental affect on their work

Source: Literature Review

Priority: 4

Priority Rationale: During long days the professional must be able to still use the system

ID: 49

Details: The system should minimise eye strain

Rationale: Golf professional's work long days

Source: Golf professional and personal experience

Priority: 4

Priority Rationale: During long days the professional must be able to still use the system

ID: 50

Details: The system should demonstrate good ergonomics

Rationale: Good Ergonomics reduce cognitive load and eye strain

Source: Golf professional and personal experience

Priority: 4

Priority Rationale: During long days the professional must be able to still use the system

ID: 51

Details: The system should use a point and click paradigm for interaction

Rationale: This is the most common method for user interaction and the method a golf professional will most likely be familiar with

Source: Golf professional profiling

Priority: 5

Priority Rationale: Supporting the user base

ID: 52

Details: The system must use effective “pop-out”

Rationale: Pop-out helps the user group logical functions making the system more intuitive and usable

Source: Literature Review

Priority: 4

Priority Rationale: Pop-out reduces cognitive load

ID: 53

Details: The system must allow a degree of flexibility in interaction

Rationale: Golf Professionals all teach in a slightly way

Source: Literature Review

Priority: 5

Priority Rationale: Stopping the way a coach teaches will cause lesson quality to be reduces

ID: 54

Details: The system must be robust to allow confidence in the system

Rationale: Users will not be happy to use the system if it is not robust

Source: Literature Review

Priority: 3

Priority Rationale: Users not using the system could possibly degrade lesson quality

3.5 Summary

Firmly specifying the requirements as has been performed in this section gives designs important guidance. This section has specified a wide range of requirements, including psychology theory that must be implemented, user profiling, usability features, biomechanical features and potential technological constraints. By specifying the requirements in this way, the design is set in firm constraints. In addition to providing constraints, the requirements can provide ideas for the system. The designs from these requirements are described in the next section.

4 Design

4.1 Introduction

The design of the system was carried out with the aid of a golf professional. Ideas about the type of system were discussed and then once an idea had been decided upon, the design of the system itself was discussed.

4.2 System Type

Initial discussions of the system led to additional requirements being formed. Details of the development of design ideas is detailed in this section, however in order to place the professional's input in context and to describe the rationale behind decisions, some requirement details are included in this section.

4.2.1 Supplying pupils with the lesson and the ability to compare their own practice sessions with the lesson video

Pupils would be provided with software that would allow them to film their lessons on their cameras and then compare their home swings to the lesson. This would allow the pupil to create increased reference knowledge of results as they would be able to link the feeling they were getting with a change in mechanics. The system would also be able to give the pupil knowledge of how they were progressing.

However, although the golf professional liked the idea of pupil's being able to view their lessons they felt there was a risk of people over analysing their own swing and changing the wrong aspects, potentially adversely affecting their golf swing. Additionally, the professional felt that using this system and potentially mean the pupil attends fewer lessons. This led to the suggestion of time limiting the video, however the professional didn't feel this would be beneficial as often older video files are compared.

4.2.2 Pupils supply the professional with videos of their practice sessions after the lesson

The pupil would film their practice sessions recording their feeling of the swing. This feeling would often relate to existing implicit skills, which are a key area of learning a motor skill. The coach in addition would receive increased KR of how the pupil was changing their swing, allowing the professional to customise their teaching approach for the pupil through increased understanding of how the pupil interprets instruction. The modified teaching method could involve targeting the pupil's implicit knowledge.

Initially the golf professional was apprehensive about this idea, being worried about the time that it could take to analyse several videos of practice, and how this would affect the revenue earned. Additionally to accurately analyse a golf swing, it must be viewed from the correct angles, as indicated in the literature review.

However, after further informal discussions regarding the psychological benefit of the method with the professional, he indicated that he had been given a piece of software that could be used for analysing the psychology of learning a golf swing. The system was very broad and unfortunately due to time constraints could now be fully analysed. Identification of the software system itself identified how the professional was keen to use psychology to improve pupil learning and how discussions about psychology had been interpreted differently. This identified one of the problems with participatory design, although the principles being suggested were explained as well as possible, it was not possible explain the system in a way that was commonly understood. This was especially surprising as the professional being questioned has been know to myself for over 10 years, of which the previous 5 years were on a working relations. This characterises the difficulties that can occur in the design process, yet highlights the importance of both informal and formal conversation in design discussions.

The final result of the design discussion was that the professional was keen to look at ways that the movement given to the pupil by the professional is developed in the intermediate stages. Hence the next lesson can be tailored towards improving that development and explain mistakes made in the development. Additionally, the professional saw this as an advantage in terms of marketing, if the pupil is thinking of their lesson when practising, there is a chance they will be thinking of their next lesson, and so more likely to book their next lesson sooner.

4.2.3 Final Solution

As mentioned in previous sections the golf professional was keen to pursue the idea of increasing the coach's feedback of the learning process for the pupil. However, the professional and users also required increased feedback and felt that clarification of the lesson might be beneficial. A website was chosen because one of the pupils was worried about installing unknown software on their PC and the golf professional indicated that they would not wish (or be able to) provide any user support for the pupil using the software. It was felt that this could be achieved using a website which showed the video and the professional's comments. During discussions of a number of ideas it was highlighted by the professional that they did not want the pupil to be able to compare videos on the website.

One of the key aspects debated was how to supply the professional with feedback from the pupil's practice session. The existing system identified by the professional utilised verbal descriptions of the 'feelings' a pupil had when performing a movement. However, the golf professional did not feel this was sufficient as often a pupil's feeling of an action, is different to the action being performed. For this reason it was felt a combination of both would allow for maximal feedback and hopefully transfer of implicit learning.

The system is designed to supplement the traditional coaching methods as opposed to replacing the coach. This is important to recognise as it is debateable if a system could ever replace the traditional coach, because although a biomechanical model has been made this is dependent on a number of biomechanical abilities. In addition

a system is unlikely to be able to provide the necessary physical demonstrations that pupils learn from.

4.2.3.1 Final Solution Flow Diagram

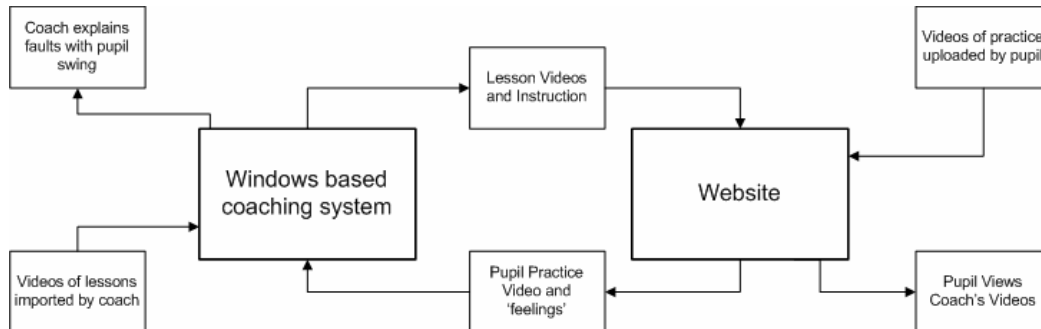


Figure 4-1 Diagram showing proposed system layout

4.3 User Interface Design

The user interface is the area both the pupil and the professional will interact with. However, due to access limitations with the users it was decided that only the coaching system would have its interface designed with the professional as it will be the most heavily utilised area. All design discussions were done with a 'paper-and-pencil' approach. This meant that the golf professional would comment on drawn screen shots, indicating changes that they would wish to see. These screen shots are included in the appendix section as Figure B-1 and Figure B-2.

4.3.1 Main Teaching Screen

This screen is where the majority of system functions will occur; teaching will take place on this screen as well as being a portal to other areas of the program.

4.3.1.1 Initial Design

The design has a number of features to aid usability:

- **Help** - Every page of the system will provide contextual help, describing how the information displayed on the current page can be used
- **One toolbar for one purpose** - To try to encourage pop-out to occur, each toolbar has only one purpose - in this case drawing. The icons are also similar design, again to encourage logical grouping
- **Controls are associated with videos** - Each control is positioned such that it is spatially related to the video it controls
- **Windows Theme** - The design is themed to the standard windows theme, the type of user interface the user is most likely to be familiar with.
- **Current Pupil Information** - The current pupil is always shown at the base of the window so the user can keep track of system state
- **Standard Video Control Buttons** - The play, pause and stop buttons are internationally recognised symbols
- **Minimalist Design** - Only the minimal amount of information is displayed on the page, this encourages the user to be focused on the task

- **Menu System** - The menu system provides all of the advanced features of the system, leaving the basics constantly displayed
- **Videos** - These are large and prominent on the screen - allowing for focus to be directed onto them, and making it suitable for viewing in group environments
- **Multiple Video Screens** - This allows the pupil's swing to be compared to learning and expert models. Pupils can also have their swing viewed from multiple angle simultaneously
- **Multiple drawing tools** - Having many different ways of highlighting information allows the professional the flexibility to teach in their own way
- **Slider** - This allows the image to be paused in a specific position, a method that has been shown to improve learning. Additionally it allows the professional to analyse the swing in detail.
- **Highlighting certain areas** - By highlighting areas of the mechanics the professional can turn the swing into an open or closed skill

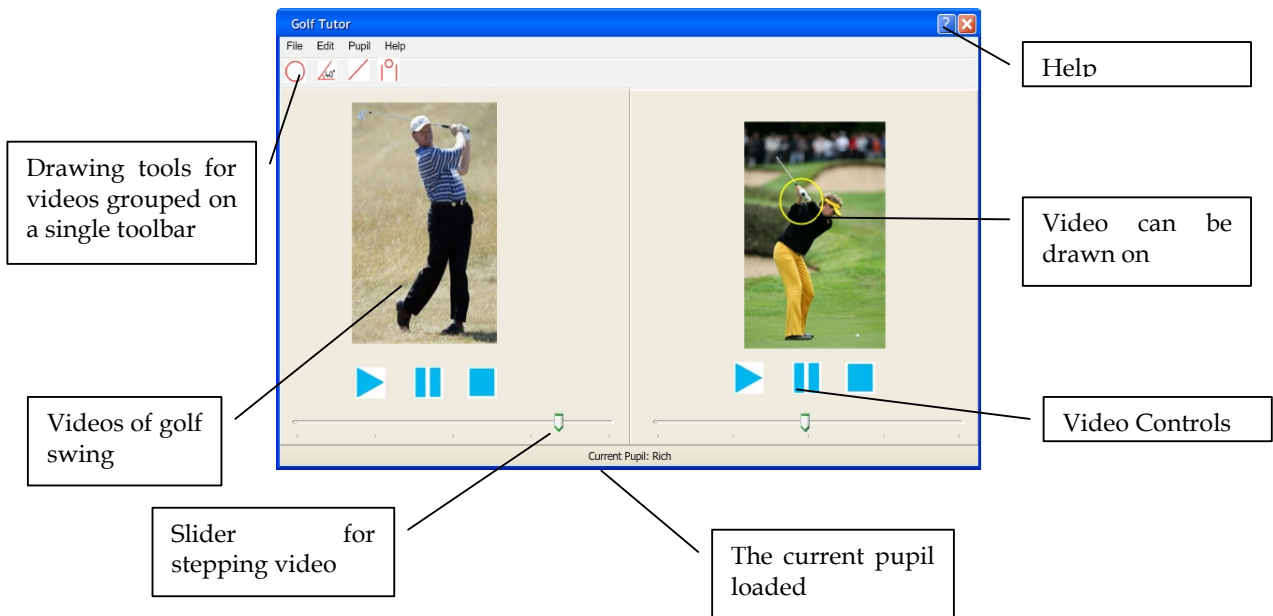


Figure 4-2 Initial main screen design

4.3.1.2 Modified Design

The following are changes suggested by the user, both functional and design. The modified diagram is included in the appendix as Figure A-1.

- Allow views to be changed from two videos to a single one. This will allow the golf professional to have a larger view of the selected video
- With the change to one and two videos the professional also suggested a single control for the videos. To indicate which video was being viewed, the selected video would be highlighted, possibly with a box around the edge.
- A list of the current pupil's videos was suggested as often the professional will wish to look at how their swing has changed
- Should video capture be implemented, a record button should be added to the video control toolbar

- Discussions of whether videos should be synchronised occurred, it was decided that this was not a necessary feature. On his existing software the professional has this feature and rarely uses it, citing the problem that people swing at different paces in different parts of the golf swing. It was felt that this feature could lead to incorrect analysis of the golf swing unless manually matching areas of the swing occurred which would be time consuming.

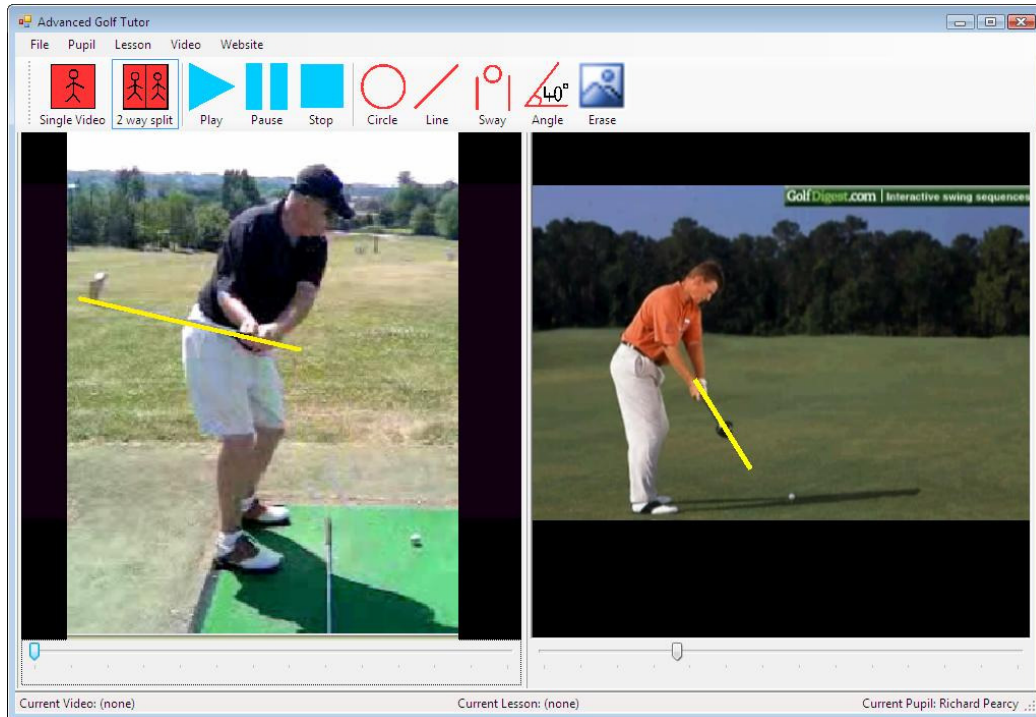


Figure 4-3 Final main screen design

4.3.2 Creating a lesson

The system uses a likeness to reality with its description of data storage. A pupil object represents the pupil and a lesson object represents the lesson that the professional is currently giving. The lesson representation was chosen as it is the most logical way to group videos. Videos will only be for one lesson, plus the pupil often refers to 'last week's lesson'.

One of the most difficult areas of the design is linking the pupil to the lesson and how is best to do it. The flow diagram overleaf indicates the initial idea of process flow.

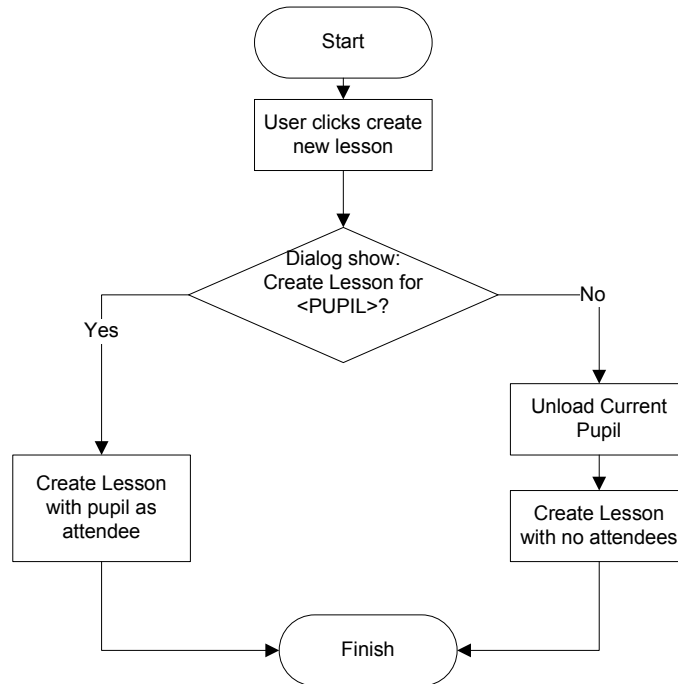


Figure 4-4 Initial New Lesson Flow

On consultation with the golf professional it was felt that the use of a dialog box was unnecessary and that the lesson should be created for the currently loaded pupil. It was also felt that this would increase the importance of the pupil object in the system and hence allow the system to be developed around this central object. In addition, from a usability perspective this was felt to be advantageous as the pupil is central to the physical lesson and the system would be developed analogous to this concept.

4.3.3 Upload Pupil Videos

In this area the professional chooses which video they wish to upload for the pupil. All of the videos selected for upload will then be available for the pupil to view on the website. This section of the design went through three iterations of design; the initial design, a modified design based on user suggestions and then refactoring due to a cluttered screen.

4.3.3.1 Initial Design

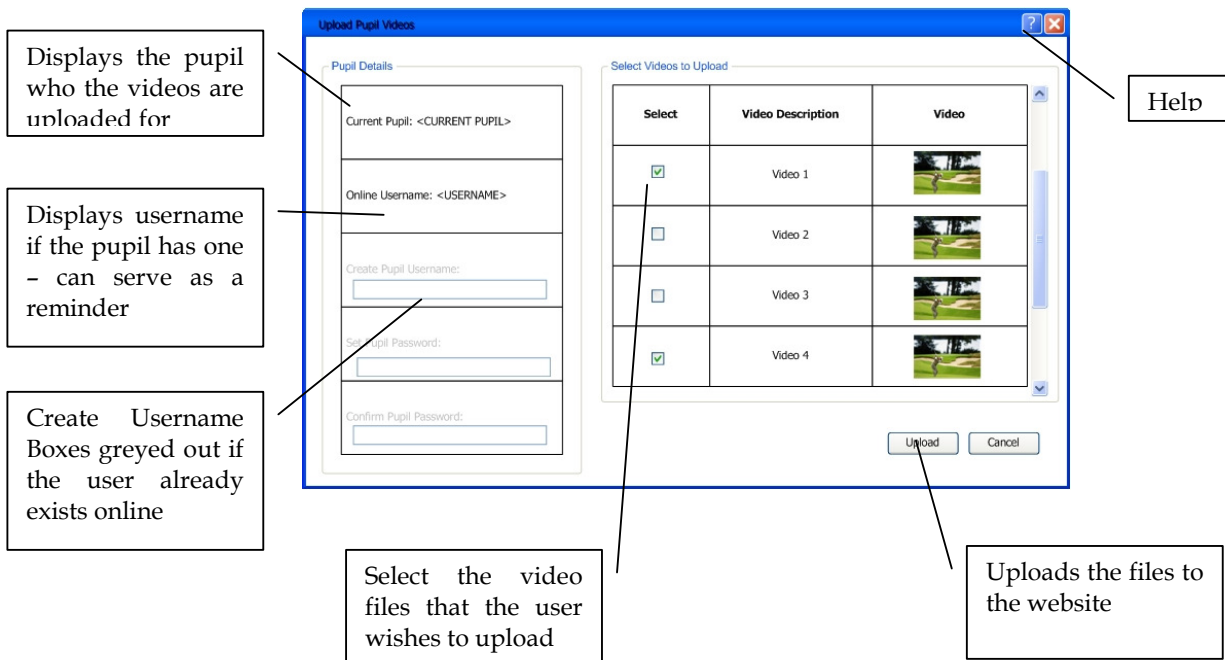


Figure 4-5 Initial design of upload pupil

The initial design includes the basic usability features of the context related help and standard Windows layout. Before reaching this place the professional will be prompted to enter his username and password, and only when correct will the page be displayed. The reasoning behind this is two-fold - security and flexibility. The flexibility means that any changes in the remote database are not hard coded, nor is the password stored anywhere on the system.

On entering a correct password the system downloads and displays the current pupil username if it exists. This could be especially useful as users may forget their username. Should the pupil not have a username, this will be indicated to the professional by enabling the "Create User Section". This allows the professional to create a unique username for the pupil, as well as setting a password. This option is only available if the pupil does not already exist on the database, stopping pupils having multiple IDs.

4.3.3.2 Modified Design

Discussions on the original design focused on the use of the lesson structure in this section as shown in Figure A-1. The professional indicated it was likely that he would wish to upload entire lessons, and so suggested that this should be included in the design. In addition he felt that the videos should be grouped by lesson as an individual file would not always be useful.

This discussion led to the development of the screen below, which features the lesson item as the central theme.

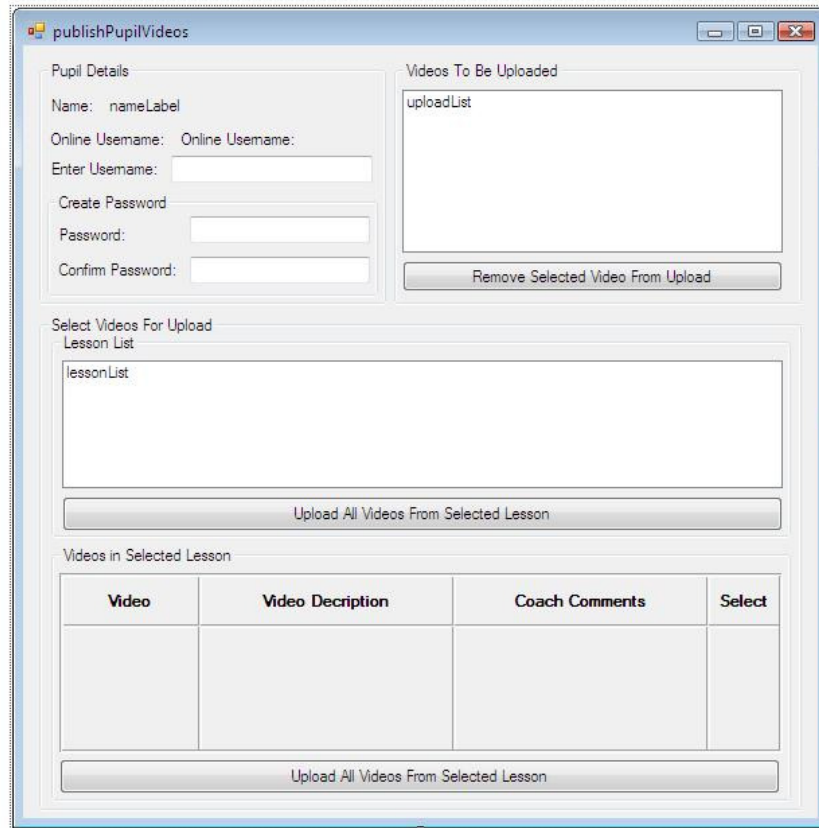


Figure 4-6 Intermediate Design of Upload Pupil Videos

4.3.3.3 Refactoring the design

The redesigned interface was very cluttered and served too many purposes meaning there is a chance of user confusion. In addition the large amount of information means that important sections are lost and sections do not pop-out, a requirement of the system. The system was refactored; the videos to be uploaded and user details appeared on one screen with a link to video selection screen.

In addition the layout of the pupil details section was rearranged, making it clearer. For instance if a pupil needed to be given a username, the unneeded boxes are hidden as opposed to the previous method of disabling them. In addition, a box to allow the coach to add comments to the upload was made, encouraging the professional to give extra feedback and key thoughts to the pupil. This is detailed in the screens overleaf

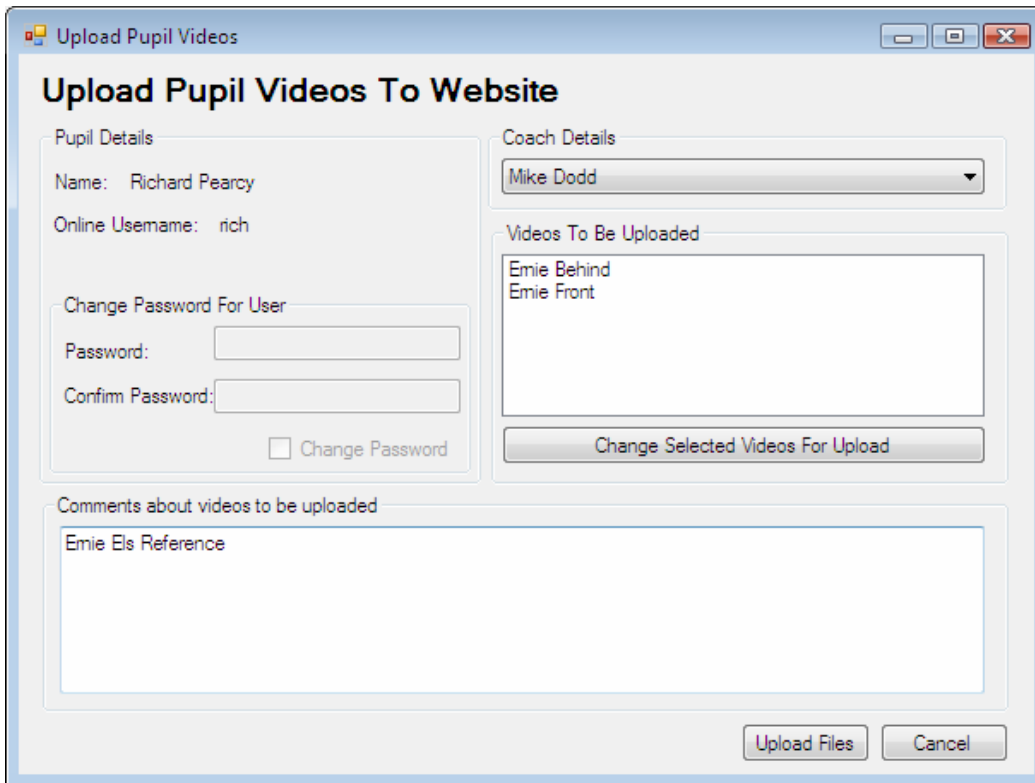


Figure 4-7 Upload Pupil Videos main screen

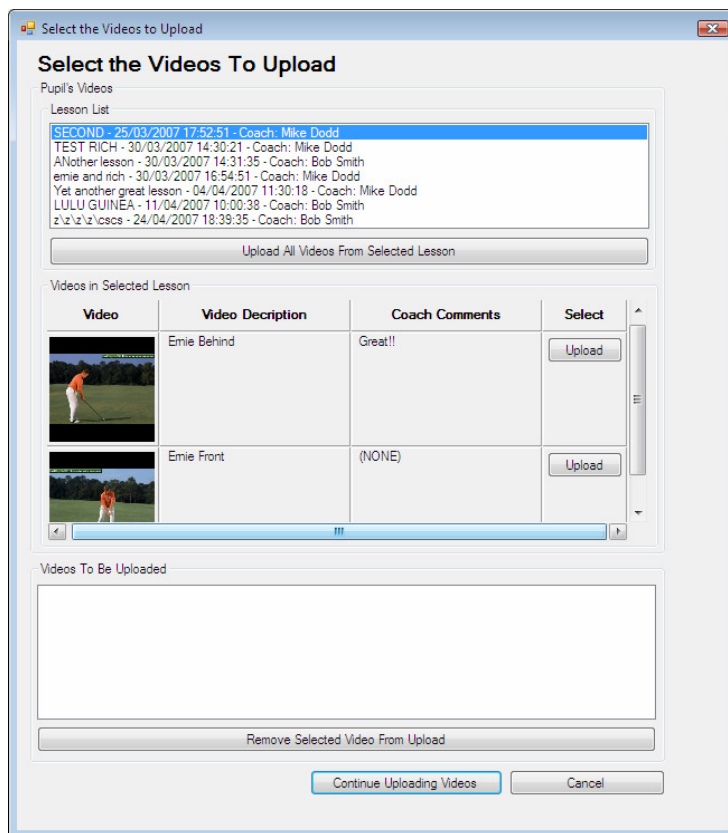


Figure 4-8 Select Videos to Upload

4.4 Database Design

Database design required two main factors to be considered - the design of tables and their relationships and where the database should be stored. Although some of the issues discussed here include implementation details it has been included in the sections to justify the design process. Decisions regarding database storage were central to the back end design

4.4.1 Database Location

There are two main locations for the database; at the golf club, or located remotely and accessed via the Internet. This leads to a number of ways to implement the system.

4.4.1.1 All Data Stored Locally

All data will be stored locally on the machine with the website accessing this database. This has the advantage of speed of storing video files for both local use and upload. It also means the professional will never have to download pupil videos as they will be directly written to the machine.

However there are numerous disadvantages of this method. Firstly, the setting up and maintenance of a web server would require technical skills that the professional is unlikely to have. If this maintenance is not performed this could make the system vulnerable to attack. In addition the machine would need to be of a higher specification than originally specified, as well as improved Internet specification including a static IP address and higher bandwidth.

4.4.1.2 All Data Stored Online

All data would be stored on a remote server. This would overcome a number of issues associated with storing all data locally. Firstly the server could be maintained remotely meaning no technical skills were required. In addition a remote server is likely to have a higher bandwidth, increasing website performance for the pupil. Remote servers are normally backed up routinely meaning information stored on them is more secure. In addition the program would be able to run off of multiple computers, meaning a professional could access data if he was coaching a pupil at an event away from his home club.

However to pay for a web server that would have the required bandwidth and storage space would be expensive. The downloading and uploading of video files could place a high strain on the professional's broadband may be time consuming. In addition the professional would be reliant on this connection to access the files, meaning a lost Internet connection could mean they will not be able to use the software.

4.4.1.3 All Data Stored Online With Local Copies

Having all data stored online with copies stored locally on the professional's machine reduces the professional's reliance on his connection to the Internet. However, this method suffers from the same cost problems as storing all data online. In addition problems exist with how the copies should be stored and updates written to the database.

4.4.1.4 All Data Stored Locally With Copies Online

All of the data is stored locally, giving the system the same speed advantages as the locally stored system, except all pupil website videos must be uploaded to, or downloaded from the Internet which will slow the system down. However, the amount of downloads and uploads are minimal in comparison to the online storage method, and not necessary for operation during lesson time.

In addition the amount of remote server space and bandwidth will be reduced as only a fraction of the data will be stored remotely. However, data duplication will occur on the remote site, but the problems of updating copies of files should be minimised as videos with their comments are simply being uploaded to and downloaded from the remote website.

The advantages of simplicity and increased reliability were the deciding factor in implementing this method.

4.4.2 Local Database Design

4.4.2.1 Entity Relationship Diagram

The following diagram indicates how the entities relate in a typical golf club. It was used as the basis for the initial database design.

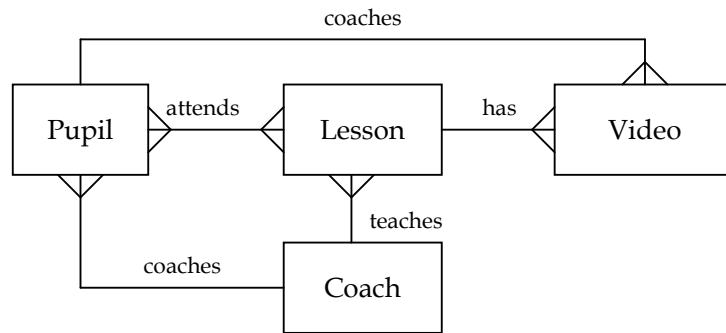


Figure 4-9 - Entity Relation Diagram

4.4.2.2 Initial Database Diagram

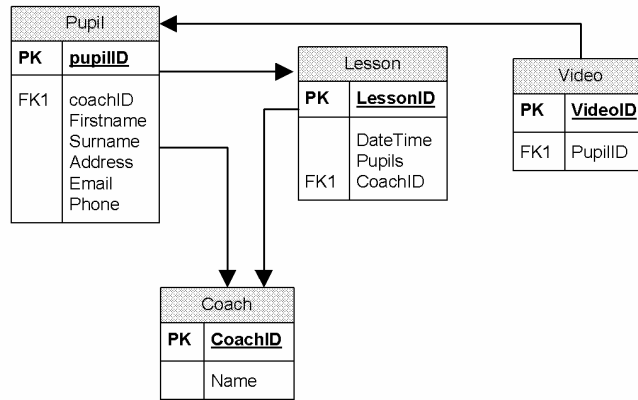


Figure 4-10- Initial Database Diagram

The pupil table had some fields that required greater consideration. Firstly, should the name field be a single field or two separate fields? It was decided to implement this as separate fields to allow for sorting by surname and first name. Additionally, it was felt that the coach field would not need this division, and the addition of a division would not add anything to the relationship. This initial design also had some problems:

- It was not in normal form as Lesson contains Pupils as a multi-attribute field. This led to the “attends” table.
- Discussions with the professional indicated that often with group lessons two or more professionals may coach a single pupil in that lesson. This meant a “coaches” table needed to be created.
- There was no room for lesson or video comments, so a comment table needed to be created.
- There was no location for the video file, so there was no way of knowing which video file the record related to.

4.4.2.3 Revised Database Diagram

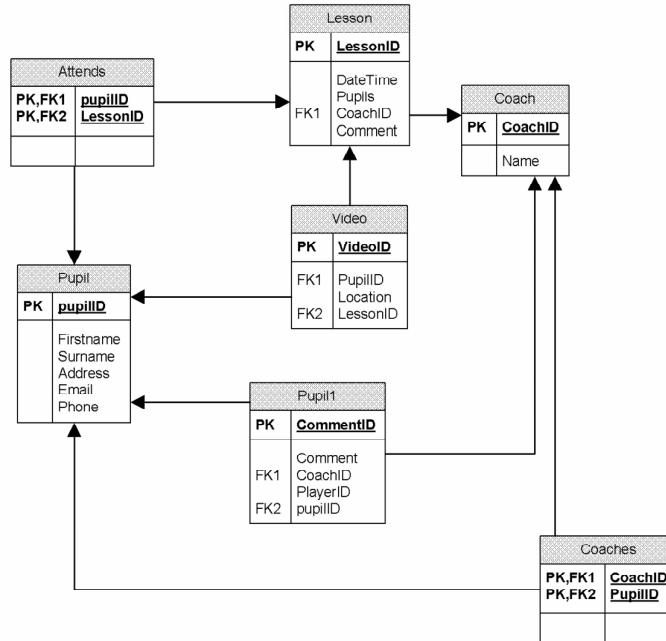


Figure 4-11 – Revised Database Diagram

The revised database does not satisfy normal form as the comment may, or may not have a coachID attached to it. If the coachID is NULL it can be used to show a pupil comment. This was chosen as apposed to a “commentBy” table as pupilID would be repeated if the comment were a pupil comment. In addition to this, adding an extra table would add complexity to the system.

4.4.3 Website Design

The remote database was designed with the intention of keeping it as simple as possible. This meant a minimalist design, and only basic features. Due to this reason and limited accessibility to users, user consultation was limited during design, however users were consulted during the development stage and as such is detailed in the implementation phase.

4.4.3.1 Website System Flow Diagram

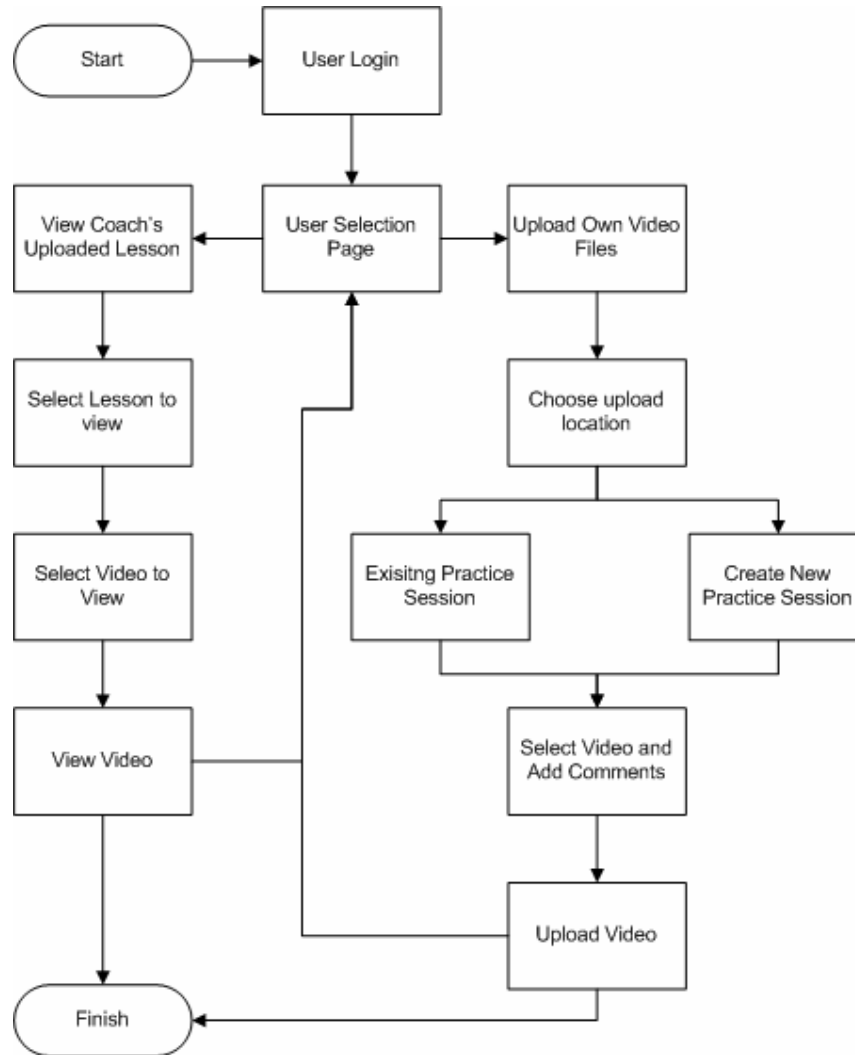


Figure 4-12 Website System Flow Diagram

4.4.4 Remote Database Design

When designing the remote database a number of factors had to be considered. Firstly, what section of the data stored on the local system does the pupil need to access on the remote system? Secondly, how should the remote and local data sources be linked and finally how should the pupil's videos and lesson videos be related?

It was decided that data needed is the video, video comments and lesson comments. These three sections would also need to be linked to a pupil object to ensure that the pupil can only access their own videos. To make sure these are linked to the local database the pupil object will also contain the local pupilID. The decision not to link the lesson and video IDs to the local database was taken because it would be difficult to ensure consistency between the two databases.

It was decided that all videos should be linked to a lesson, as is the case in the main system. As also was the case in the local database, the use of a NULL field to specify whether the lesson was a 'coach' or 'pupil' video. Again the possibility of dividing the table, or the inclusion of a Boolean field was an option; however it was felt that this would offer no advantage over the NULL field method.

4.4.4.1 Remote Database Diagram

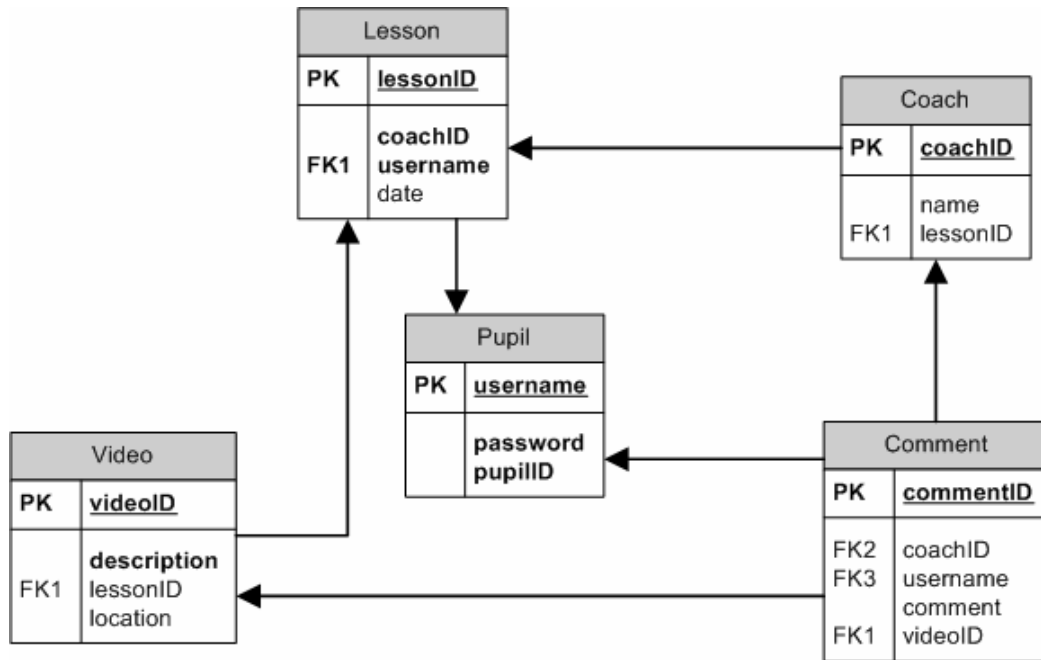


Figure 4-13 Remote Database Table Diagram

4.5 Summary

The design of the system considered three main areas; user interface design, system flow and backend design. The development of these designs occurred in a participatory fashion where possible; this highlighted some of the issues that exist with the participatory design method. However, more importantly that design cannot occur on an individual basis. Even with five years of personal experience of coaching, aspects were overlooked in the initial designs and only when these were commented on by the golf professional were their importance realised. Not only does this justify the role of users in the design process it highlights the importance of an iterative design process. Iterations and changes to the design still occurred during the implementation stage, the important of these changes are discussed in the next chapter.

5 Implementation & Testing

5.1 Introduction

The system was implemented based heavily on design and with limited user input for the development of the website. It was decided to implement the system in Visual C# as this provided the easiest method of creating the standard Windows interface. Additionally, as video files are being played, the incorporation of DirectX means the system can play videos without being forced to use specific codecs. The areas discussed in this section are include parts of the implementation that were the most challenging to implement or have a significant impact on the functioning of the project or have changed from the design. For this reason, all final screen designs are simply included in the appendix because although important to the usability of the system, their implementation does not vary greatly from the design.

5.2 Setting up the servers

The system uses three servers; a web server, a database server and an FTP server. Each of these servers was setup locally on the development machine and accessed via localhost. Wit no personal experience of setting up a server, this provided an additional challenge to coding the solution.

5.2.1 Database Server

As Visual C# was used, it was logical to use SQL Server 2005 and gain the advantage of their integration. Amongst the features of the integration the ability to access the database using the Windows login credential means the coach will not have to remember a username and password.

During development a problem occurred as multiple readers of data are not supported by default. Due to the large amount of many-to-many relationships multiple readers were necessary throughout the system. This meant it needed to be enabled in both the client login and on the server.

5.2.2 Web Server

As the system was being developed using C# and SQL Server, it was decided that it would be advantageous to use the integration of these technologies. For these reasons it was decided to use ASP.NET on an IIS server. In addition as ASP.NET was used, some code could be reused from the main system.

5.2.3 FTP Server

This was a simple extension of the installed IIS server. However, it did require a lot of configuration of file permissions to make sure the system could upload only to the "videos" directory

5.3 Video Implementation

The videos in the system form the major teaching area for the coach and it was decided that they should offer split screens. This led to the development being split into several areas: video handling, video storage and split screen control. Each area had its own issues associated with it, as well as issues common across all areas.

5.3.1 Video Handling

The video was implemented using Microsoft DirectX; this has the advantage of allowing videos to be played as long as the codec is present on the system. Playing videos is relatively simple, and simply involves associating the video file with a panel and calling `video.play()`. The simple code associated with setting up a video object is stored in a function `createNewVideo(String filename, ref Panel videoPanel, ref Video video)`. `filename` is the location of the video file, `VideoPanel` is the panel that the video will be played on, whilst `video` is either the left or right video object when using split screen.

```
private void createNewVideo(String filename, ref Panel videoPanel, ref Video
video)
{
    //get original height and width
    int height = videoPanel.Height;
    int width = videoPanel.Width;
    //create new video
    video = new Video(filename);
    video.Owner = videoPanel;
    this.videoname = filename;
    saveToolStripMenuItem.Enabled = true;

    //show the first frame
    video.Play();
    video.Pause();
    videoPanel.Width = width;
    videoPanel.Height = height;

    //enable all of the buttons
    playButton.Enabled = true;
    stopButton.Enabled = true;
    pauseButton.Enabled = true;
}
```

5.3.1.1 Video Controls

Controlling a video with the play, pause and stop buttons is relatively trivial, however the addition of a track bar was more complicated. Issues with setup include dworking out the number of frames, working out graduations and synchronising the video and the track bar. The function `setupTrackbar(ref TrackBar trackBar, Video videoFile)` handles the setup of the track bar, with `trackBar` being the trackbar to setup, and `videoFile` being the video associated

with the trackBar. The ability to pass references to the function meant that only a single function was needed for both videos when the system was used in split screen.

```
private void setupTrackbar(ref TrackBar trackBar, Video videoFile)
{
    trackBar.Enabled = true;
    double numberOfFrames = videoFile.Duration /
    videoFile.AverageTimePerFrame;

    //convert to integers (rounded)
    int wholeNumberOfFrames = Convert.ToInt32(numberOfFrames);

    //update the tracking bars (contains the number
    trackBar.Maximum = wholeNumberOfFrames;
    int largeChange = wholeNumberOfFrames / 10;
    trackBar.LargeChange = largeChange;
    trackBar.TickFrequency = largeChange;
}
```

Calculate number of frames of the video and rounds it to the nearest integer

Make one unit on the track bar equal to one frame. Give the user 10 'ticks' across the track bar for stepping

5.3.2 Split Screen Control

Setting up the split screen was one of the more challenging aspects requiring many areas to be considered; changing between single and split screen, showing which screen was selected, and adapting the controls for which screen was shown. The video controls are called directly through button presses.

5.3.2.1 Splitting the Screen

```
private void twoWaySplit_Click(object sender, EventArgs e)
{
    if (!twoWaySplitBoolean)
    {
        twoWaySplit.Checked = true;
        singleVideo.Checked = false;
        twoWaySplitBoolean = true;

        videoTableLayoutPanel.ColumnStyles.Add(
            new ColumnStyle(SizeType.Percent, 50));
        videoTableLayoutPanel.ColumnStyles[0].SizeType = SizeType.Percent;
        videoTableLayoutPanel.ColumnStyles[0].Width = 50 ;

        //trackbar
        trackBar2 = new TrackBar();
        trackBar2.Name = "TrackBar2";
        trackBar2.Scroll += new EventHandler(trackBar2_Scroll);
        trackBar2.Dock = DockStyle.Bottom;
        trackBar2.Enabled = false;
        //video panel
        videoPanel2 = new Panel();
        videoPanel2.Name = "videoPanel2";
        videoPanel2.Dock = DockStyle.Fill;
    }
}
```

Setup parameters to indicate the type of display (split or single) including display.

The video panels are stored in a table layout, so we need to add another column for the new video.

Create the track bar and video Panel - all stored as class level parameters

```

...twoWaySplit_Click code continued

    //drawing panel
    drawingPanel2 = new TransparentPanel();
    drawingPanel2.Name = "drawingPanel2";
    drawingPanel2.Dock = DockStyle.Fill;
    drawingPanel2.Click += drawingPanel_Click;
    drawingPanel2.MouseDown += drawingPanel_MouseDown;
    drawingPanel2.MouseUp += drawingPanel_MouseUp;
    drawingPanel2.MouseMove += drawingPanel_MouseMove;
    drawingPanel2.BringToFront();

    //containing panel
    Panel containingPanel = new Panel();
    containingPanel.Controls.Add(videoPanel2);
    containingPanel.Controls.Add(drawingPanel2);
    containingPanel.Controls.Add(trackBar2);

    //bring the drawing panel to the front
    containingPanel.Controls[1].BringToFront();
    containingPanel.Dock = DockStyle.Fill;
    videoTableLayoutPanel.Controls.Add(containingPanel, 1, 0);
}
    
```

Create the drawing panel as a class level parameter

Create a containing panel for all of our control to ensure layout remains constant

Add the control panel to the layout panel, creating the second video panel

5.3.2.2 Viewing a Single Video

```

private void singleVideo_Click(object sender, EventArgs e)
{
    //only need to do something if we are in twoway split mode
    if (twoWaySplitBoolean)
    {
        twoWaySplitBoolean = false;
        twoWaySplit.Checked = false;
        singleVideo.Checked = true;
        //get rid of the right hand panel
        try
        {
            video2.Dispose();
        }
        catch
        {
            //do nothing
        }
        video1Selected = true;
        //remove all of the end controls
        for (int i = 1; i < videoTableLayoutPanel.Controls.Count; i++)
        {
            videoTableLayoutPanel.Controls.RemoveAt(i);
        }
        videoTableLayoutPanel.ColumnStyles.RemoveAt(1);
    }
}
    
```

Update the system settings and user view

Clear up the right hand video

Remove all of the controls and then remove the right hand column

5.3.2.3 Changing between the selected video panels

Changing between the video panels is simply done by clicking on the panel that you wish to change. This is then highlighted by a change in the border around the selected video file. This method is only called by the click handler if the panel clicked on is not selected panel. Unfortunately, the highlighting was not implemented to include a bright border as was desired due the additional drawing required, which could not be implemented in the time scale of the project.

The reason for the choice of a selectedPanel variable is that it reduces handler creation. By using a selected panel clicks and drawing can be handled by a single handler. In addition the video1selected variable allows the appropriate video to be played when the play button is pressed.

```
private void changeSelectedPanel()
{
    //its the first video panel we have already selected
    if (selectedDrawingPanel == drawingPanel)
    {
        selectedDrawingPanel = drawingPanel2;
        videoPanel2.BorderStyle = BorderStyle.Fixed3D;
        videoPanel.BorderStyle = BorderStyle.None;
        video1Selected = false;
        trackPosition.Focus();
    }
    else
    {
        //we are changing to panel1 from panel2
        selectedDrawingPanel = drawingPanel;
        videoPanel.BorderStyle = BorderStyle.Fixed3D;
        videoPanel2.BorderStyle = BorderStyle.None;
        video1Selected = true;
        trackBar2.Focus();
    }
}
```

Change the border styles of the selected drawing panel and give focus to the new track bar

5.3.3 Saving Video Files

When the coach saves video files, the system needs to store a copy of the file locally and in its own directory. To do this the location of where the video files are stored is in the settings files, which can then be changed through a simple change of a variable. In addition as the video files needed to be uniquely named, the original filename cannot be used as it is not guaranteed unique and this led to the use of the videoID, unique as it is a primary key. In addition this project only uses AVI files for simplicity reasons, meaning all files have '.avi' extension. This design change rendered the location field in the database obsolete, as both location and filename had now been predefined.

The code to perform this save is simply:

```
File.Copy(originalLocation, Properties.Settings.Default.videoLoaction
+ videoID.ToString() + ".avi", true);
```

5.3.4 Uploading Video Files

Uploading video files is done using FTP. FTP was chosen as it is a common protocol for transferring data over the Internet and is also supported in C#. The code was implemented in a class `FTPTransfer` which has the simple interface of `uploadFile(String uploadFile, String remoteFilename)`, with `uploadFile` being the location of the file to be uploaded and `remoteFilename` being the new uploaded filename. The uploaded filename, like the local filename is based on the `videoID` of the uploaded file and is obtained by inserting the record into the database.

5.4 Implementation of Drawing

The drawing in the system was probably the technically most difficult area and only had the basics implemented with only the line and circle drawing shapes implemented. However, these were chosen for two reasons - firstly they are a default shape in the drawing toolbox and secondly virtually all errors in the golf swing can be highlighted with these simple shapes. Other shapes have been included on the toolbar so the system toolbar retains the same level of "pop-out".

The drawing paradigm chosen was the click-drag-release method. This paradigm is used throughout Windows and is the reason for this method being chosen over the click-drag-click method, which may not be easy for some people to perform.

5.4.1 Drawing on Panels

Unfortunately, Windows does not supply a high level of support for user controlled drawing. C#.NET provides a drawing library for drawing shapes onto panels, however this is not for users drawing onto panels, but for designers to create custom shapes on their interface.

A shape can be drawn by simply getting the graphics handle from the form, choosing a Pen and then calling the draw shape method.

```
Pen p = new Pen(Pens.Yellow.Color, 5);
Graphics dc = drawnPanel.CreateGraphics();
dc.DrawLine(p, base.P1, base.P2);
```

However, this method only makes the shape visible until the page is redrawn, an event that can occur for a variety of reasons. This means it was necessary to override the paint method to ensure that my shapes were persistently drawn. To do this, each shape was a class, and all shapes were a subclass of `DrawnShape`. This meant the use of a list of shapes could be used, simplifying the paint override through allowing `shape.draw()` to be called.

```
protected override void OnPaint(PaintEventArgs e)
{
    base.OnPaint(e);
    //redraw all of our shapes
    foreach (DrawnShape shape in shapeList)
    {
        shape.draw();
    }
}
```


5.4.2 Letting the user draw

This was a challenging aspect of the system as for usability reasons the drawn shape must always be seen whilst being created. To do this the shape starts drawing when the user clicks on the drawing and then the mouse is tracked using the mouse move handler. Each time this handler is called a new shape is drawn at the new mouse position, which in turn causes the other shapes to be redrawn and consequently makes the shape being drawn flicker occasionally. Unfortunately because of the need for the instant response the double buffering method that is often used to solve flickering cannot be used.

5.4.3 Drawing on Videos

Unfortunately, the method of drawing on the same panel as the video does not work as the video 'hijacks' the paint methods and as such does not allow the user to draw on the panel. To solve this, a 'glass', or transparent panel must be placed over the video. Unfortunately, the transparent background for a standard Windows panel does not render transparent, it merely reflects the background colour of the component behind! This meant the transparent panel needed had to be manually created, with the background paint overridden. This component was created using code from <http://www.thescripts.com/forum/thread234245.html>.

5.5 Website Implementation

The website was implemented using ASP.NET and C#. This allowed the rapid development of the system with the database class from the Windows system being reused. Additionally, the integration with IIS and SQL Server 2005 allowed full use of the database.

The structure of the website is relatively simple and is implemented using MultiViews, allowing all of the data to be displayed on a single page but at different times depending on user inputs. The site layout was developed using CSS and as such should any future development wish to make the user interface 'prettier' this can be done simply.

As previously mentioned user involvement during the design of the website was limited. This meant a key change occurred during implementation. It was originally decided to call the practice session that the pupil created a 'home' lesson to emphasise that learning occurs in the practice session as well as in taught lessons.

Unfortunately this caused the user problems in understanding the principle of the home lesson and linked it too strongly with the taught lesson uploaded by the professional. Even when the user had the difference explained, they could see the difference but still felt they were linked.

The main change to the website simply rephrased lesson, to practice session and as such the user felt they understood the page better.

Advanced Golf Tutor Website

To logically group your videos, enabling your coach to correctly associate the video with the movement you are walking on, any uploaded video needs to be associated to a lesson. This lesson is a 'home' lesson and as such is not the same as the lesson that your coach uploaded.

Upload To New Lesson
 Add Files To Existing Lesson

Description:

Enter the movement / feeling that you are working on (e.g. getting your swing steeper, one-piece takeaway)

Choose your video to upload:

Files can be a maximum of 10MB and must of type .avi

Enter a short description of the video - e.g. (6 Iron from behind)

Enter below how you feel about that movement and what you were trying to achieve. Also indicate what the shots you were hitting were like.

Figure 5-1 Initial implementation of upload page

5.6 Summary of Implemented Areas

The previous discussion of the implementation of the system highlighted the important features, and some of the difficulties faced in creating the software. However, due to the time constraints on the project and the importance of evaluation in the project, not all areas could be implemented, these are detailed in the next section.

5.7 Areas Not Implemented

Unfortunately certain areas of the system were not implemented. These were mainly due to time constraints, however their implementation was still considered.

5.7.1 Advance Drawing Tools

Advanced drawing tools such as the sway tool (a circle with two lines) could be created from existing drawing objects. For example when creating the sway tool, the shape sizes could be divided into percentages, such that the circle fills the top 25% of the shape and the lines fill the bottom 75%. This should be relatively simple to create and if the new complex shape inherited DrawnShape, it would fit into the existing drawing system without modification.

5.7.2 Capture from Firewire Video Cameras

This feature would be advantageous to the coach as direct capture from the video camera would stop the intermediate process that is currently needed. Many toolboxes are available for implementing the capture. If the captured video was saved as a temporary file, and then loaded into the analysis screen as would be the case if a video had been imported, the capture would work seamlessly.

5.7.3 Other Video Formats

Other video formats can already be played in the coaching system, however it is not possible to play them in the website. This was one of the reasons for limiting the system to AVI files. To fully implement the saving of videos, a change to the database would be necessary, with the possibility of adding a FileType table. The FileType table will include the details of the file, and as such could be linked to the appropriate website player.

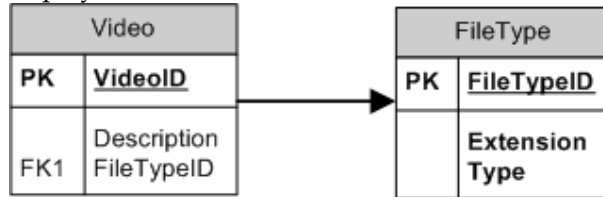


Figure 5-2 Possible Addition of FileType Table

5.7.4 Context Based Help

Although an essential part of any system from a usability perspective, it was not possible to implement this in the time constraints. However, although not having a help system the evaluation could still occur, this is due to the system being designed to be used without the aid of the help system through being intuitive and familiar.

5.8 Testing

Testing on the system was done during development and as such limited. The reasons for this are two-fold; the focus on the project is developing a system that could be used to test a psychological principle, and to develop a system that could test this principle was very time consuming and as such time for testing was limited.

5.8.1 Method

Testing was performed during development, and as such was loosely structured. For this reason development occurred in blocks, with each block being tested in the following ways:

- During development of the block difficult lines/blocks of code would be tested in isolation
- Once the block was created it was tested in its entirety
- The block would then be tested in conjunction with the whole program

Each of the development blocks were often linked to a Form or area of functionality, and as such were often able to be tested in isolation.

5.8.2 Tools Used to Aid Testing

As previously mentioned, servers were set up on the development machine and were used by the program. All program components contacted localhost, as if it were a network resource, with the aim of making network portability easy.

Having administrative rights over the database server was essential as it formed the basis for database testing. SQL queries were tested by directly querying the database, and the results of inserts could be seen using the included viewing tools. In addition entries were inserted to check data retrieval by the program.

5.8.3 Website Testing

The website of the system was tested both on `localhost` and over the local network. This testing was to see if the website depended on anything that was stored locally on the system. In addition, as the network is slower it emphasised the delay that a user may receive when accessing a website.

5.8.4 Future Testing

As limited and unstructured testing occurred, full testing of the system is needed. Most importantly would be situating the web server on a different machine from the coaching system. This would simulate the delay the Internet can cause and again check for any local dependencies.

It is also necessary to develop a full structured test plan for the coaching system. Testing each input with a range of values (both valid and invalid) and experimenting with inputs on the boundaries of validity, as the majority of testing focused on “pass/fail” values as apposed to the important “grey area” testing.

5.9 Summary

Implementation and testing covered the principle requirements of the system, and allowed the system to be developed in a timely fashion so that it could be effectively evaluated. Details of the evaluation are included in the next section, as our details of requirements not met.

6 Evaluation

6.1 Introduction

To evaluate the system effectively and see if it offers any benefit towards learning would require a longitudinal study. Improvement in the golf swing can take many months to be replicated in improvements in skill performance. Not only does the skill take time to 'get used to' through integrating the closed skill learnt into the full open skill of a game of golf, pupils must be weaned off relying on knowledge of results when modifying their technique.

Unfortunately this improvement would not be visible within the time frame of the project; hence the evaluation must cover two phases:

1. Does the system allow learning to occur? Basic tests can show if a pupil can learn or improve at a given skill.
2. Does the system interfere with the learning process? The usability of the system must be assessed to see if interaction with the system interferes with learning.

Firstly, however as is the case in any software system it is important to see how the system meets its requirements. This is described in the next section.

6.2 Requirements not implemented

There were few requirements that were not implemented, or could not be tested.

- Requirement 11 - Any system given to the user must be able to be used on both Windows and Macintosh machines - This was not tested as no access to an Apple Macintosh was available, and it was not a key area for the prototype system.
- Requirement 29 - The data in the system must be kept in accordance with the Data Protection Act - This was not tested as it seemed inappropriate for the concept system
- Requirement 30 - The data in the system must be easily backed up - As the system was a prototype, data was not essential to the system, and could be backed up using SQL commands, and copy and paste.
- Requirements 34, 36, 37 all concern environment and as such have not been explicitly tested but the system has been developed with these requirements in mind.
- Requirement 45 - The system should comply with Nielsen's Heuristic Evaluation guidelines - See evaluation for details on this.

The requirements not met, with the exception of 45 were not implemented or tested because of the scope of the project. However, the system not complying with Nielsen's heuristics is a more serious issue, and as such is detailed in the following section.

6.3 Evaluation of learning

To test the ability of a pupil to learn using the system a simple test was devised. The golf professional gave a pupil a lesson using the system with the normal technique. The professional then explained the fault using the system and taught the pupil a new movement to fix this fault. The pupil went away and practised the movement, videoed the movement and verbalised their feelings on the movement. The professional analysed these movements and made comments, and explained the movement again, this time based on the pupil's practice and movements.

This section follows the format of the lesson with both the golf professional's and pupil's comments included at each stage. The section begins with an initial subject analysis of the pupil's swing from the professional, followed by the pupil's comments on their practice sessions. The professional then analyses the pupil's practice sessions, suggesting improvements based on the pupil's comments and videos. The user involvement in the section concludes with a subject analysis of the pupil's golf swing is performed by the golf professional, and the section is finally concluded with an analysis of the learning process.

6.3.1 First Lesson

6.3.1.1 Coach Comments on Swing

"The pupil takes the club away too much on the inside. This leads the club being flat and shut at the top. To solve the issue the pupil needs to think about creating a wider arc during the initial takeaway. The fault was indicated by comparing the swing to Ernie Els' at the halfway stage and highlighting the shaft angle."

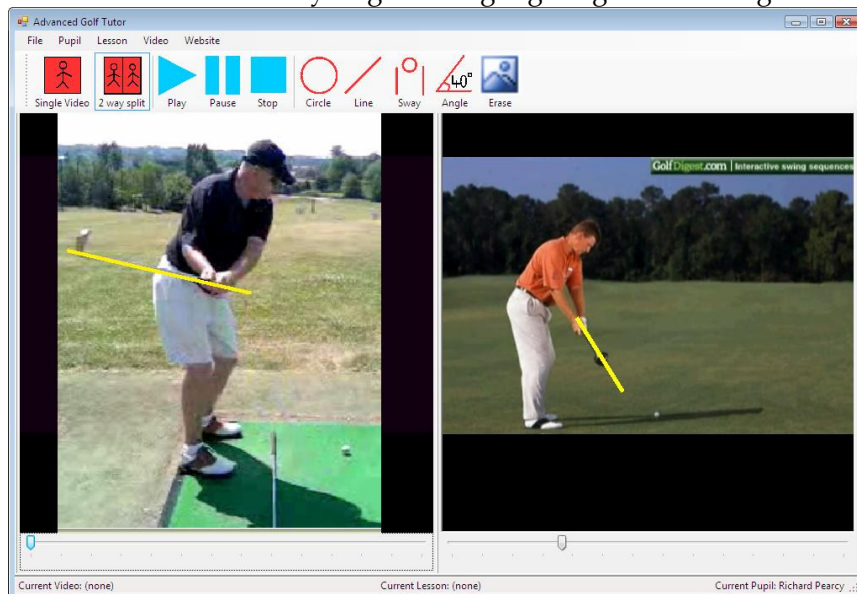


Figure 6-1 Figure showing the software being used for swing analysis in the initial lesson

6.3.2 Pupil's Comment on Pupil Practice

"I felt that I was getting a wider takeaway, and being able to see that club so far inside on the video made me realise why I was getting so flat. I am now feeling that I am making a big, wide turn at the start of my swing. I am being careful not to make too big a turn and get flat. Unfortunately I still am hitting the ball fat¹ occasionally."



Figure 6-2 Pupil Swing during practice

6.3.3 Professional Analysis of Practice Session

"It is clear to see that the swing is not as far inside as it was. This is a definite improvement. The pupil is still too far inside, however this could be a result of trying to turn too much and performing the action in the wrong fashion as the pupil mentioned in their comment. To solve this the pupil was instructed to turn on the outside and get the hands further away from the body."



Figure 6-3 Pupil Swing after second instruction

¹ A fat golf shot occurs when the club strikes the ground before the ball

6.3.4 Professional's Analysis of Swing after Second tuition

"The pupil now has a wider arc at the start of the swing, and the shaft of the club is more down the target line at the halfway stage. When comparing the pupil's swing to the pupil's swing before tuition using the software it is clear to see an improvement. "

6.3.5 Summary

From the professional's subjective analysis of the golf swing it is clear that learning has occurred. The pupil has felt an increased level of KR and the professional has adapted their coaching based on the pupil's comments. Further analysis of the system occurs later this section, including both the pupil's and professional's thoughts on the system. Evaluation of the both the professional's and pupil's comments are included in section 6.6.

6.4 Professional's Analysis of Learning with the Software

6.4.1 Professional's Thoughts on Video Analysis

"The software allowed me to fully analyse this pupil's swing in slow motion, as I prefer to do. I used a combination of tools to analyse the video, mainly the split screen, comparing the pupil to Ernie Els. I feel that being able to compare the pupil to a professional who executes a move correctly helps the pupil learn better. Additionally, I used the slider to play the swing in slow motion. I prefer using a slider to a 'slow motion' playback as there are areas of the swing I may wish to pause on when viewing it.

I also used the drawing tools to highlight areas of the swing that were incorrect and needing working on. The tools that were present in the system (line and circle) are adequate for this analysis, however I would need more of the tools to be working to effectively analyse other faults in the swing."

6.4.2 Professional's Thoughts on Pupil Videos and Comments

"The pupil videos were easy to analyse, although the quality unfortunately was not as good as I achieve from my own video camera. I feel that the pupil verbalising their thoughts helps them maybe more than it helps me, although saying that it did indicate that I needed to explain the method in a different way. This method of teaching is similar to some of my better pupils who may have several short lessons every week when working on a big change."

6.4.3 Professional's Thoughts on Speed of Learning

"The pupil has changed the start of their swing quite quickly, however I feel it would be difficult to quantify whether this method allows the pupil to learn quicker than my normal teaching. The problem is, pupils take different lengths of time to change different aspects of their swing. Only long-term performance measurement could possibly assess the speed of learning in my experience."

6.5 Pupil's Analysis of Learning with the Software

6.5.1 Pupil's Thoughts on Building a Mental Representation of the Golf Swing

"There is so much than can go wrong with a golf swing. Right from gripping the club, to how you position yourself prior to making a swing. To be able to look at yourself as the coach sees you and compare that with a professional's swing gives you a feeling of how to progress"

6.5.2 Pupil's Thoughts on Videoing Practice and the Quality of Videoed Practice

"It's a great check of how you think you are implementing the lesson you had with the professional, and the reality. It's very easy to think you are practising what you were shown, when in fact you have not changed, just because the old felt "comfortable" and you could hit the ball. But changes to the golf swing normally mean you hit the ball worse before the change has a benefit. I can now compare my practice session with my lesson and make sure I am heading in the right direction,. so when I return to the professional for the next lesson he should be able to see that I have not spent a long time practising the wrong way"

6.5.3 Pupil's Thoughts on Multiple Videos Detailing Progress

"Because I thought I was just swinging flat, looking at the swing at the top would tell me nothing and give me no idea how I get into the wrong position. By seeing the swing in different phases from the start and then the coach explaining where it should be, this gives me a lot more confidence in making the change."

6.5.4 Pupil's Thoughts on Verbalising Faults and Actions

"Verbalising helped but the video is very important for me as a visual aid as I personally struggle to comprehend someone explaining a "feeling"."

6.5.5 Pupil's Thoughts on Having a Fault Cure Re-Explained

"Having the fault re-explained helped me; my impression was that I was not taking the club away on the inside and that I was just swinging flat. However, seeing the video with the lines drawn on, it became obvious why he is a professional and I am not!"

6.5.6 Pupil's Comparisons with Existing Software

"This method is an extended learning experience. The GASP system is great but once I come away from my lesson I am on my own, hoping I am practising the right thing. From bitter experience, I know if a coach asks me to make a small change then more often than not I will go away and over-emphasise the change. For me personally there is no feedback or gentle reminder of what I was trying to change with the GASP system once the lesson is over."

6.6 Evaluation of the User Evaluation of Learning

The user evaluation of learning has indicated two main areas of the system that are important:

- The professional is able to teach with the system
- The pupil is able to learn with this system

The professional being happy to teach with the system is very important, and from the video analysis it is clear to see that the coach has utilised a number of psychological principles in the system to aid learning, one of the aims of the system. For example, the coach broke the fault down into a closed skill, through focusing the pupil's attention on performing the correct takeaway, as opposed to a correct golf shot. The professional performed this through playing the video in slow motion and pausing in sections; in addition to focusing on the key aspects of the skill, he highlighted these areas with a drawing tool. The closed skill highlighted by the professional was demonstrated using a template - the golf swing of Ernie Els (former World Number 1 Golfer), an effective teaching method highlighted by Newell et al. (1990). The learning model used was an "expert model".

The professional however has explained the mechanics of the golf swing in the lesson, rather than using the implicit knowledge of the pupil. This has been shown to have a negative effect in competition; however this is something that could not be tested in this short term evaluation. The feedback given to the pupil in the form of the video and the comparison with the learning model allows the user to form a level of knowledge of results (KR). In addition by indicating that the pupil swung too flat and inside, the coach has provided the pupil with KR. The delivery of KR being in the form of immediate KR is correct for the changing of specific skill, but may not be suitable for long-term development where summary KR is more beneficial. The precision of the KR given is very exact, specifically as the image is analysed in slow motion; again this precision has been shown to aid learning.

In addition to immediate KR, the system does provide some summary KR; this is in the form of the practice videos. The professional can see the pupil's swing over several practice sessions and as such gains a summary of the pupil's performance. In addition the pupil felt that using the range of videos gave a broader view on progress, which is also a summary and as such can be classified as summary KR. Schmidt et al. (1998) indicated that the presence of both immediate and summary KR allows the user to be guided by the immediate KR but does not form a dependence on KR. In addition, through working on the movement over time and comparing their swing with the user model encourages problem solving, another key aspect to learning.

The evaluation also highlighted the motivating effects of KR. The pupil commented on how he felt the system helped him improve and gave him a goal, indicating that the pupil is motivated to improve this skill. In addition, the pupil indicated how he found the increased level of KR useful in guiding the modelling of the skill; something that the literature indicated is the case in learning motor skills.

Overall, the evaluation has shown that the pupil learns with the system, and the coach is able to use the system to effectively express themselves. In addition, the coach has demonstrated that they utilise the majority of principles that are key to effective learning of a motor skill. This is emphasised by the pupil's realisation that they have increased KR from the system. A longitudinal study on the system would show if this increased KR would improve the tuition the pupil receives.

6.7 Heuristic Evaluation

The following evaluation of the coaching system was conducted using Nielsen's Heuristic Evaluation. The evaluation process involved three users and myself, all as evaluators. One user - the professional - was tasked with evaluating the coaching side of the system. The other two users, both of whom have taken golf lessons, evaluated the website of the system. In addition evaluation of both parts of the system using the same method as the users was performed by myself before the users performed their evaluation.

The personal evaluation demonstrated the difficulty in analysing software created by the evaluator. Areas such as wording and prominence of controls are difficult to identify, as the evaluator implicitly knows where things exist and what instructions mean. This meant the users testing the system found more errors than myself. However, there was an overlap with some of the more concrete issues, such as exit buttons.

The evaluation for the coaching based system included some typical usage scenarios to make sure the professional covered areas he might not have been familiar with. In addition the professional was given free reign to use the system as they wished in the evaluation. The usage scenarios were deliberately broad to encourage the professional to think as they would in a lesson.

1. Create a new lesson for Ernie Els with the video of Ernie's video from the desktop
2. Create a new pupil
3. Compare two swing videos, highlighting spine angle on both
4. Upload a lesson video for Tiger Woods
5. Download a pupil video

The pupil was given two tasks and freedom to navigate the site. The tasks were:

1. View a lesson of your choice
2. Upload a video of your choice

The following are combined results of users utilising Nielsen's principles with the results from my heuristic evaluation. The following principles have been divided into two sections, one for the coach's system and one for the website. Each of these sections are then sub-divided into each of Nielsen's 10 guidelines from his website. Each evaluator was asked to categorise the faults based on the guidelines, however some problems could not be categorised and so appear in an "others" section. Possible reasons for the difficulty are highlighted in the evaluation of the process.

6.7.1 Coach's System

6.7.1.1 Visibility of system status

Problem: Did not realise video was loaded into selected panel

Fix: Change wording of menu to indicate that the video will be loaded to the selected panel

Problem: Current status of lessons, videos and pupils visible but not prominent enough

Fix: Make the status bar even more prominent

6.7.1.2 Match between system and the real world

Problem: The change selected videos to be uploaded wording is confusing

Fix: Change the wording of the button

Problem: Confused about the link between website and uploading videos

Fix: Rearrange menu system and change phrasing

6.7.1.3 User control and freedom

Problem: No exit on Welcome screen except for the 'X' in the top corner

Fix: Add exit button to screen

6.7.1.4 Consistency and standards

Problem: There is No File->Save for saving videos, as would be seen on other standard windows systems

Fix: Add save functionality to the file menu

Problem: Double clicking on pupil name in load pupil does not load the pupil

Fix: Add double clicking on a selected item performs the select function

Problem: Not sure how to size circle drawing tool

Fix: Possibly add resizing to circle as the drawing method already currently uses the standard Windows paradigm

Problem: It appears you can load videos when no videos for a pupil exist

Fix: Disable load video function if no videos exist for the pupil

6.7.1.5 Error prevention

Problem: Lesson comments not mandatory

Fix: Make lesson comments mandatory

Problem: Occasionally unclear on start position when circle

Fix: Change cursor to cross

Problem: Email Address not checked to see if it is valid

Fix: Add checking to email

6.7.1.6 Recognition rather than recall

No problems of recall found

6.7.1.7 Flexibility and efficiency of use

Problem: When selecting multiple people for a lesson (using SHIFT/CTRL Click), there is no indication you can do this

Fix: Change wording to include plural (e.g. Select Pupil(s))

6.7.1.8 Aesthetic and minimalist design

Problem: When moving from Welcome screen you can see other forms, although you cannot click on them

Fix: Hide unused forms

Problem: Main window not maximised

Fix: Force main window to be maximised

Problem: Welcome screen relatively smaller – not much impact

Fix: Create a larger, brighter welcome screen

Problem: Colour scheme dull and drab

Fix: Difficult as the colour scheme is the standard Windows colour scheme

6.7.1.9 Help users recognize, diagnose, and recover from errors

Problem: Error Message displays too much detail

Fix: Remove the extended caption, which was left over from debugging

Problem: Some error messages for inserting into database are generic (e.g. Error Inserting into Database) and improved problem diagnosis would aid error recovery

Fix: Catch specific database errors in the system rather than generic SQL Errors. This will then form the basis of customised error messages.

6.7.1.10 Help and documentation

Problem: No contact details for technical support

Fix: Enter contact details into help file

6.7.1.11 Other Problems

Problem: Did not realise that the slider could be used for slow motion video playback

Fix: Increase the pop-out effect of the slider

Problem: Video lists take a long time to load

Fix: Unsure

6.7.1.12 Summary

None of the errors highlight can be described as severe, and the majority of the problems identified can be attributed to cosmetics or wording. All of the problems identified have trivial solutions.

6.7.2 Pupil's System

6.7.2.1 Visibility of system status

Problem: Cannot check if a video uploaded correctly

Fix: Give opportunity to view uploaded videos

6.7.2.2 Match between system and the real world

None found

6.7.2.3 User control and freedom

Problem: More back buttons needed on page as opposed to using browser back buttons

Fix: Add back button to title block so visible on all pages

Problem: No logoff button

Fix: Add logoff button to title block, again so visible on all pages

6.7.2.4 Consistency and standards

User indicated design was consistent throughout

6.7.2.5 Error prevention

Problem: Warning for file upload size and file type, but incorrect files aren't stopped

Fix: Add filter to upload box

Problem: Comment Boxes aren't mandatory

Fix: Add validation to boxes

6.7.2.6 Recognition rather than recall

No problems of recall found

6.7.2.7 Flexibility and efficiency of use

Problem: Unable to select multiple videos for upload to same lesson

Fix: Support multiple uploads, but must come with increased time warning

6.7.2.8 Aesthetic and minimalist design

Problem: One user was pleased about minimalist design whilst the other felt it was a little bit dull in colour

Fix: Enable theming of the page through custom CSS pages

6.7.2.9 Help users recognize, diagnose, and recover from errors

Problem: Page gives server error if too large file is uploaded

Fix: Replace with friendlier error message

6.7.2.10 Help and documentation

Problem: No explicit help or documentation

Fix: Process explained in the page already, however additional comments such as how to film the videos and from what angles would be useful.

6.7.2.11 Summary

Like the coach system, the errors identified were not severe and offered trivial solutions. Further analysis of both the website and the coaching system is included in the next section.

6.8 Evaluation of User Evaluation

6.8.1 Process

The process itself only involved a limited number of users, which according to Nielsen should find just over 50% of the problems. However, the users found problems using Nielsen's guidelines. All users were told to look over the guidelines and that the aim of the problem was to find these sorts of problems and that each problem should be linked to a heuristic if possible. However, one user did not use the heuristics at all in the evaluation and had to be asked at the end to link problems to them. Another user found their own issues first, and then reviewed the system with the heuristics looking for any further issues. These results indicate that heuristic evaluation can be difficult to perform should the users not have any experience of the system, in addition categorising errors was found to be very difficult. Users often said they could categorise their issue into more than one of Nielsen's principles and in some cases none at all. This is an issue that clearly requires further investigation, as? the broad overlapping nature of Nielsen's heuristics meaning more, or less usability issues are found.

6.8.2 Participants

The participants in the system were all experienced in their field, each having had many years experience in coaching or being coached respectively. These domain skills I feel were important in allowing the user to test the system, as it is a specialised domain. However, as mentioned previously I feel the users' limited HCI experience made the process more difficult, and potentially more time consuming meaning the results may not have been ideal. Ideally a usability expert

would have been consulted to supplement the user evaluation; however this was not possible due to the situated nature of the software and porting the software would have taken many, many hours.

6.8.3 Results

The results indicate that usability problems exist in the system and these need to be rectified should the system be used in a longitudinal test. In addition, further usability testing will be needed to see if further issues exist. According to Nielsen's guidelines, approximately only 50% of the system's problems will have been found. The system itself did not demonstrate any severe issues preventing the user from completing their work, which is very good, however when you are dealing with a creative process such as coaching these usability issues may affect the quality of coaching the pupil receives.

6.9 Summary

The evaluation has indicated that the main objectives have been met; the system has no major usability issues and has been shown to allow learning to occur. Problems with the process have been identified, as have evaluations still needed, these areas are discussed in detail in the next and concluding chapter.

7 Conclusion

7.1 Introduction

In summary, this dissertation has covered a number of diverse areas of research and software development which have been brought together to develop a system that can be used to test a theory in sports coaching, namely the way feedback is given to the pupil. Existing systems often build on increasing the level and accuracy of information given to the pupil and coach, however rarely do they cover the use of other information, such as summary KR, implicit knowledge - all of which are key skills in learning a motor skill.

Of the many theories of the way we learn motor skills, one key theme emerges - pupils have to create themselves an abstract view of the movement, built up from 'feelings' of the movement. The way the pupil receives the information regarding the movement is believed to be as important as the information presented to the pupil in the development of this 'feeling'. The system aimed to improve the pupil's development of their mental representation through enabling the professional to use a wide range of information techniques including pupil feedback. In addition, through increasing the information available to the pupil, it is hoped that the pupil will be able to increase their performance more rapidly through increased "trust". Trust is a concept coined by Rotella (1995) to describe effective performance, and belief in technique under pressure. This theory relates to Masters (1992) study on pressure and implicit knowledge.

To ensure the system enabled the professional to coach effectively, the literature review covered the state of the art coaching methodologies and psychological principles. In addition basic analysis of the biomechanics of the golf swing creates a feeling for the areas that a professional will have to capture, and the detail that this information needs to be in. The biomechanical analysis also indicated the vast difference in rotation, extension and flexing of different orthodox golf swings. indicating the need for a professional to analyse the swing. The requirements for the system were built upon these principles, as well as thorough analysis of the current systems of teaching pupils golf. This, combined with details of HCI principles that aid the development of usable software, led to the basis of the design process.

The design was performed with the aid of a local teaching professional; to utilise his knowledge and experience of coaching golf. The golf professional chosen was a personal friend, as well as my personal coach and so access to him was less formal than would often be the case in other participatory design techniques. This was key in the development of the final system, as many of the design ideas that were explained during more formal conversations quickly became confused. These confusions related to the explanation of psychological principles and were overcome using informal conversation. Details of this issue are described in further detail later in the chapter. The initial designs were developed into a final system whose user interface was then developed also using a participatory method, leading to the redesign of the layout and components of many of the systems.

The implementation of the system was performed in Visual C# to encourage a Windows “look and feel” as well as to utilise the built in system tools for video control and database control. The system heavily relies on the use of server technologies, utilising a SQL server, a web server and an FTP server reflecting the movement of technology to the Internet.

The evaluation of the system indicated that the system allowed learning and the coach was able to utilise the majority of motor learning theories that were indicated in the literature review. Additionally the system showed no major usability errors, meaning that the pupil will receive uninterrupted coaching. Finally, the evaluation of the system can be used to form the basis for hypotheses on the success of the system when used for coaching as will be described in this section.

7.2 Methodology

A variety of well know practices were used throughout the system and there are a number of interesting findings associated with these employed practices. The following two methods have their issues discussed as well as the possibility for further work in these areas.

7.2.1 Participatory Design

Participatory design was used throughout the system development process with many areas of the system being affected by this process. Communication with the professional was regular and occurred through both formal and informal means. Initially the majority of the conversations on the topic of the system were formal, with questions specifically asked. The process however developed a more informal attitude as the design process continued.

The reasons for the shift in approach are two-fold; firstly, both parties got used to the idea of the design process, and secondly the process was more successful when it was more informal. The increase in effectiveness of the process being related to the increase in informal conversation is something Curtis et al. (1988) also noted. The initial formalities differed from the very informal relationship that usually exists between the professional and myself. Kraut et al. (1993) indicated a reason for this initial change, stating that official roles can alter the nature of conversation. This change in role could have been one of the reasons the formal conversations did not appear to be effective, with the nature of the conversation being foreign to both parties.

This dissertation indicates that the type of conversation is important to the participatory design process where the participants are known and two factors that could influence the effectiveness of the process: if the conversation is formal or informal, and if the participants are playing their natural role in the conversation.

7.2.2 Learning Evaluation

The learning evaluation, although very short and limited in its scientific method, produced a large amount of information about the learning process with the system.

The evaluation itself was subjective, the evaluation of the pupil's performance being conducted by the teaching professional. This raises an interesting question: if a different professional had carried out the evaluation would the results have been the same? Different professionals have different teaching methods and as such some may not have taught the "one-piece" takeaway that our pupil was coached.

However less subjective data could be gathered, through recording the process it was possible to highlight areas of coaching theory that the professional may not realise they are using. The level of the information given to the pupil with the system is increased along with the level of Knowledge of Results (KR) that the pupil receives. The type of KR received is varied and is in the form of both summary and immediate. The system must be carefully used to ensure that the pupil does not begin to 'crave' KR through frequent professional feedback; this can be done through the professional amalgamating practice videos into a single piece of feedback to the pupil.

The issue of KR and its effects on performance raised in this dissertation led to the possibility of a study being created to determine the effect of summary KR on both pupil and coach performance. The variables that could be controlled are:

1. The type of KR the coach receives of the pupil's swings (summary vs. detailed individual)
2. The type of KR the pupil receives (summary vs. detailed individual)
3. The type of feedback given to the professional (video vs. pupil record of 'feeling' vs. both)

In addition to the above variables, the type of feedback that the pupil receives can be viewed in an alternative method. The concrete video is actually an abstract representation of the golf swing for the pupil - with the pupil never being able to see their swing from this 'out of body' experience during normal play. However, the abstract description of the 'feeling' of the movement the pupil is getting could be viewed as a more concrete representation for the pupil. Through including both of these notions in the system, the professional is able to receive both concrete and abstract views on the pupil's practice.

Current research has not covered the feedback given to the professional and the way this feedback is given could affect the coaching the pupil receives. To effectively evaluate the difference a longitudinal study of golfer performance would need to occur. Unfortunately, with golf quantitative analysis is not always a valid method of assessment, and qualitative methods would be needed to both complement and supplement the numerical data. Problems with quantitative data include variables in conditions and equipment (e.g. different balls perform better with different swing types) when dealing with distance and accuracy based skill tests. Additionally, handicap alone cannot be considered as a measure for analysis, for example a pupil who greatly improves their golf swing but shows a limited improvement in their short game typically will not show the same reduction of handicap as a pupil who improves their short-game greatly but fails to show the same level of improvement in their golf swing.

Qualitative evaluation often has an expert comparing the swing to a predefined mental image of the correct movement (Knudson et al., 2002) and as such the evaluation would be based on the conformance to a predefined image, rather than a

set of criteria. This poses problems; firstly a professional will teach to their image, not an independent image (should this image be able to be defined) and secondly, the best person to assess development of a pupil to a specific professional's model, is the professional to whom the mental image belongs, bringing bias into the evaluation.

It is possible to see that there are numerous problems with testing, however through combinations of qualitative and quantitative evaluations of performance, over a long period of time an accurate picture should be able to be produced.

7.3 Further Developments

7.3.1 Applying This System to Other Sports

One question that must be raised when developing systems, what are the system's alternative uses? It is natural to look to expand a coaching system into other areas of sport. However, in order to do this we must analyse what would make this system successful in golf, and how does that transcend to other sports.

Golf is a heavily 'technique based' sport and unlike many other sports an increase in aerobic fitness will not have a great effect on success rates of the average golfer. However, other sports do place a similar importance in good technique and these, like golf, tend to be individual sports (or sports where you compete as an individual in a team environment such as a batsman in cricket). In many team-based sports, importance is placed on developing tactics to support team play, or counteract opposition play. In golf neither of these practices are needed.

In addition the individual nature of the sport encourages the individual practice sessions that are key to the learning model employed in this system. Below are two of the sports the system could be adapted for use in:

1. **Cricket** - Both batsman and bowlers rely heavily on their technique, with a batsman having only a very limited time to react to a ball travelling at up to 100mph; similarly a bowler must propel the ball at these speeds with staggering accuracy. Cricketers often have technique-based errors similar to golfers, e.g. unwanted head movement (the head moving across the line of the stumps can lead to a batsman being frequently caught l.b.w.).
2. **Running** - Although an aerobic based activity, technique plays a huge role in deciding the winner in a race lasting less than 10 seconds. Gait analysis of the participant can indicate incorrect leg or head positions, and slow motion analysis will enable this analysis. Again, like golf, running would require the role of a coach for analysis as many very successful athletes have "unorthodox" techniques (e.g. Michael Johnson and Paula Radcliffe).

7.3.2 An Alternative Way of Using HCI in Coaching

HCI is currently moving towards encouraging creativity support by technology, i.e. by computers, as opposed to focusing on efficiency of task completion. Creativity in coaching is important; often coaches will have to think of creative ways to explain a technique, ideally building on the pupil's existing implicit knowledge.

One of the main advocates for the use of creative technology in golf is David Leadbetter. Leadbetter is regarded as one of the finest golf coaches in the world and he utilises a number of creative techniques to aid coaching. Often these are not heavily technology based, and are used as aids for developing mental representations of the golf swing. One of the Leadbetter's creations is the SwingSetter pictured in Figure 7-1. The balls on the SwingSetter move, giving visual and audible cues for different positions of the swing and provide one example of a creative way of providing the user with feedback.

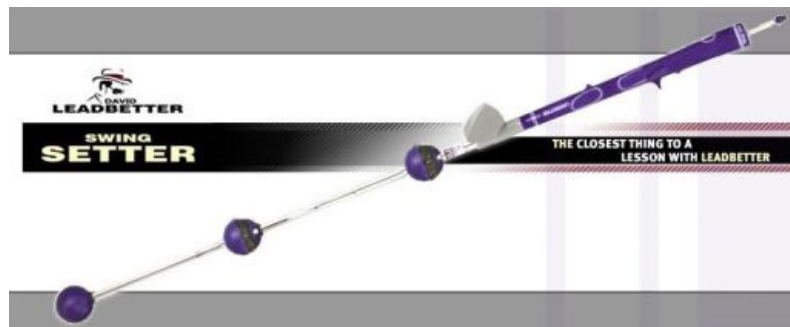


Figure 7-1 David Leadbetter SwingSetter

If creativity is to be supported in the system, the role of the system needs to be clearly defined, particularly where in the creative process should the system sit. Lubart (2005) defines four categories of creativity support:

1. Management of creative work
2. Communication between collaborators
3. Creativity enhancement techniques
4. Integrate human-computer cooperation

It is unlikely that any professional would wish the system to sit in the third and fourth categories, feeling that the system is taking something from their job professional role. However, there is a role for the system in the first and second categories. Through aiding the management of creative work, the system will allow the coach to focus on the development of creative communication methods to the pupil. These methods could be as simple as line fitting to a golf club, or as involved as setting an appropriate lesson schedule for the pupil's ideal development. All of these methods reduce the cognitive demands on the coach, freeing up their resources for coaching. Any future research in this area would ideally consider two areas: the effect of the system on coach creativity, and the effect of coach creativity on pupil performance.

7.4 Guidelines for Coaching Systems

During the development of the system a number of issues were faced which can be learnt from in the development of future coaching systems. These issues have been summarised in the form of guidelines for the development of future coaching systems. They are deliberately designed to be vague, in order to force the developer into thinking about issues they may face when developing for different sports:-

1. Simple and clear User Interface

Most coaches have limited computer experience so keep the user interface simple and clear.

2. **Incorporate 'standard' advanced OS features into the system**
Coaches often learn a small subset of advanced features from the operating system to speed up their work – incorporate these into the system.
3. **Use Informal Communication**
Talking outside of their natural language and environment does not lead to good results. Coaches are great at explaining things – it's their job – take advantage of it!
4. **Do not treat all feedback in the same way**
The feedback a coach gives or receives when teaching comes in a variety of forms, most of which are not obvious until they are analysed in detail, even to the coach.
5. **Evaluations are difficult**
Coaching is a specialist skill; coaches do not have the usability experience to carry out excellent heuristic evaluations. However, usability experts may not have the necessary coaching skills to test the system for usability issues. A compromise must be sought.

7.5 Summary

The dissertation has reviewed and used as a foundation many areas of coaching system development; from the way the coach receives information, and then how they relay it back to the pupil. In addition, a number of future research areas have been identified including the role of creativity in sports coaching, the role of informal conversation in participatory design and how feedback received by the professional affects their pupil's performance.

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Appendix A - Existing System Flow Diagrams

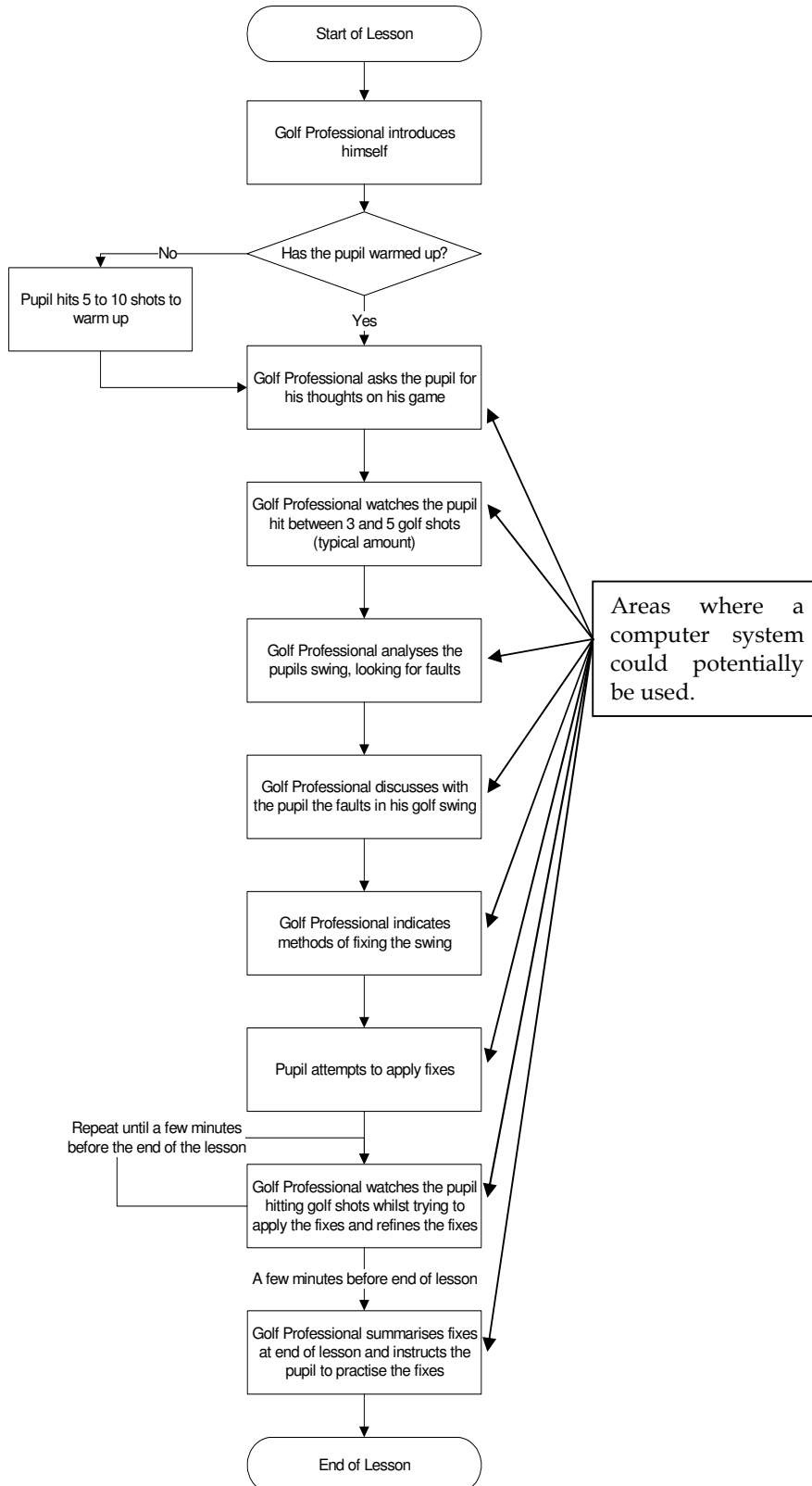


Figure A-1 Flow diagram of the lesson format

Advanced Golf Tutor

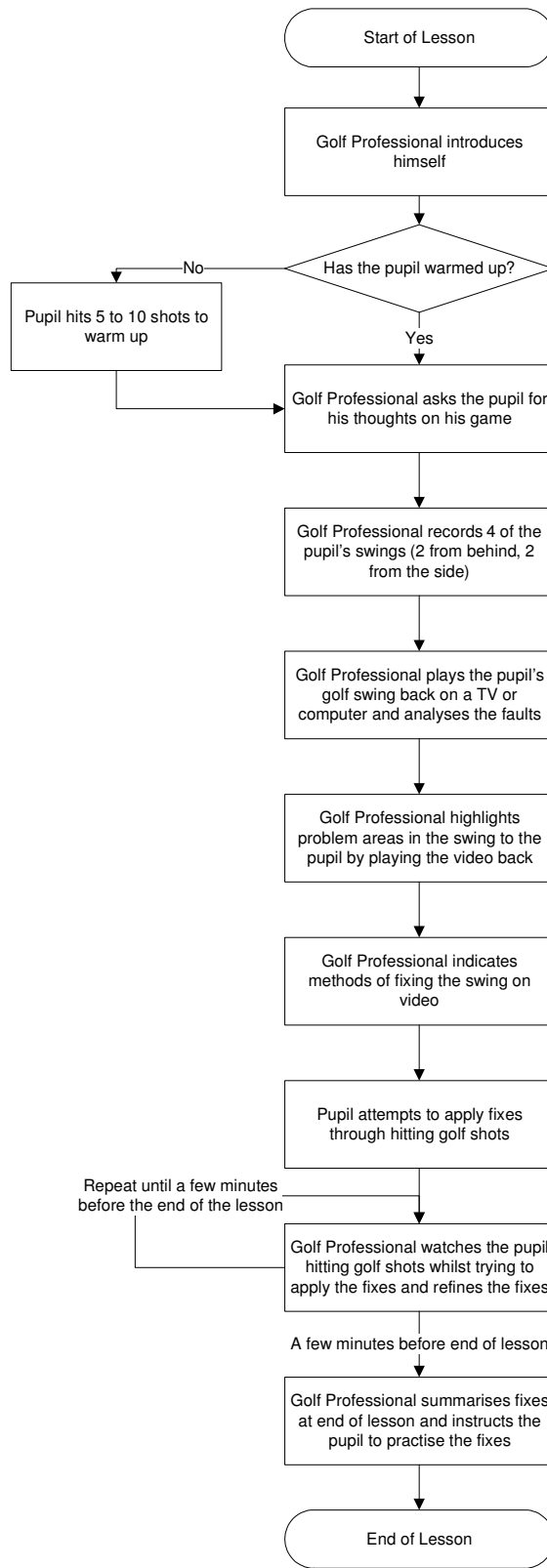


Figure A-2 Flow diagram of a typical video lesson

Appendix B - Conversations with users

B.1 Summary of conversation with golf professional

1. What are the best aspects in the GASP system?

Being able to show the customer their swing helps me to demonstrate to them their faults. Being able to store the files for future reference.

2. What do you use the most when teaching with GASP?

I use the split screen to compare a good swing with the customers. I also use the swing plane facility quite often.

3. Do you feel pupils learn better with the GASP system?

I feel the experienced golfer learns more from gasp as their faults are often miniscule and are easily picked up on screen.

4. What are the worst / most annoying bits of GASP?

Having to pay for an extra program to download images for customers.

5. Was GASP easy to learn to use?

Once shown it was fairly straight forward.

6. Are there any improvements that you would like to see in GASP?

No because I use only the basic functions.

Basically I have had a few ideas and would like you to comment on whats good / bad about them, with improvements/suggestions. All of these would be in addition to the basic features of GASP. Also if you have any ideas of your own please include them.

The first idea being using the web to allow you to post the videos of lessons on the web with what you felt were the problems with the swing and the feeling to fix them so that the pupil can access them outside of the lesson.

From a business prospective I would not find this an advantage as people through the door increases sales at the club. This personal contact would also be better for the pupil as information sent via web could be like reading a book. Information good but I believe the pupil needs to feel the positions taught. What a pupil thinks they are doing is not necessarily what they are doing. If used in conjunction with a 'traditional' lesson, it could possibly be useful.

The second being allowing the user to upload videos of them practising after a lesson with comments on the feeling they are trying to create to allow you to see how they are trying to change something and how its going wrong for them. This could then be used by you in the next lesson to help them change the movement.

If the video received was not filmed from the correct angles then it would be difficult to make the correct comments. Also time would be a big issue, especially if the pupil was not paying an acceptable rate for this service.

B.2 Summary of conversation with end user

How often do you have lessons?

Once a fortnight to once a month

What makes you go for lessons?

To improve my golf so I can compete better in competitions. The golf professional helps improve my game

What type of lesson do you have?

Normally I have a lesson using the GASP system, however occasionally I have a standalone lesson if it is a quick "checkup"

What are the best/worst bits about lessons?

One of the best bits about a lesson is knowing how you stand, where the club is at different phases, something that you can't get from 'feelings' alone. However, once a fix has been told by the pro it is often difficult to remember the exact words, and often a movement that I was feeling gets 'overdone' or is incorrect. Often when explaining this movement to the pro at the next lesson you begin to realise why the movement is incorrect.

What are the best bits about GASP?

Being able to compare your swing with another pro, and also to see your swing as others see it

What are worst aspects of GASP?

Not being able to use it outside of lessons

B.3 Design screens modified with user

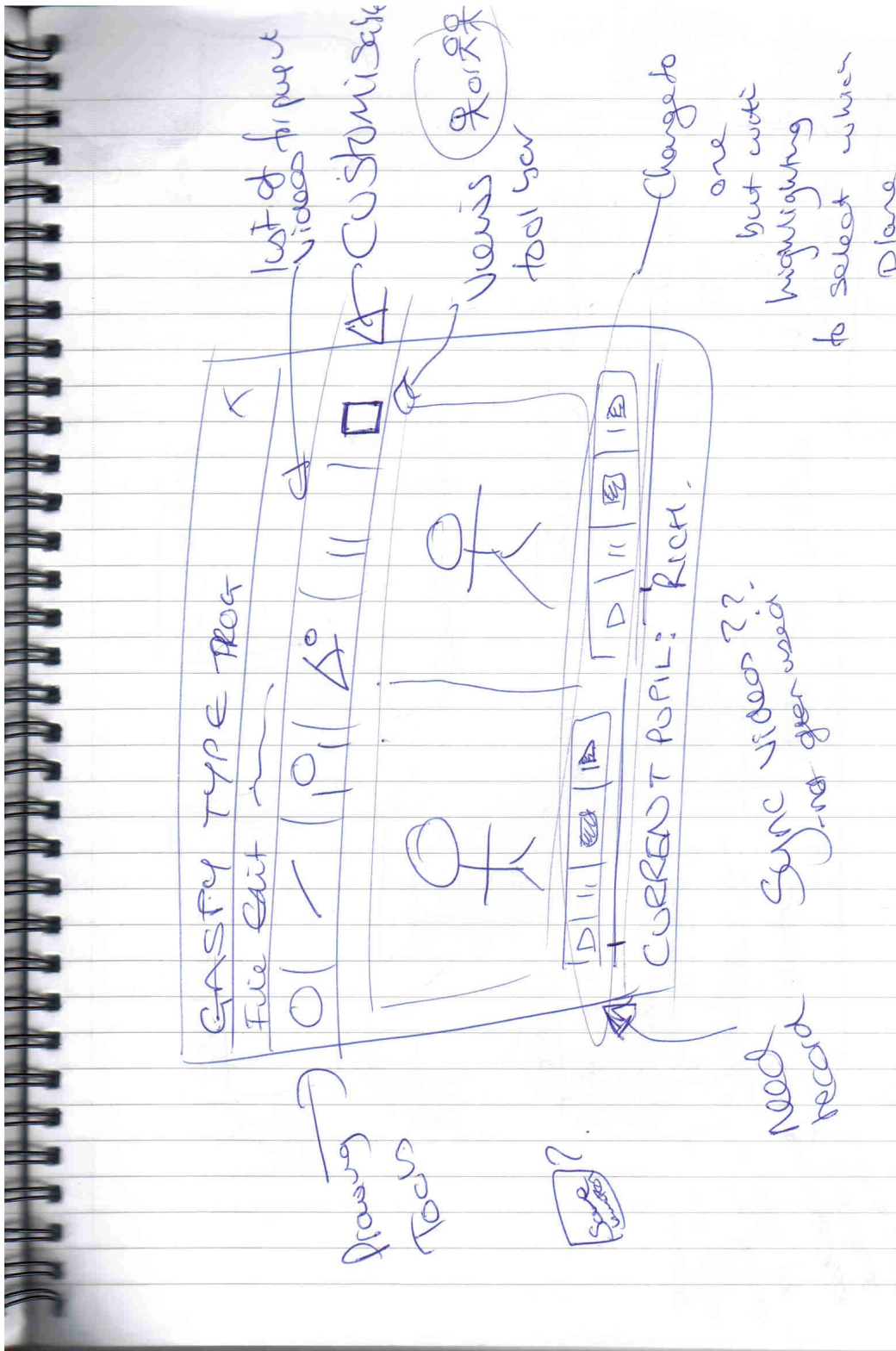


Figure B-1 User modified design of main screen

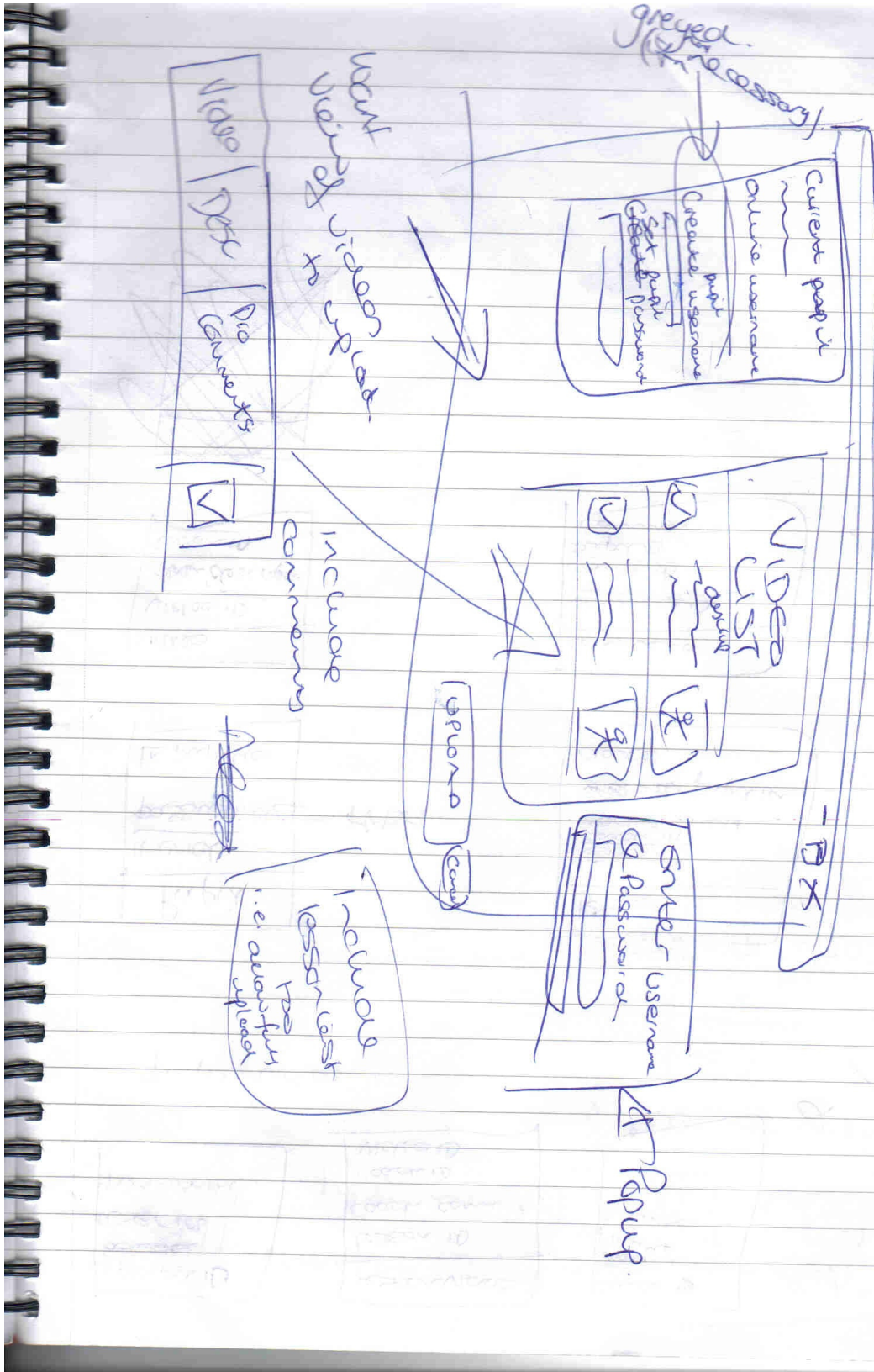
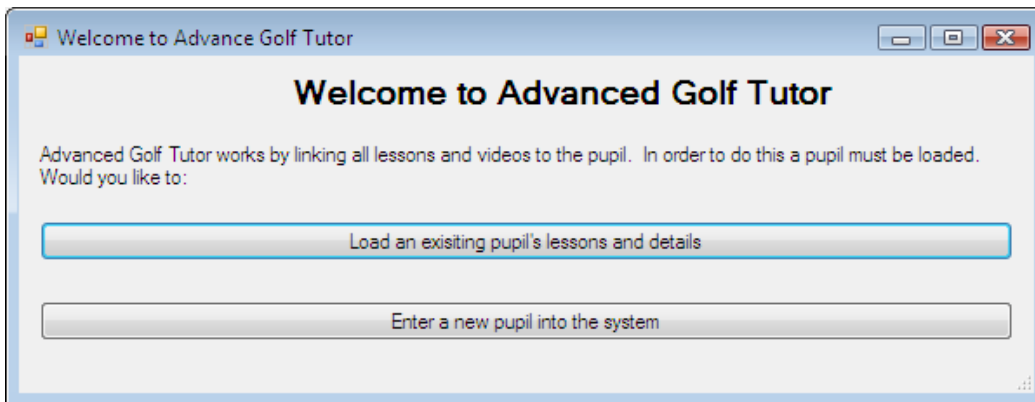


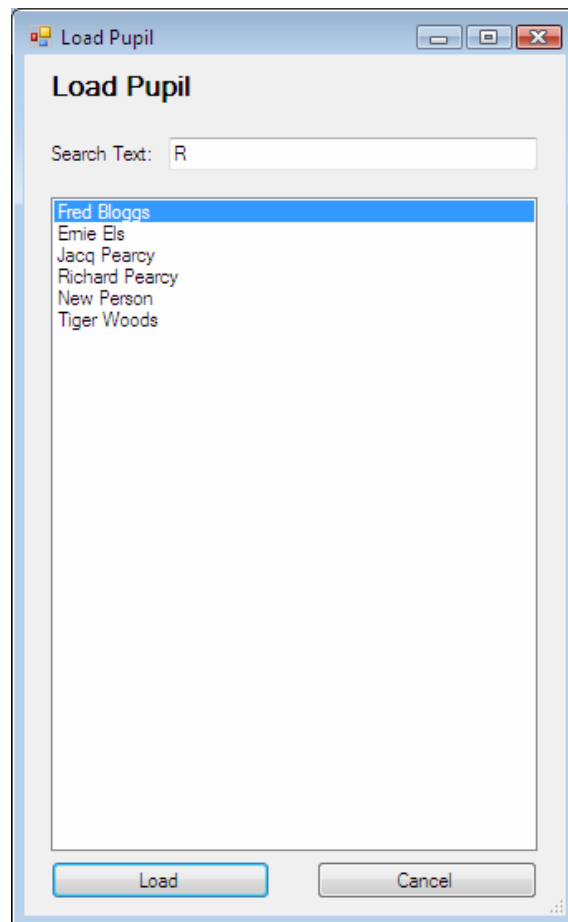
Figure B-2 User modified design of upload pupil

Appendix C - Coach System Screen Shots

C.1 Welcome Screen



C.2 Load Pupil



C.3 New Pupil

Add new pupil

Firstname: Joe
Surname: Bloggs
Main Coach: Bob Smith
Telephone: 0123456789
Email: joe@bloggs.com
Address Line 1: Joes House
Address Line 2: Joes Lane
Town: Joesville
County: Joeshire
Post Code: JO3 4BL

Buttons: Add Pupil, Cancel

C.4 Main Screen

Advanced Golf Tutor

File Pupil Lesson Video Website

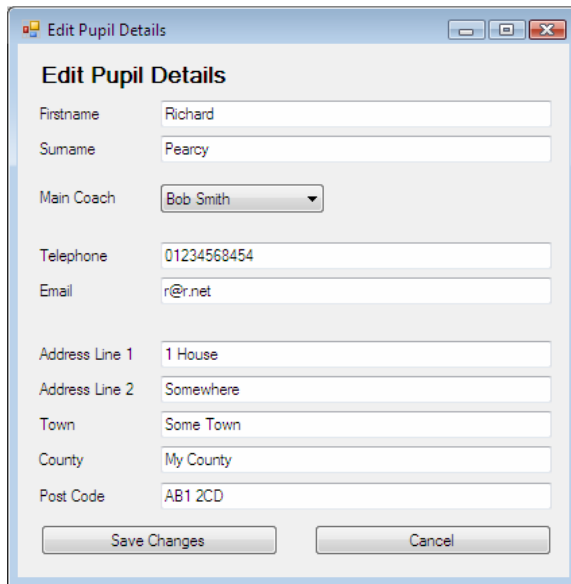
Single Video 2 way split Play Pause Stop Circle Line Sway Angle Erase

Comment By: Bob Smith
Great!!

Comment By: Richard Pearcy
Poor

Current Lesson: (none) Current Pupil: Richard Pearcy

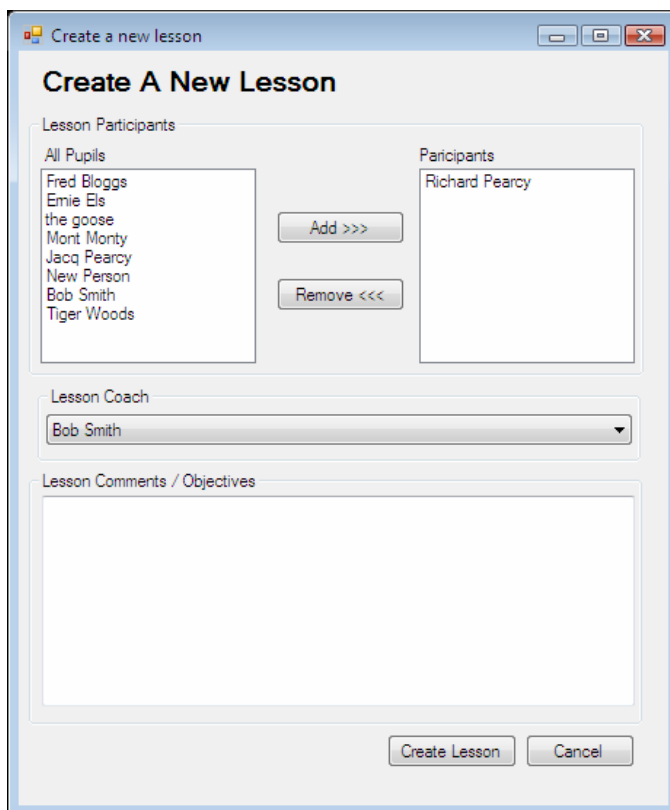
C.5 Edit Pupil Details



The 'Edit Pupil Details' dialog box contains the following fields and controls:

- Firstname: Richard
- Surname: Pearcy
- Main Coach: Bob Smith (dropdown menu)
- Telephone: 01234568454
- Email: r@r.net
- Address Line 1: 1 House
- Address Line 2: Somewhere
- Town: Some Town
- County: My County
- Post Code: AB1 2CD
- Buttons: Save Changes, Cancel

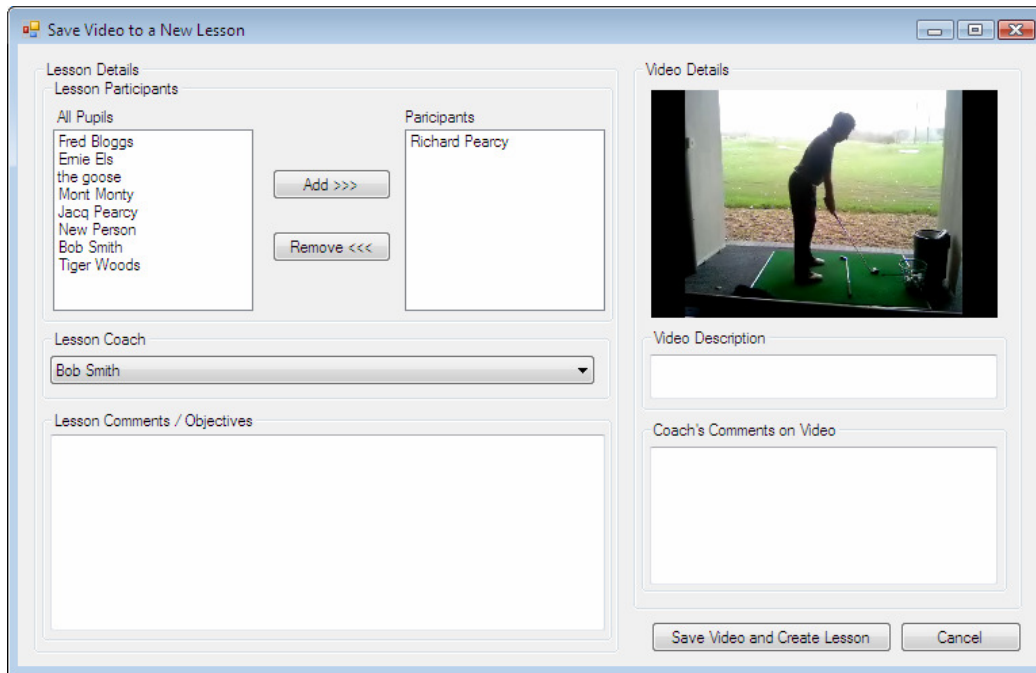
C.6 Create Lesson



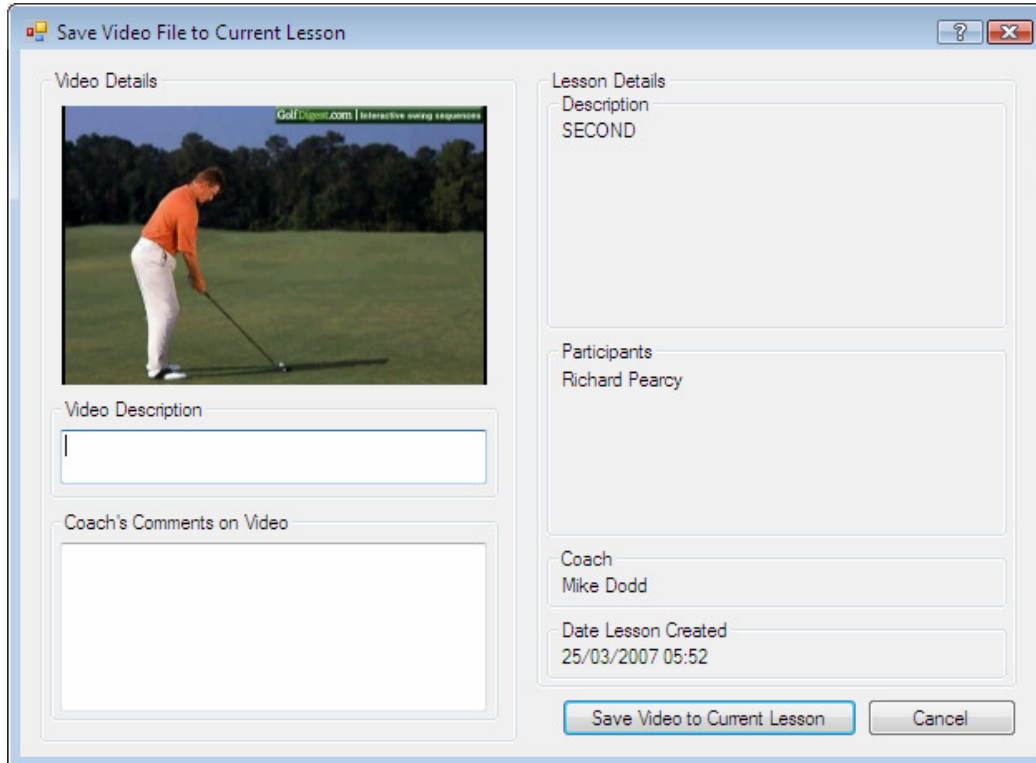
The 'Create A New Lesson' dialog box contains the following sections and controls:

- Lesson Participants:**
 - All Pupils: Fred Bloggs, Emie Els, the goose, Mont Monty, Jacq Pearcy, New Person, Bob Smith, Tiger Woods
 - Participants: Richard Pearcy
 - Buttons: Add >>>, Remove <<<
- Lesson Coach:** Bob Smith (dropdown menu)
- Lesson Comments / Objectives:** (Empty text area)
- Buttons: Create Lesson, Cancel

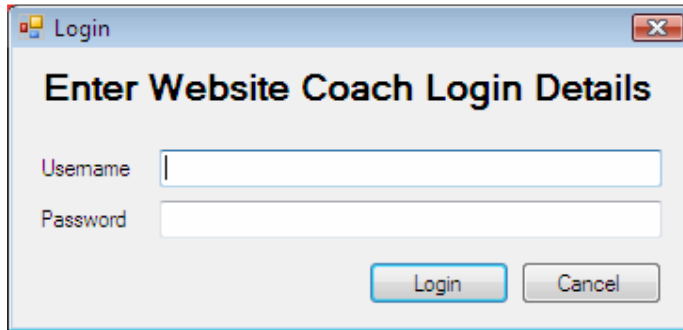
C.7 Save Video to New Lesson



C.8 Save Video to Current Lesson

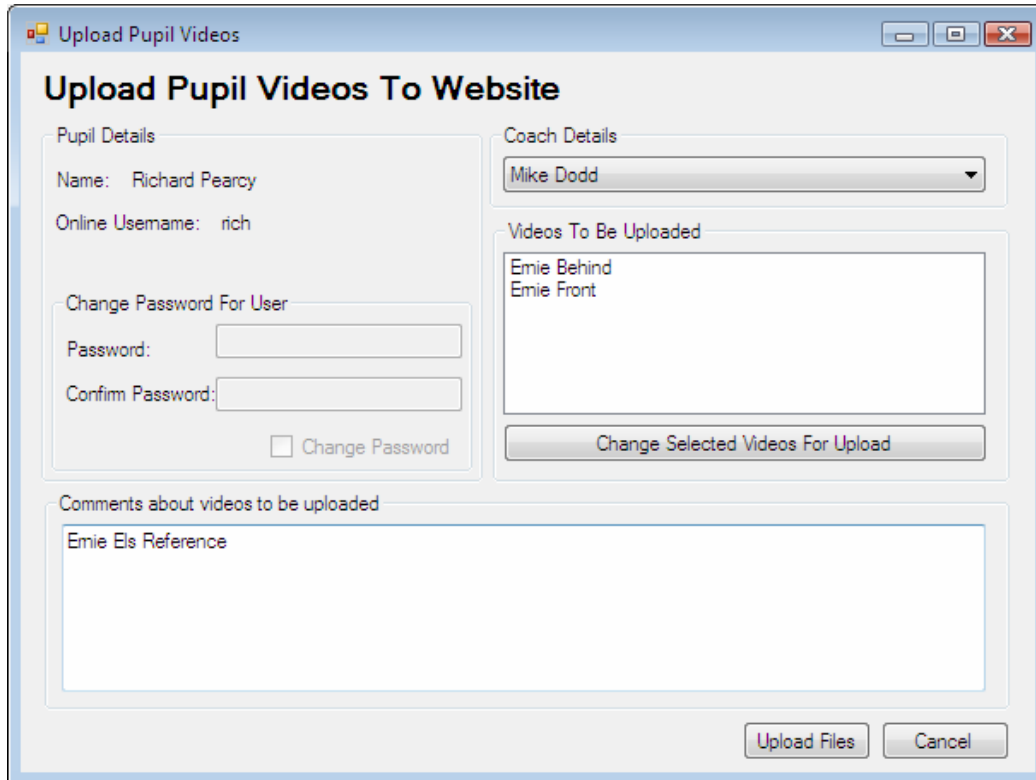


C.9 Login Screen



The screenshot shows a standard Windows-style dialog box with a title bar that says "Login". The main heading inside the dialog is "Enter Website Coach Login Details". Below the heading, there are two text input fields: "Username" and "Password". At the bottom of the dialog, there are two buttons: "Login" and "Cancel".

C.10 Upload Pupil Videos

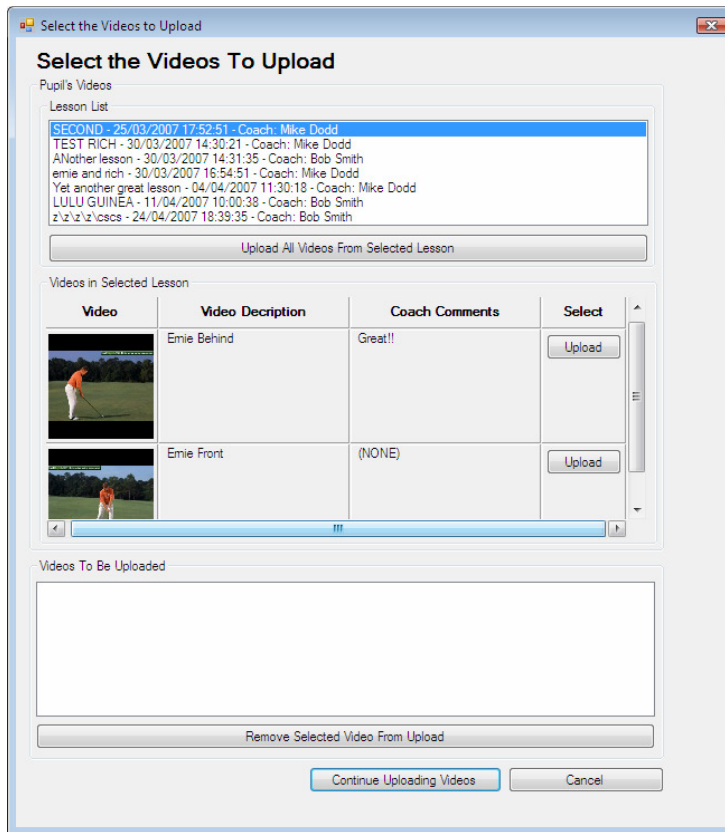


The screenshot shows a dialog box titled "Upload Pupil Videos". The main heading is "Upload Pupil Videos To Website". The dialog is divided into several sections:

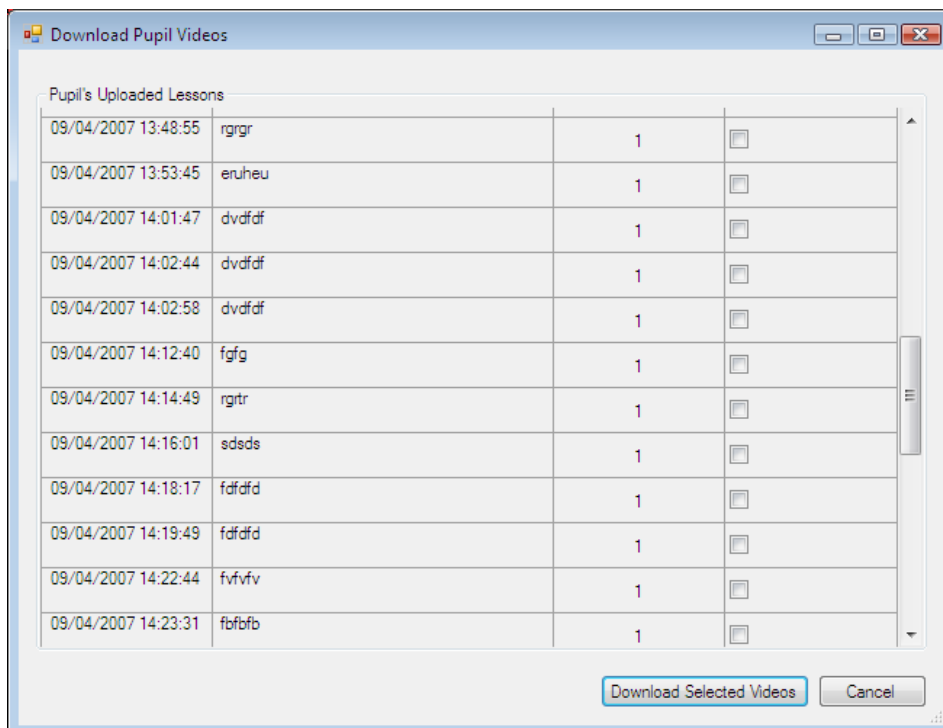
- Pupil Details:** Name: Richard Pearcy, Online Username: rich.
- Coach Details:** A dropdown menu showing "Mike Dodd".
- Change Password For User:** Fields for "Password:" and "Confirm Password:", with a checkbox labeled "Change Password" below them.
- Videos To Be Uploaded:** A list box containing "Emie Behind" and "Emie Front", with a button "Change Selected Videos For Upload" below it.
- Comments about videos to be uploaded:** A text area containing "Emie Els Reference".

At the bottom right of the dialog, there are two buttons: "Upload Files" and "Cancel".

C.11 Select Uploaded Pupil Videos

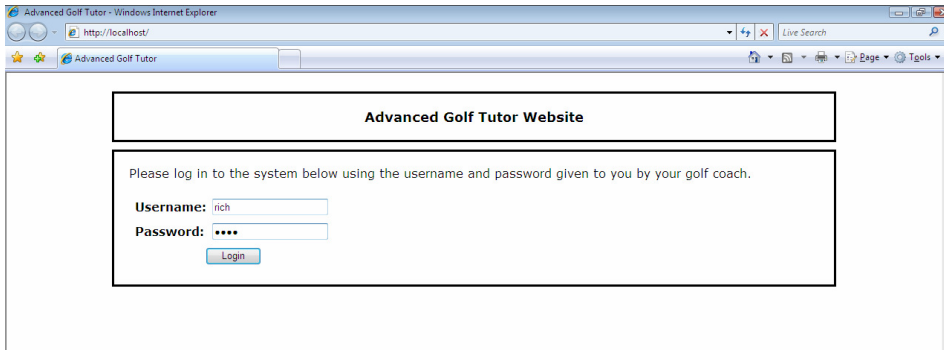


C.12 Download Pupil Videos

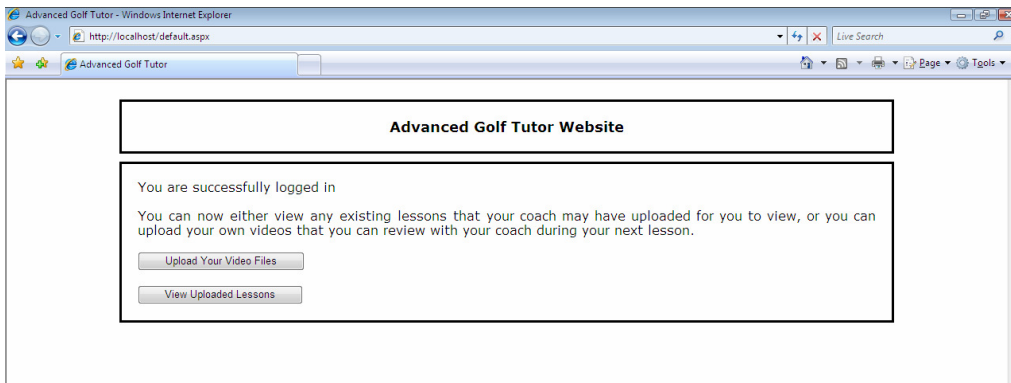


Appendix D - Website Screen Shots

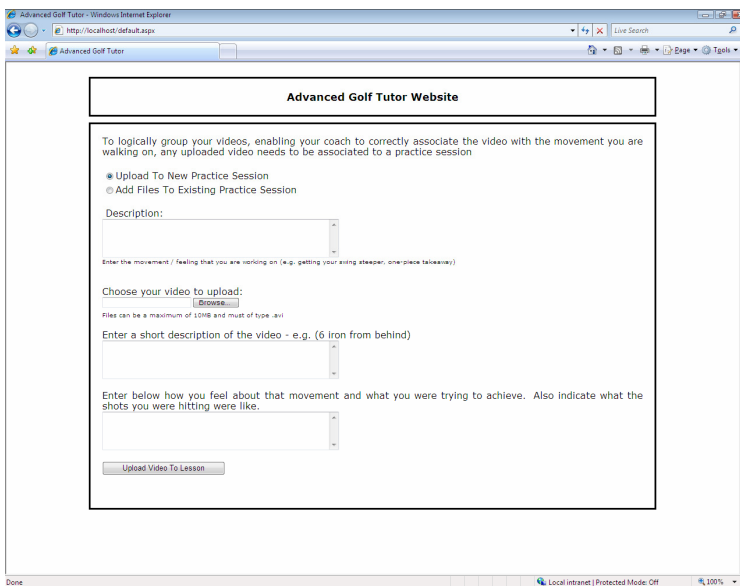
D.1 Login Screen



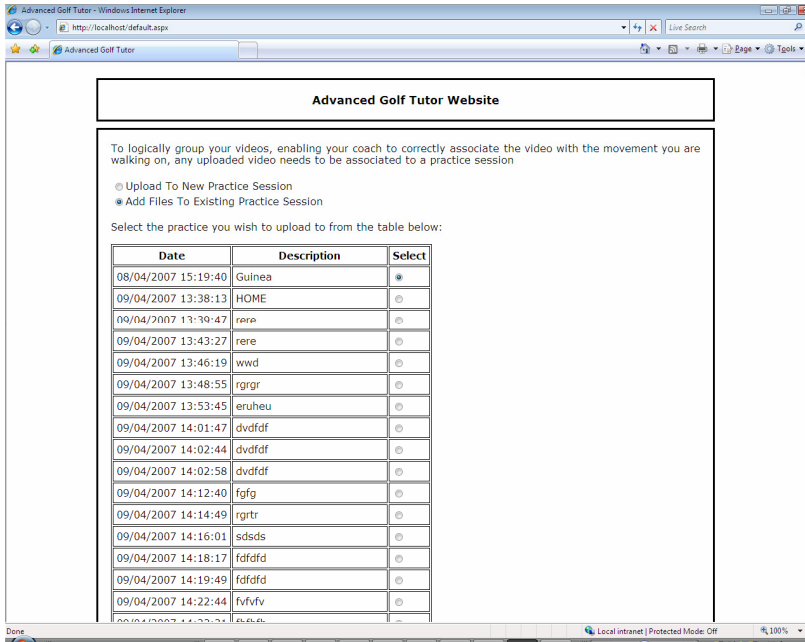
D.2 Select Screen



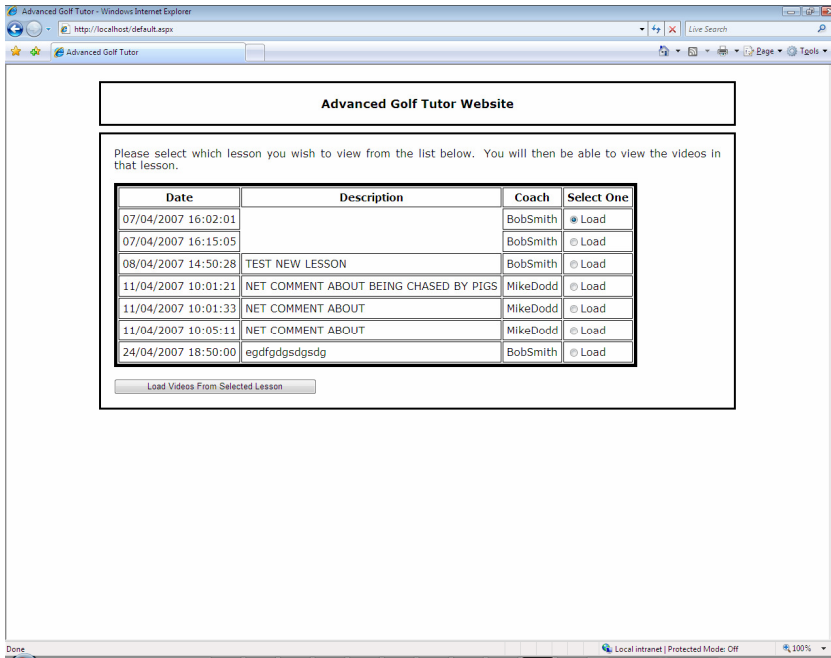
D.3 Upload Videos to New Practice Session



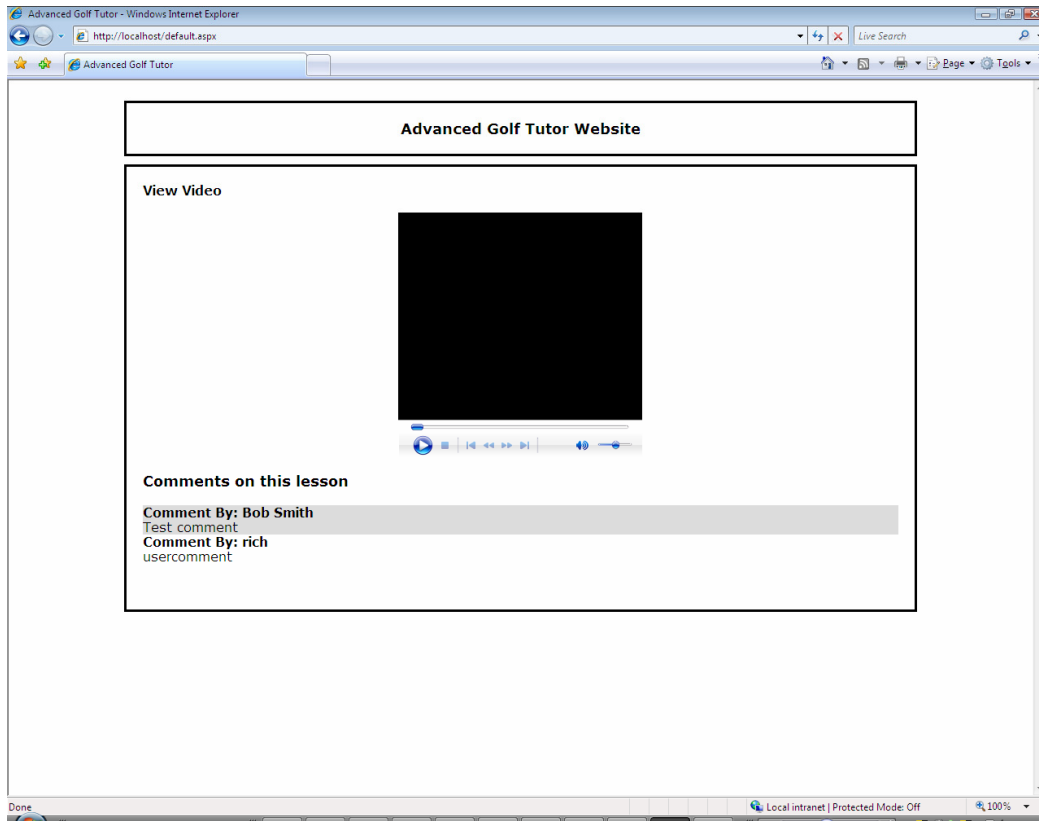
D.4 Upload Videos to Existing Practice Session



D.5 Select Upload Lesson to View

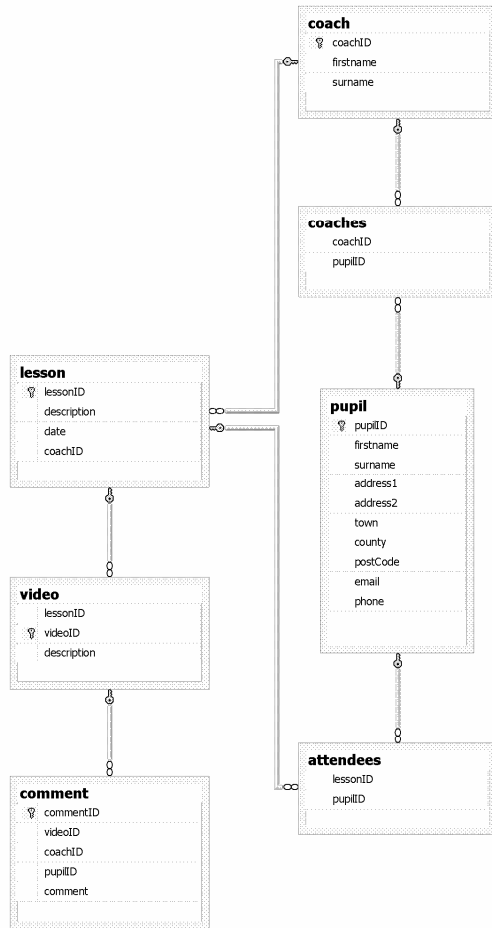


D.6 View Uploaded Video



Appendix E - Database Diagrams

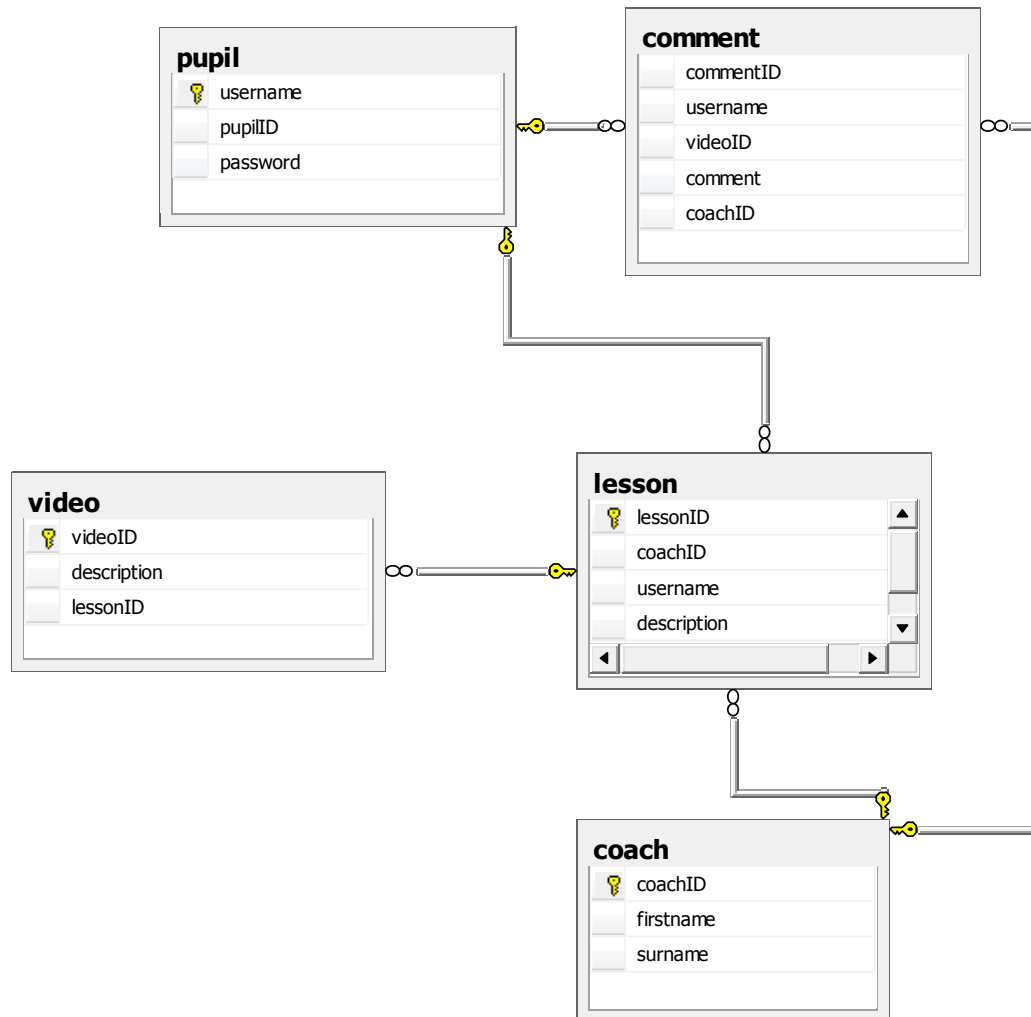
E.1 GolfCoaching Database Diagram



1-1

Figure E-1 Golf Coaching Database Diagram

E.2 GolfOnline Database Diagram



Appendix F - Guidelines

F.1 Nielsen's Usability Guidelines

- 1. Visibility of system status**

The system should always keep users informed about what is going on, through appropriate feedback within reasonable time.
- 2. Match between system and the real world**

The system should speak the users' language, with words, phrases and concepts familiar to the user, rather than system-oriented terms. Follow real-world conventions, making information appear in a natural and logical order.
- 3. User control and freedom**

Users often choose system functions by mistake and will need a clearly marked "emergency exit" to leave the unwanted state without having to go through an extended dialogue. Support undo and redo.
- 4. Consistency and standards**

Users should not have to wonder whether different words, situations, or actions mean the same thing. Follow platform conventions.
- 5. Error prevention**

Even better than good error messages is a careful design which prevents a problem from occurring in the first place. Either eliminate error-prone conditions or check for them and present users with a confirmation option before they commit to the action.
- 6. Recognition rather than recall**

Minimize the user's memory load by making objects, actions, and options visible. The user should not have to remember information from one part of the dialogue to another. Instructions for use of the system should be visible or easily retrievable whenever appropriate.
- 7. Flexibility and efficiency of use**

Accelerators -- unseen by the novice user -- may often speed up the interaction for the expert user such that the system can cater to both inexperienced and experienced users. Allow users to tailor frequent actions.
- 8. Aesthetic and minimalist design**

Dialogues should not contain information which is irrelevant or rarely needed. Every extra unit of information in a dialogue competes with the relevant units of information and diminishes their relative visibility.
- 9. Help users recognize, diagnose, and recover from errors**

Error messages should be expressed in plain language (no codes), precisely indicate the problem, and constructively suggest a solution.
- 10. Help and documentation**

Even though it is better if the system can be used without documentation, it may be necessary to provide help and documentation. Any such information should be easy to search, focused on the user's task, list concrete steps to be carried out, and not be too large.

Appendix G - Supplied Files

The supplied code for the system will not run “as is” and requires some configuration of the system that it will be run on.

- An FTP, a web and a (two if local and remote databases are on different machines) SQL servers are required.
- Install Microsoft DirectX SDK
- The SQL server(s) must have the GolfOnline and GolfCoaching database created to required using the supplied scripts.
- The FTP upload space must allow the user coach (with password “coach”) write permissions on the directory websaddress/videos/.
- The remote SQL server must have give the users coach and web (with password “webpassword”) permissions
- The settings file in the coach system must be updated to indicate the location of the video files.
- The remoteSettings and dbsettings must have the server details included in them.
 - remoteSettings.txt format
database location
database name
ftp location
website location
 - dbsettings.text
database location
database name
- The system must be built using visual studio (solution files for each in the appropriate directory) as well as compiled website files in a separate directory if these are preferred (although recompiling and publishing is recommended)