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A sports technology needs assessment for performance monitoring in swimming

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Abstract

In recent years, technology has played an increasing role in many sports, including swimming. Far beyond the stopwatch and hand marked events, detailed biomechanical attributes can be measured using technology such as instrumented blocks, wire tethers and underwater/dolly cameras. With the advent of micro-technology, there has been an increasing trend toward the use of wearable sensors such as heart rate monitors, cadence aids and – more recently – activity monitors. The micro-electromechanical system (MEMS)-based inertial sensor class of activity monitor is of particular interest to the CWMA (Centre for Wireless Monitoring and Applications) at Griffith University.

Due to the intensely competitive nature of professional sport, the difference between winning and not winning can be as little as a few hundredths of a second. An improvement to any single physiological or psychological parameter could potentially give one athlete a ‘winning edge’ over his or her competitors. This paper provides a context-driven needs assessment to illustrate the first step toward achieving this goal through the use of technology in swimming.

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Keywords: context-driven needs assessment; inertial sensors; winning edge; stakeholders; athlete; coach; sport scientist; researcher

1. Introduction

One of the primary objectives in high performance sport is to achieve success measured in terms of championships or medals won, and world records held. The workforce responsible for such achievement

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includes high performance directors, sport scientists, coaches, and the athletes themselves. These stakeholders utilize expert knowledge from a range of dominant scientific disciplines including physiology, biomechanics, motor control, perception and motor learning, and even nutrition and psychology, to maximize training and competition performance. The quantitative measures for performance in these disciplines can be used to define the needs and requirements of information and monitoring systems, which seek to facilitate improvement in elite level athletic performance by providing feedback [1].

In pursuit of developing an integrated performance monitoring system for aquatic use, Justham et al published a critical evaluation in 2008 of existing analysis techniques in swimming [2], and concluded that more thorough feedback could be provided through the use of inertial sensor technology. As a form of needs assessment, Le Sage et al furthered the research in 2011 [3] by surveying key stakeholders – coaches, biomechanists and swimmers – to develop a list of user requirements ranked by importance. The most highly ranked requirement – “sport/skill specific measures” – suggests that targeting specific sports, contexts and/or stakeholders will help to define project scope.

This paper seeks to extend what is known about needs and requirements assessment in sports technology by applying the context-driven approach by Ringuet-Riot [4] to an existing cloud-based software project [5] for the sport of swimming in Queensland, Australia. This software project, tentatively referred to as VDAT (Visual Data Analysis Toolbox), depends heavily on the ability for users to interact with technology. For this reason, each context in this context-driven needs assessment can represent a location, range of time and/or comparative form of analysis.

2. Contexts

By dividing project requirements into location/time/comparison contexts, it is possible to loosely categorise the technology and information relevant to each, as well as the interrelationships between them. In this study, each context represents a set of end goals that is then grouped by the stakeholders to which they are most relevant. The first context/stakeholder target is a fine grain view of the athlete; the last is a course grain view of the research potential. The eight contexts selected for this study are as follows:

- Pool Session: While the athlete is training or competing in the pool, and the coach is supervising.
- Exercise Session: While the athlete is exercising in the gym or otherwise, and the coach is supervising.
- Post-Session: After the completion of a single training or competition session.
- Intra-Season: Within a group of training and/or competition sessions.
- Inter-Season: Between seasons.
- Multi-Season: Across two or more seasons worth of data.
- Multi-Athlete: Comparing performance of two or more athletes within the same sport.
- Multi-Sport: Differences in requirements for sports other than swimming.

3. Stakeholders

While contexts provide constraints, stakeholders define the required outcomes. Within each context, stakeholders may have typical and/or atypical requirements for the system depending on their areas of expertise and the team or teams they are working with. Each stakeholder brings a unique set of skills and is looking for their own set of key performance indicators relevant to their work. In order to link stakeholders to their corresponding contextual targets, each stakeholder was classified into one of four major categories. The four categories for this study are defined as follows:

- Athlete: A swimmer who participates in training and competition.

- Coach: The primary supervisor of one or many athletes, who is tasked with keeping athletes on track, motivating them, pushing them to work harder and analysing their overall performance and wellbeing.
- Sport Scientist: A scientist skilled in analysing advanced sport-related metrics (e.g. biomechanist, physiologist, nutritionist), tasked with understanding the intricacies of technique (or other factors) and providing recommendations to one or many coaches.
- Researcher: An academic interested in finding new information, methodologies and technological progressions that can be demonstrated and validated in a peer-reviewable capacity. It is noted that, in the studies analysed, researchers are often excluded as stakeholders despite their relevance; in many cases, they will need the most detailed feedback in order to fulfill their academic requirements and continuously build upon contemporary technology.

4. Requirements Table

By means of a focus group, a cohort of five people assembled a table of useful performance metrics in swimming organised by stakeholder and context, thereby defining a framework to assist in the integration of existing research with evolving inertial sensor technology [5][6][7][8][9]. This integration process forms the basis of a larger project for which this paper attempts to outline the scope.

While requirements and targets can be individual to each stakeholder, many of them will be codependent; that is, other contexts as well as other stakeholders may share them. For this reason, Table 1 – the consolidated result of discussions within the focus group – allows each target (context/stakeholder pair; table cell) to use other targets as dependencies. Table 1(a) suggests useful metrics for athletes and coaches, while Table 1(b) details requirements for the broader sport scientist and researcher stakeholder categories.

Table 1(a). Athlete and coach stakeholder requirements for each of the eight contexts

	Pool Session	Exercise Session	Post-Session	Intra-Season	Inter-Season	Multi-Season	Multi-Athlete	Multi-Sport
Athlete	lap times, strokes per lap, golf score, training types, workloads	visual data, real-time feedback, validation against ergo, mocap and other systems	video replay, performance diary (stroke types, injuries, mood etc; simple and straightforward	historical progression mapping, milestones, workloads	competition milestones results tables, KPI improvements	as left, long-term goals, rate of improvement	'how do I compare?' 'what do I need to improve?' role models	as left, unconstrained environment,
Coach	as above, underwater video, stroke timing, stroke phase info, performance impact, objective measures	as above, historical data to compare, fatigue estimation	as above, video annotation, technique visualisations, athlete coaching tool	as above, volume, frequency, intensity, assessed injury monitoring	as above, basic measures, coaching interactions and interventions, compliance	as above, improvement of technique, ability to create and modify models to strive for	as above, as left, tailor programs to what each athlete requires	as left, injury prevention, pre/post - injury changes

Table 1(b). Sport scientist and researcher stakeholder requirements for each of the eight contexts

	Pool Session	Exercise Session	Post-Session	Intra-Season	Inter-Season	Multi-Season	Multi-Athlete	Multi-Sport
Sport Scientist	as above, fatigue metrics, kinetic measures, technique changes, symmetry	as above with more detail, as left , raw sensor data	drill into data from left , full flexibility to examine, cause and effect analysis, generate reports	from left , identify key performance indicators (KPIs), sensitivity analysis	as above , as left , advanced measures, changes in technique, performance outcomes	as above , as left , advanced visualisation techniques, data aggregation	comparative studies, X-factor, performance improvements from tools (e.g. skins), generic vs individual training, finding the best protocols	as left , environmental conditions e.g. heat, robustness, effect of equipment, technology as a toolkit
Researcher	as above, system verification, data plotting, data use metrics, gold standard	as left , validation studies, statistics	as above , raw data analysis, scripting tools, data plotting, visualisation	as above , long term study of KPIs, injury tracking	as above , as left , research questions, location, coaching details	as left , tactics and goals through research		

Even with a small cohort, it was difficult to have absolute agreement about which stakeholder requires which metrics, both due to the anecdotal and presumptive nature of the data, and because each individual and each team will create unique strategies to give them the winning edge over their competitors. Despite these limitations, the table can be used as an outline of how a targeted software project could be delegated among multiple developers to produce a prototype system for further evaluation.

To better illustrate how this information could be used, the dependencies in Table 1 – noted in bold – were extracted for use in Figure 1 as directional symbols. As with Table 1, each of the eight contexts are listed as columns and each stakeholder occupies a row. To represent dependency direction, ↑ indicates dependency on the above stakeholder's metrics, ← indicates dependency on the left context's metrics, and O indicates no dependency; the latter therefore indicating a potential starting point for development.

By selecting a target/end goal (any cell from Table 1 / Figure 1) and tracing it through each of its dependencies, it is possible to estimate the overall size and structure of any particular development proposal and thereby assist in judging its feasibility. Any number of end goals can be integrated to form a project. Project size and scope will depend on stakeholder requirements, and must consider the typical constraints of time, funding and manpower.

	PS	ES	PS	IS	IS	MS	MA	MS	
A	O	O	O	O	O	←	O	←	A
C	↑	↑	↑	↑	↑	↑	↑, ←	←	C
SS	↑	↑, ←	←	←	↑, ←	↑, ←	O	←	SS
R	↑	←	↑	↑	↑, ←	←	↑, ←	O	R
	PS	ES	PS	IS	IS	MS	MA	MS	

Figure 1. Dependency map from Table 1(a) and 1(b); row = stakeholder, col = context, O = starting point, ↑← = dependency

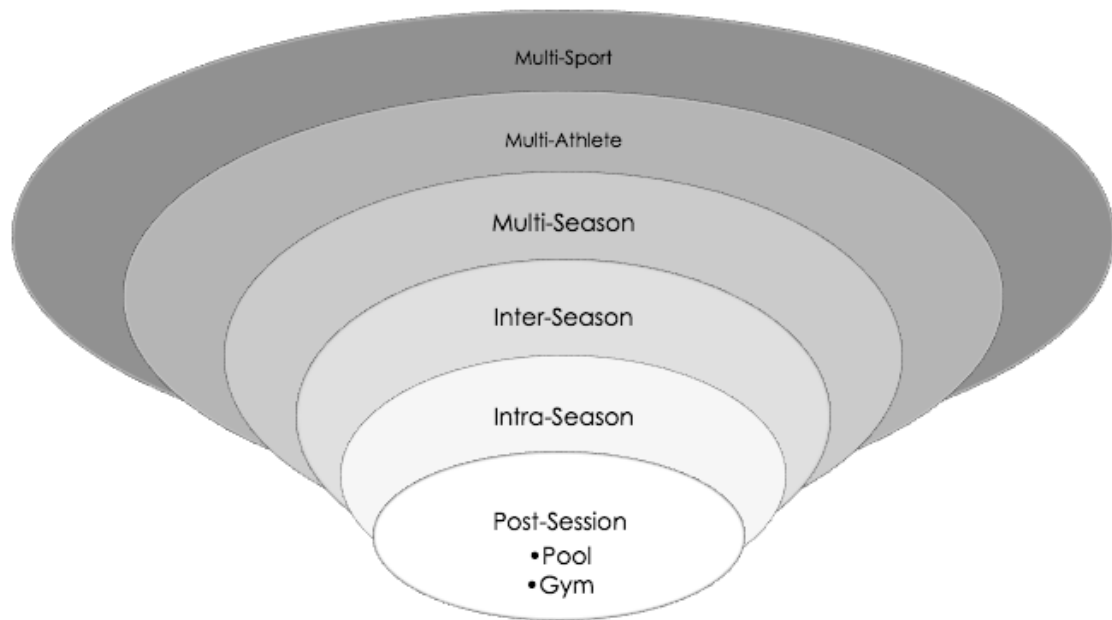


Figure 2. Workflow diagram detailing the major stages in development

In addition to the finer details, the dependency map in Figure 1 shows a consistent trend toward reliance on the fine-grain metrics of the athlete at the top left of Table 1. By reversing this trend – asserting that a dependent is the inverse of a dependency, and replacing each dependency direction with its reciprocal (\leftarrow becomes \rightarrow , \uparrow becomes \downarrow) – it is possible to use target contexts (as listed in Section 2) to define major stages (steps) in project development. The workflow diagram in Figure 2 explains this step-by-step approach, and illustrates the ever-broadening scope of each consecutive step.

This workflow diagram can act as the foundation of any number of sports technology software projects, each constrained in their own ways by time, cost, and the summative requirements and contributions of all sporting stakeholders and software developers involved.

Per project, sporting stakeholders can assign themselves a role within one or many project stages (workflow steps) to ensure that their requirements are met, and should establish working relationships with surrounding parties to ensure consistency among the project team. For example, it is recommended that a sport scientist interested in fatigue metrics will work with other sport scientists in the poolside context (see Table 1), and should be familiar with the metrics available within the coach/poolside and athlete/poolside target frameworks (see Figure 1). From this stakeholder's perspective, only the first workflow step is considered relevant to their interests in the short term (see Figure 2).

Projects involving cloud technology are likely to require a significant number of software developers. These developers, as well as some researchers, will share the project roles of concept and design, research and development, testing and review, and training and deployment. This distributed, structured approach will be used to facilitate the coordination of future projects within the CWMA and QAS in this area.

5. Discussion and Future Work

While the detail and statistical accuracy of this study is unverified, there are patterns in the collected data to suggest that it can realistically serve as a roadmap for future projects. For example, metrics toward

the top-left of Table 1 correspond to perceptible, explicable characteristics that can be compared to the existing gold standard as proof of concept, while metrics toward the bottom-right focus on extracting previously unknown information by creating new data modeling and visualisation techniques.

In future work, Table 1 will act as a preliminary needs assessment for the development of a visual data analysis framework, starting in the sport of swimming. With the dependency map in Figure 1 and workflow diagram in Figure 2, Table 1 can also be used in conjunction with existing publications to direct future research:

- Research detailing the existence of patterns in data can be used to develop visualisations; for example, a cyclic simulation of arm stroke phase timing may be possible using the work of Lee et al [10].
- Research into coaching, teaching, feedback and learning may be used to develop non-visual or multi-sensory feedback methods; for example, coaching techniques may be influenced by the work of Shea and Wulf [11], which examines the generalisability of learning through instruction and the difference between using internal versus external attentional foci.

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