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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 use of technology in various situational contexts related to swimming. The end goal is to improve training outcomes by allowing the strategies and requirements of stakeholders to be targeted.

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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 athletes themselves. These stakeholders utilize expert knowledge from a range of dominant scientific disciplines including physiology, biomechanics, motor control, perception, motor learning and even nutrition and psychology to maximize training and competition performance [1].

Many scientific assessments rely on technology, and often use information and monitoring systems in the form of software packages to perform or collate measurements. These systems seek to facilitate improvement in elite level athletic performance by providing relevant contextual feedback to the stakeholders involved. In 2008, Justham et al published a critical evaluation of existing analysis techniques in swimming, and concluded that more thorough feedback could be provided through the use of inertial sensor technology [2]. In pursuit of developing an integrated performance monitoring system for aquatic use, Le Sage et al furthered this research in 2011 by surveying key stakeholders (coaches, biomechanists and swimmers) to develop a list of user requirements ranked by importance [3]. 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 applies the context-driven approach to needs assessment by Ringuet-Riot [4] to an existing cloud-based software project [5] for the sport of swimming in Queensland, Australia. This software project, the Visual Data Analysis Toolbox (VDAT), is an initiative to make real-time athlete performance data visually accessible from any location via the internet. The process of performing a context-based needs assessment involves grouping stakeholders into major categories (athlete, coach, sport scientist, researcher) and defining a set of situational contexts that can be relevant to all of them. These contexts are derived from generalisable data 'sets' that consider location (pool or gym), time (session or season) and/or change over time (comparing athletes).

2. Situational 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 (column in Table 1) represents a set of end goals divided and targeted towards the four aforementioned stakeholder categories (rows in Table 1). The first context/stakeholder target (Table 1, row 'Athlete', column 'Pool Session') provides a fine-grain view for the athlete: well-established metrics that are directly applicable to their situational context. The last (Table 1, row 'Researcher', column 'Multi-Sport') provides a course-grain view, which focuses more on research potential. There is a tendency for coarse-grain metrics to be dependent on fine-grain metrics, as indicated by the terms 'as above' and 'as left'. 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. Stakeholder categories

In this study, a stakeholder is defined as either a person affected by the use of technology or a person who may benefit from information and monitoring technology being available to them. Each stakeholder brings a unique set of skills and is looking for their own key performance indicators. The end goals described for each situational context are divided among the four major stakeholder categories, remembering again that coarse-grain metrics will usually be dependent on fine-grain metrics. The four categories are defined as follows:

- Athlete: An individual 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, golf score, training types, workloads	visual data, real-time feedback, validation against ergo, mocap, etc	video replay, performance diary (stroke types, injuries, mood, etc) straightforward	historical progression mapping, milestones, workloads	competition milestones, KPI changes	**as left**, long-term goals, rate of improvement	rankings team progress role models	**as left**, uncon-strained enviro-nment
Coach	**as above**, underwater video, stroke time/phase, performance impact	**as above**, historical data to compare, fatigue estimation	**as above**, video annotation, technique visualisations, athlete coaching tool	**as above**, frequency, intensity, injury monitoring	**as above**, coaching interactions, intervention, compliance	**as above**, improvement of technique, modelled strategies	**as above**, **as left**, tailored programs	**as left**, injury preven-tion and healing

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/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 visual technique, data aggregation	**as left**, comparative studies, X-factor, performance improvements from tools (e.g. skins), generic vs individual training, finding the best protocols	**as left**, environ-mental conditions (e.g. heat), robustness, effect of equipment, technology as a toolkit, quantif-ication tool
Researcher	**as above**, system verification, 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 the metrics required by each stakeholder. This is both due to the anecdotal and presumptive nature of the data, and because 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 illustrate how this information could be used, the dependencies in Table 1 (‘as left’, ‘as above’) 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 also indicating a potential starting point for development.

	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**	

Fig. 1. Dependency map from Table 1(a) and 1(b); row = stakeholder, col = context, O = starting point, ↑← = dependency
A = Athlete, C = Coach, SS = Sport Scientist, R = Researcher, PS = Pool Session, ES = Exercise Session, PS = Post-Session, IS = Intra-Season, IS = Inter-Season, MS = Multi-Season, MA = Multi-Athlete, MS = Multi-Sport

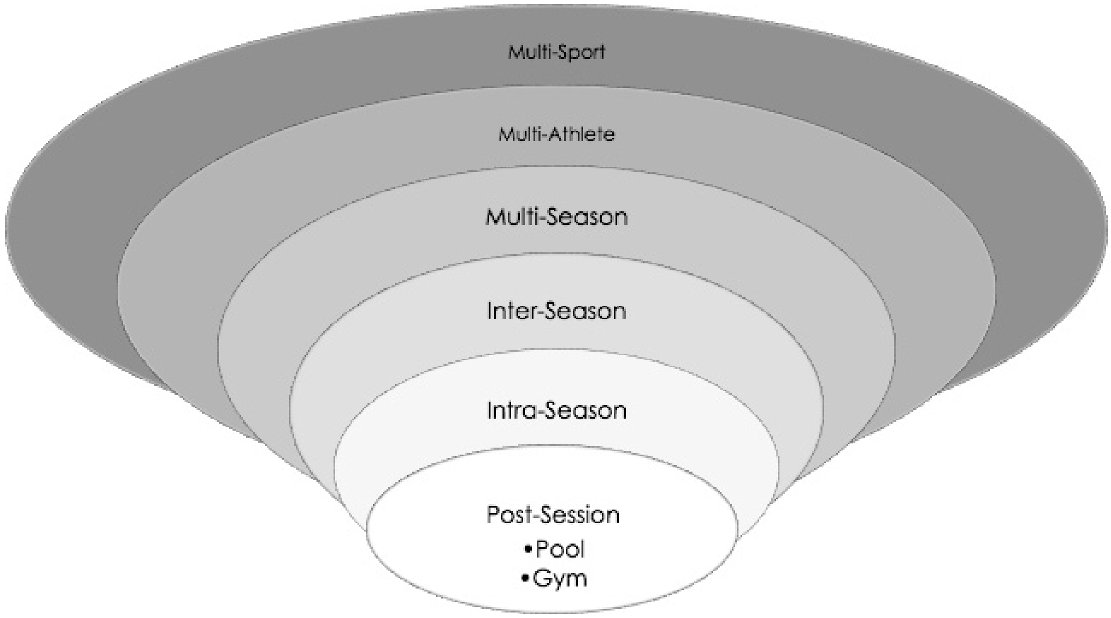

Fig. 2. Workflow diagram detailing the major stages in development

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.

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. The reciprocal of this trend (asserting that a dependent is the inverse of a dependency), where ← becomes → and ↑ becomes ↓, allows the use of situational contexts (Section 2) to define major 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 of the 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, and should be familiar with the metrics available within the coach/poolside and athlete/poolside target frameworks (Table 1, Figure 1). From this stakeholder's perspective, only the first workflow step is considered relevant to their interests in the short term (Figure 2).

5. Discussion and future work

The benefit of the context-driven approach to needs assessment is that it allows significant detail to be presented to stakeholders in a manner that retains context. While the detail and statistical accuracy of this study is unverified, there are patterns in the collected data that suggest it can serve as a roadmap for future projects. For example, metrics toward the top-left of Table 1 correspond to perceptible and explicable characteristics that can be implemented using the current VDAT framework. These can also be compared to existing gold standards as proof of concept. Metrics toward the bottom-right of the table focus on creating new data modeling and visualisation techniques. These extend the interactive analysis paradigm described in [9] and represent the future direction of VDAT as a whole.

Using VDAT, anyone within the athlete's team will be able to access performance data tailored to their needs as a stakeholder. Constraints relating to the location, timeframe or scope of the available data are project-specific considerations and not fundamentally limited by the framework. Future work will focus on the creation of useful visualisations for specific sports. For example, a cyclic simulation of arm stroke phase timing may be possible for the sport of swimming using the work of Lee et al [10]. This distributed, modular approach to software development will be used to facilitate the coordination of future projects within the CWMA and QAS in this area.

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