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Interaction Technology

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ABSTRACT

With this monograph we introduce a new, systematic taxon-
omy of Sports Interaction Technology (Sports ITech) that
defines a design space of existing and future work in this
domain. We set the taxonomy in a context of our view on
sport science and sports practice, target outcomes of sports
and the underlying factors influencing them, and the role
that sports technology plays to support sports science and
practice. In that setting we systematically build and illus-
trate a taxonomy for the design space for Sports ITech as
a sub-area of sports technologies, with specific attention
for the adequate inclusion of knowledge from the sports

sciences. We build on the basis of existing taxonomies and a vast body of literature from multiple domains of HCI, technology, sports science, and related work in Sports ITech, complemented with what we identified as obvious gaps in the literature. We finally share the conclusions after a discussion of the limitations of our work.

The contributions of this monograph are as follows. First, we offer a description of a design space, exemplified through existing work in a way suitable to support designers, technologists, and sports people with a design mindset to design, deploy, and adapt Sports ITech. Second, we see this as a call to action to bring HCI and the sports sciences closer together in the new field of Sports Interaction Technology, to set a shared agenda for future developments. Third, we offer this as the collation of a reading guide and wayfinding support in the literature from the many underlying disciplines of Sports Interaction Technology.

1

Introduction

1.1 Background and Motivation

With this monograph we bring together a systematic taxonomy that
defines a design space of Sports Interaction Technology (Sports ITech).
This taxonomy, exemplified by existing work in the field, is meant to
be used by designers of Sports ITech. It will help better highlight and
position existing work. It will also provide input and inspiration for the
design and deployment of such technology.

The articulation of this design space is an outcome of the Dutch
ZonMw funded Smart Sports Exercises (SSE) project, which aimed
to develop novel kinds of digital-physical training exercises in ambient
intelligent environments. In those environments, body worn movement
sensors and a pressure sensitive floor were used to measure athlete
behaviour during sports activities. Displays, integrated in the floor,
provided feedback or presented novel exercise forms and training games.
The SSE project focused partly on developing and validating tools for
sensing and modelling individual and group level volleyball behaviours
(Salim *et al.*, 2020a; Beenhakker *et al.*, 2020). The project also con-
cerned the design, validation, and embedding of novel digital-physical
exercise forms in sports practice (Postma *et al.*, 2019, 2022c). Extensive

analysis of the volleyball context was used to develop concepts and prototypes that were evaluated in a user-centred approach with trainers, innovation managers, industry professionals, and athletes. While doing so, we experienced a need to map the design space in order to more easily explain our work to stakeholders as well as to identify gaps and opportunities for further designs. This monograph presents the resulting framework that reaches beyond the specific volleyball use case of the SSE project into the larger field of Sports ITech. The SSE project was in that sense reminiscent of the choices that Sports ITech designers generally encounter. Not only do the specifics of the sport or the technology influence the design space, but also the frameworks that underpin the objectives of a design. Through this monograph we share the collective insights from literature in the field in the form of a taxonomy to benefit future Sports ITech designs.

1.2   **Global Approach**

We developed our taxonomy in several iterative steps. The initial insights were derived from a research through design approach (Stappers and Giaccardi, 2017), in which we built prototypes of Sports ITech and reflected on their purpose and value in a user-centred approach. We felt that there was room for an explicit articulation of a design space; therefore we surveyed existing literature and used our own artefacts to exemplify an initial sketch of the design space. We then gathered additional literature sources in order to: 1) articulate how we see the context of sports science, sports practice, and general sports technology in which Sports ITech is placed, and 2) articulate the design space of Sports ITech itself in a literature-grounded, cohesive and extensive taxonomy. Here we describe and exemplify the resulting design space through theory (i.e., existing frameworks) and practice (i.e., existing artefacts of Sports ITech). This makes it possible to highlight sparsely populated areas in the design space and to represent important positions in order to facilitate inspiration and inquiry into designing the right thing (cf. Frayling (1994, 2015) Stappers and Giaccardi (2017), Zimmerman *et al.* (2007), and Dalsgaard (2010) on research into/through/for design).

As is often the case with design space papers,[1] the framework and exemplifying examples are the result of design, design research, and followup research from a variety of researchers working on various types of interactions, contexts, and goals.

1.3 Sports Interaction Technology as Part of a Larger Context

Our Sports ITech taxonomy does not stand in a vacuum – it is articulated within our view on the larger context of sports practice and sports science on the one hand, and innovative developments of sports technology on the other hand. To capture the dynamic interplay between sports and technology, we developed the '21st Century SPORTS Framework' for **S**upporting in-**P**ractice **O**utcomes through **R**esearch & **T**echnology in Sports (see also Figure 1.1). Over the next couple of paragraphs we will use this framework to sketch in broad strokes this broader context of sports and (interactive) technology.

Within sports there are targeted outcomes: what people strive for in sports. The 21st Century SPORTS framework summarises these as performance, learning, and engagement. Underlying factors in a complex network of relations that may influence attainment of these outcomes are, for example, physiology, biomechanics, genetics, and nutrition – but there are many more possible factors (cf. Hristovski *et al.*, 2017; Williams and Kendall, 2007). In sports practice, athletes, coaches and trainers attempt to *maximise outcomes* based on insights about these underlying factors, their mutual relations, and their apparent relation to the outcomes. In sports science, scientists attempt to *obtain new and more detailed fundamental insights and models* regarding what are the underlying factors, and how they are related to each other and to the targeted outcomes.

Sports technology, finally, is a tool to support these endeavours. Technology supports athletes in achieving better sports practice; but it also supports scientists in generating new fundamental knowledge. In brief, the 21st Century SPORTS Framework distinguishes three types

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[1]E.g., Lakier *et al.* (2019), Müller *et al.* (2010), Kosmalla *et al.* (2017b), Mueller and Muirhead (2015), Ishii *et al.* (1999), Mueller *et al.* (2011), and Surale *et al.* (2019).

of Sports Technology, namely Physical Sports Technology, Sports Data Technology, and Sports Interaction Technology: (see Figure 1.1).

1. **Physical Sports Technology** is typically characterised by a strong focus on gear (e.g., the clap skate in speed skating (Ingen Schenau *et al.*, 1996)), materials (e.g., artificial turf in hockey and other sports (Fuss *et al.*, 2007)), the built environment (e.g., the physical organisation of children's playgrounds (Withagen and Caljouw, 2017)), and apparel (e.g., the shark-suit in swimming (Hutchinson, 2008)); often with a focus on increasing safety and/or performance.

2. **Sports Data Technology** focuses on data science. Typically, it aims to leverage (big) data to gain more insight into sports performance. Research generally targets measurement and analysis of sports data (e.g., Brefeld *et al.*, 2019) as well as dashboard and retrieval systems that help athlete and coach *make sense of the data* (Stein *et al.*, 2017). The insights acquired from these analyses contribute to a better scientific understanding of sports, as well as to better interventions in training programs and match strategies in sports practice.

3. **Sports Interaction Technology**, which is the focus of the remainder of this monograph, involves novel kinds of digital-physical exercise systems and aims to boost performance, engagement and learning through human machine interaction *that occurs with and around the 'acting body'.* That is, the user in Sports ITech is typically engaged in whole-body movement activities as part of, or related to the human machine interaction. Sports ITech shares characteristics with the general notion of exertion games (games that center on exertion and bodily effort both as purpose of the interaction as well as the main modality to control the interaction; Mueller *et al.*, 2016). However, in contrast with this, our definition of Sports ITech focuses more strongly on interactive training and competition. Although exertion plays an important role, it is not the end goal nor a necessity in itself but rather it is at the service

of sport-specific qualities and characteristics. This places different demands on the design of interactive applications.

Sports ITech typically involves HCI technology implemented with a sense-think-act cycle,[2] where the system senses input (e.g., sports relevant behaviour), decides upon appropriate responses in the context of the desired activity (e.g., a novel soccer training activity), and delivers these responses through displays, wearables, novel tangible interfaces, or smart environments. For example, in Football Lab (Jensen *et al.*, 2014a), a football area is surrounded by four "rebounders", smart goals enhanced with sensors that measure hit position, and lights and loudspeakers that provide feedback and game instructions, where the system responds in certain ways to player actions in order to encourage them to carry out soccer-related exercises.

In the remainder of this monograph we focus on Sports Interaction Technology and describe a taxonomy to systematically describe and analyse this field in terms of form and function of the technology.

1.4 Aim and Contribution

Building on a variety of our own Sports ITech design projects for climbing, cycling, rowing, running, skiing, and playing volleyball, we postulate that the development of a Sports ITech design space framework satisfies a latent need, both for HCI technologists and designers who enter the sports domain as application context, and for sports professionals who approach their work with a design mindset and want to incorporate interaction technology in their work. Students in these fields can benefit from a better understanding of Sports ITech, but also researchers, professionals, and policy makers may find benefit in this work.

In existing partial taxonomies, sports science and movement science are often underrepresented (e.g., Kajastila and Hämäläinen, 2015). As we will argue in a subsequent section, we see a need to integrate more

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[2]Note that the sense-think-act adage is purely a high-level descriptor of a typical HCI system's architecture and should thus not be taken to represent the way in which human athletes interact with the world.

fundamental knowledge from those disciplines into this subdomain of
HCI, in line with the HCI tradition and history of embracing methods,
knowledge, and techniques, and practitioners, from other fields of science
(cf. Lazar *et al.*, 2017). After computer science and information science,
ethnography, psychology, and design, the rise of sports HCI can be
supported by more explicit inclusion of expertise from fields including
sports science and human movement science.

With this monograph we aim to offer a threefold contribution. First,
we contribute by more clearly framing and articulating a research do-
main, namely that of Sports ITech. This can help in identifying gaps,
realising new opportunities, and grounding choices for design, research,
and development in this still relatively young field. Second, this mono-
graph embodies a call to arms for drawing more sports and movement
scientists to the field of HCI in support of this subdomain. Third, thanks
to the extensive multidisciplinary bibliography, this monograph aims to
orient the reader exploring literature from the many disciplines under-
pinning Sports ITech (e.g., 'motor learning', 'game design', 'pedagogy'
and 'interaction design').
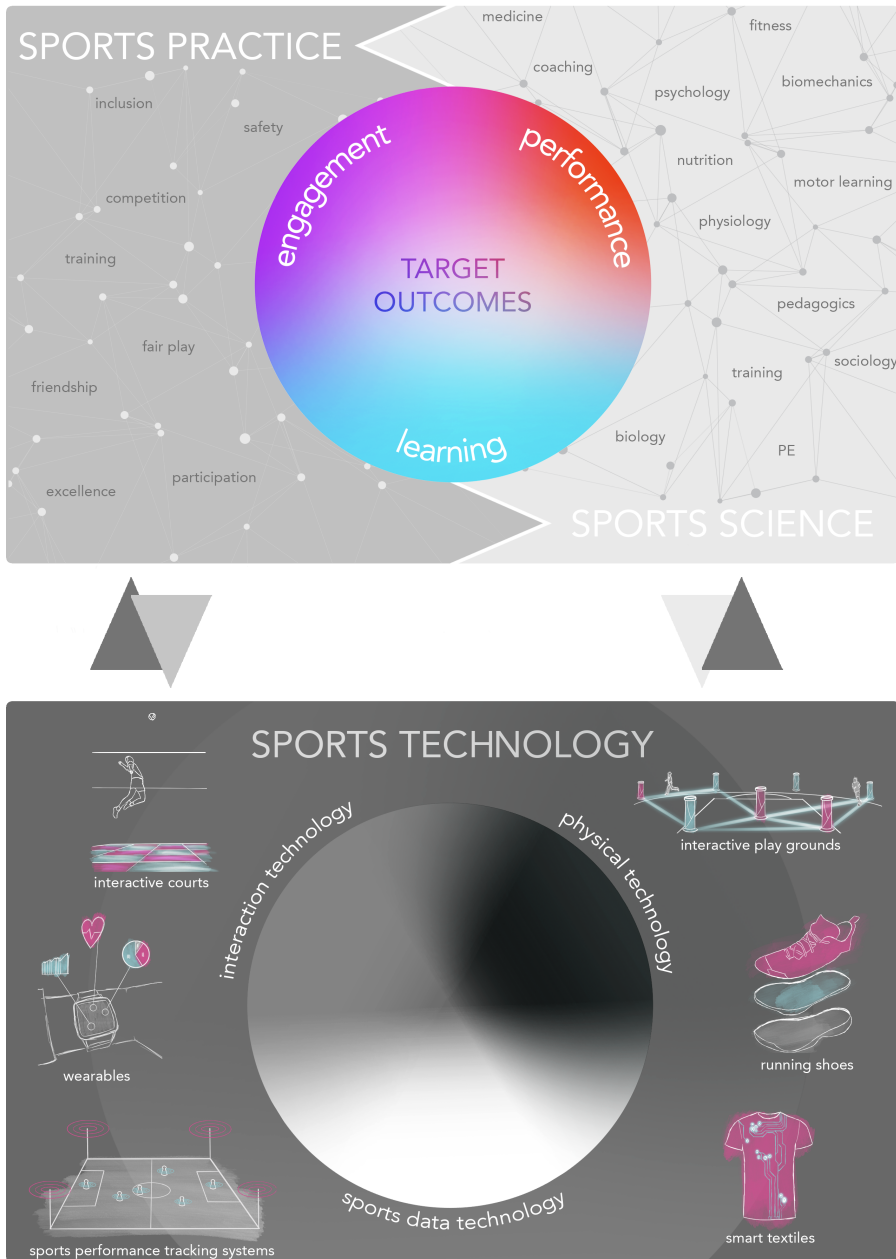
Figure 1.1: The 21st Century SPORTS Framework for **S**upporting in-**P**ractice **O**utcomes through **R**esearch & **T**echnology in Sports. The figure illustrates the interrelation between sports practice, sports science, and their intended outcomes, and the role of technology to support these, with the *sports science* aspect and the *sports technology* aspect further illustrated with exemplars.

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