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Redefining Sports: Esports, Environments, Signals and Functions

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***Abstract*—The sports landscape is constantly changing due to innovation and entrepreneurship. The availability of technology led to the emergence of esports and augmented sports. Biofeedback and sensing technologies can be used for athlete monitoring and training purposes. Research on motor control deals with planning and execution of bodily movements and provides some insights towards formal presentation of sports.**

Previous research provided many sports categorization models. On many occasions, published articles did not distinguish competitive gameplay activities (gaming) from athletic performance (esports). Our goal was to define esports by extending existing universal sport definitions and propose a novel modular computational framework for categorizing sports through environments and signals.

We have fulfilled our goals by illustrating how signals flow within competitive (sports) environments. Our esports definition introduces esports as a group of sports similar to motorsports. Moreover, we have defined mathematical foundations for signal processing by various actors (athletes, referees, environments, intermediate processing steps). We have demonstrated that representing sports as a multidimensional signal can lead to the categorization of sports through computation. We claim that our approach could be applied to transfer training methods from similar sports, analysis of the training process, and referee error measurement.

Our study was not without limitations. Further research is required to validate our theoretical model by embedding available variables in latent space to calculate similarity measures between sports.

***Keywords*—esports; sports categorization; information representation; signal processing**

I. Introduction

THE world of sports is subject to constant changes, innovation, and entrepreneurship [1]. One interesting and relatively recent development was the emergence of esports [2]. Moreover, the availability of hardware and increase in computing power led to the creation and evolution in the area of augmented sports, e.g., augmented dodgeball and laser tag [3, 4].

Virtual worlds created by game developers became the arena for a competition that pushes the limits of human cognitive capabilities where only those who that adapt can improve their gameplay [5]. Training equipment is becoming more sophisticated with the Internet of Things (IoT) and the advances in sports science and technology. Portable and wearable technologies improve the ability to monitor athletic performance [6–8].

Computer games are specialized software. Some game developers expose the application programming interface (API) to interact directly with the game engine or with the data that are a byproduct of a game. In such cases, users can develop their tools on top of the lower-level abstractions [9–12]. A replay feature typically works by recording game states or player inputs. An input-based replay system requires a deterministic game to produce identical outputs for independent game simulations [13]. Moreover, computer games can be used as cognitive stimuli and leveraged in different contexts [14]. Media publications and research highlight that the use of customizable peripheral devices, DIY solutions, and support from game developers underlines the ability to include disabled people in esports [15, 16].

New training methods can be developed using biofeedback, which show great promise in the improvement of movement optimization in athletes [17–19]. Emerging technology can also be used in task training, supporting cognitive rehabilitation, and physical rehabilitation of sick and injured people [20–22]. Movement planning and execution is a topic of interest in various fields of science, including sports sciences, medical sciences, and robotics. Investigating various topics in these fields requires computational knowledge and processing of different types of signals [8, 23].

A. Motor control

Motor control is subject to numerical simulation with scientific software. The authors of OpenSim specifically designed and showcased the ability of their software to simulate neural control of human and non-human movement [24].

To provide context required to understand our work we collected and described some motor control theories. Understanding motor control is key to our theory proposed in Section II. Researchers have proposed multiple theories of motor control describing the planning and execution of bodily movements some of these theories are:

(1) Reflex Theory — positing that complex movements are a chain of reflexes as responses to stimuli. (2) Hierarchical Theory — envisaging multiple control levels that coincide with the structure of the nervous system. In this model the higher levels are always in charge of lower levels of control. (3) Motor Programming Theories — suggesting that

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movement is planned and can be independent from external stimulus. This theory introduced abstract motor program and their hierarchies. (4) Systems Theory — presenting a view of the body as a mechanical system with defined degrees of freedom, synergies, non-linear behavior, self-organization, and variability. In this theory two movements that seem different might be a result of the same movement program which in its execution was affected by external forces. Moreover this theory uses the hierarchical representation of movement synergies, where the higher levels of a system activate lower levels that compose a synergy. (5) Ecological Theory — focusing on detection of information within the environment and how it affects actions [25].

By these descriptions, motor control deals with the internal representation of movement and how that representation changes after each movement execution [26].

B. Theory of sport perspective

Some authors argue that there might be insufficient physicality and general public recognition for esports to be called sports. These arguments could be countered by comparison with some Olympic sports such as archery, shooting sports, bobsleigh, luge, or curling [27]. Moreover, general public recognition of esports can be seen in market metrics for events played out in a variety of games [28].

Comments on the lack of physicality of esports fail to address the human-computer interaction element of pointing devices which are an interface to interact with simulated environments. Because esports uses computer games to provide a competitive environment, virtual reality (VR) games stand in contrast to such statements [29, 30].

Esports and gaming use the same environments, yet a clear distinction between gaming and esports should exist. Gaming can be viewed as a leisure or recreational activity. Esports naturally should be subject to more or less organized training processes to maximize the player's performance with the goal of victory and achieving an expert level of skill [31]. There are significant skill differences between recreational players and esports athletes that need to be examined in order to understand skill acquisition [32, 33]. Sources that define esports point toward the lack of consensus on their fit into the current sports landscape. Some argue that esports might be an activity subject to the "sportification" phenomenon [34].

C. Sport categories and game genres

Some authors suggest a distinction between open-skill and closed-skill sports that could help model cognitive differences between athletes based on the specific demands of competitive environments [35]. Other authors use different criteria based on sociology, administration and organization, energy expenditure, and physical activity level [36]. There are many different recognized game genres among computer games. According to Si and co-authors [37] proposed categories are:

(1) first-person shooter (FPS), (2) real-time strategy (RTS), (3) role-playing game (RPG), (4) chance-based (CB), (5) word and trivia (W&T), (6) simulations, (7) sports (Sport based games)

Another research group [38] listed its own categories: (1) first-person shooter (FPS), (2) real-time strategy (RTS), (3) role-playing game (RPG), (4) multiplayer online battle arena (MOBA), (5) collectible card games (CCG), (6) action games, (7) fighting games, (8) rhythm games, (9) sandbox (games with the free mode of exploration called "sandbox"), (10) sport games.

Despite the authors' use of them, there is no clear definition of these categories and their limits. Ongoing discussions on whether esports should be considered sports point toward why the current theory might be insufficient and should be revised, extended, or redefined.

Based on the current scholarly understanding of esports (sports), signals (stimuli), and environments that play a crucial role in sports training, competition, and human performance optimization, we have identified a theoretical research gap. Therefore we aim to define esports by extending existing universal sport definitions and propose a novel theoretical modular computational framework for categorizing sports through environments and signals.

Despite many authors mentioning esports in their research, there is no distinction between gaming and esports provided in their work. The lack of a proper esports definition and recognition is an issue that might lead to further confusion and the publishing of research that does not deal with esports players. In some publications, it is unclear whether the trial group consisted of casual gamers, esports players, or a mix of these groups and their skill levels [39–41]. Based on this theoretical research gap, we formulated the following research questions (**RQ**):

- **RQ1** Is it possible to extend sports definitions to include esports and competition based on emerging technologies?
- **RQ2** Is it possible to define a modular, composable, computational theoretical framework that could allow sports categorization based on sports characteristics as observed in the available signals?

II. Theoretical Framework

A. Esports definition

Our definition of esports is as follows: "Esports is a group of sports that use electronics and telecommunication technologies to create the means of competition for their users that intend to maximize their skill." In that regard, it extends the original definitions of sport. This definition is similar to what is widely accepted for motorsports. Therefore we state that the definition of esports compiles with and broadens many existing definitions of sports in general [42]. This type of sport uses electronics that provide the interface for simulated environments.

The emergence of esports can be spontaneous or inspired by their physical sports counterparts. Fitting examples of such sports are racing games (F1, iRacing, Asseto Corsa, and others), flight simulation and combat games (Microsoft Flight Simulator, War Thunder, X-Plane, and others), board games (chess, Go, shogi, card games, and others), and sports games (FIFA, eFootball, NBA2K, Madden NFL, EA Sports UFC 4, PGA Tour). In this regard, esports offer a way to practice or train different skills. Using technology and simulated environments in place of costly equipment can alleviate expenses; this is visible in motorsports through the possibility of deliberate practice and military flight and combat simulations [43, 44].

Moreover, any game that contains potential tasks that can be completed in a competitive way could become an esport through speedrunning. The phenomenon itself is related to completing the game goals as fast as possible [45]. In this regard speedrunning is easily comparable to physical sports that contain a racing element for example swimming, running events, and motorsports, where the measure of performance is the time of task completion.

B. *Sports modelling framework*

Here we define our theoretical framework for categorization of sports based on the environment characteristics and signals (stimuli). We recognize that not all signals can be classified as a stimulus for biological systems, and yet these signals can be measured and used to differentiate sports.

We propose to categorize sports based on measurable signals which can interact directly with the environment or be further processed. We include signals that are sent back by the physical, simulated or hybrid environments.

Our framework should allow any competitive activity to be analyzed by objective performance measurements. Viewing data through the underlying goal of improvement or victory in specific competitive tasks should uncover optimal ways of interacting with environments.

The compositional structure of our framework for sport categorization is based on motor control units (MCUs) (human, animal, software or other) and their interactions with the competition environment. Different models of motor control and movement planning were introduced in Subsection I-A. We view MCU as some entity that takes part in a competition. Our view of sports extends the ability to include robot or software based sports where human involvement is mainly in the autonomous system construction.

Categories of sports that are distinct from each other in view of our compositional structure of interaction are:

- Sports with a physical environment, where one or more motor control units compete (e.g., swimming, track and field, climbing, boxing, skiing, cross-country skiing).
- Sports with a physical environment, where one or more human motor control units and one or more animal motor control units compete (e.g., equestrian, polo, horse racing, dog sledding).
- Sports with a physical environment, where one or more human motor control units compete through a mechanical proxy (e.g., cycling, Formula 1, air racing, sailing).
- Sports with a physical environment, but the means of control are electronic. One or more human motor control units compete (e.g., drone racing).
- Sports with a digital environment. Motor control units interface with the environment by using human-computer interaction devices. One or more human motor control units compete (e.g., StarCraft II, Dota 2, Counter-Strike: Global Offensive, League of Legends).
- Sports with more than one environment. Motor control units compete within one physical environment and one or multiple digital environments.

The presented model is easily extensible by adding more MCUs or environments. Each of the arrows presented in the figures depicts a signal. Examples of the signals are:

- biological signals:
  - HR – heart rate,
  - LA – lactate level,
  - M – body mass,
  - VO_2 – volume of oxygen intake (consumption),
  - CK – creatine kinase.
- physical signals:
  - x – position x of an athlete,
  - y – position y of an athlete,
  - z – position z of an athlete,
  - v – velocity,
  - a – acceleration,
  - F – force.
- digital signals:
  - l – processing latency,
  - cl – communication with server latency,
  - r – display refresh rate,
  - u_x – unit positions x,
  - u_y – unit positions y,
  - u_z – unit positions z.

All of the example biological and physical signals listed above are used in sports research [46–49]. Symbols used in the figures are presented in equations 1-4 and are as follows:

$$R(t) = \begin{bmatrix} v_1(t), & v_2(t), & ..., & v_{n-1}(t), & v_n(t) \end{bmatrix} \quad (1)$$

1: Vector R – Received, depicts all of the signals that MCUs can receive and process, $R : \mathbb{R} \mapsto \mathbb{R}^n$.

$$B(t) = \begin{bmatrix} v_1(t), & v_2(t), & ..., & v_{m-1}(t), & v_m(t) \end{bmatrix} \quad (2)$$

2: Vector B – Broadcasted, depicts all of the signals that MCUs broadcast to the environments, $B : \mathbb{R} \mapsto \mathbb{R}^m$.

$$MCU_{athlete}(t) = f_{athlete}(R(t)) = B(t) \quad (3)$$

3: MCU of an athlete takes a vector of received $R(t)$ signals and maps them, via some function $f_{athlete}$, to broadcasted $B(t)$ signals.

$$RE_{referee}(t) = f_{referee}(R(t)) = B(t) \quad (4)$$

4: RE of an referee takes a vector of received $R(t)$ signals and maps them, via some function $f_{referee}$, to broadcasted $B(t)$ signals.

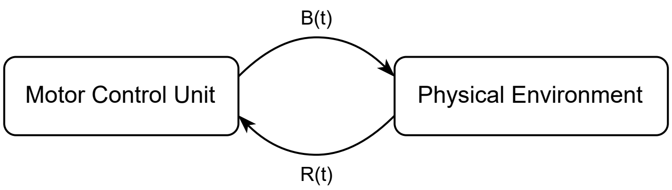

Fig. 1: A model of sports where the competition happens in the physical environment.

In the real-world (physical) environment the rules of competition can only be set with respect to the rules of the physical world which can be described or discovered.

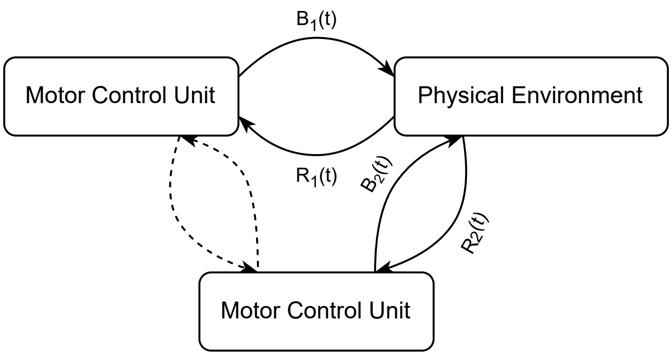

Fig. 2: A model of sports where the competition happens in the physical environment and two MCUs compete with each other at one time.

All of the outgoing signals are viewed as the means of competition and reflect the readiness of an athlete to compete based on accumulated experience. The weighted sum of these signals with respect to the compound competition function should reflect the skill of an athlete.

Proposed example categories of sports based on our framework are depicted in Fig. 1-6. We only provide the most basic examples of sports categories described through our framework. In other cases, sports should be verified and modeled individually. Every arrow depicts one or more signals that are subject to corruption or loss of continuity. Every dotted arrow depicts an indirect route that a signal takes. Every vertex depicts a signal processing step. Multiple signals received by the MCU from more than one source or from a chain of preprocessing steps are subject to potential desynchronization or latency issues. This phenomenon is widely known in esports as "lag" and corresponds to latency [ms] and packet loss. Research on how latency can impact users in computer games is relevant for network design, user performance analysis, and user experience analysis [50–54].

After the initial signal is broadcasted to the environment, every intermediate step is subject to unknown variable time delay. The modularity of our theoretical framework can be inferred from 1-6, as these display various configurations of nodes that can describe certain abstract sport categories.

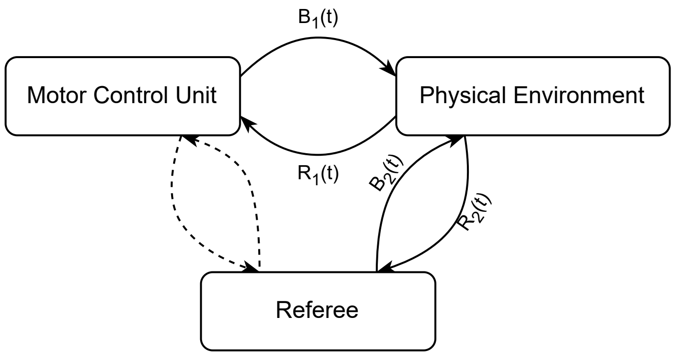

Fig. 3: A model of sports where the competition happens in the physical environment and a single referee is present.

The scoring in many sports is often subjective. In these cases if a referee is introduced to our model, the feedback received by the MCU can contain an error which comes from the difference between environment and referee signals. In the proposed framework this error is a scalar value changing over time. In most sports it is key to minimize such error at the institutional level to ensure fair competitions. On the other hand, athletes should attempt to minimize such errors by adaptation. At this stage we do not consider the possible internal movement representation errors, and resulting feedback dissonance.

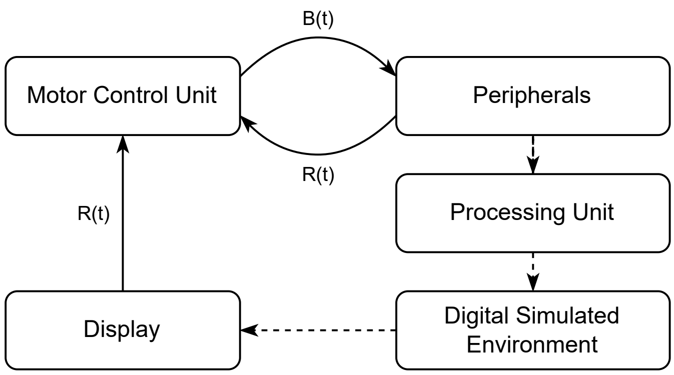

Fig. 4: A model of sports where the competition happens in the digital simulated environments (esports).

Esports are different from physical sports, mainly because of game engines that simulate environments. Game developers have the ability to allow dynamic rule changes that directly affect how the environment responds and is interacted with. As such, the simulated environments can provide individualized stimuli automatically or implicitly through errors in communication required for multiplayer gameplay.

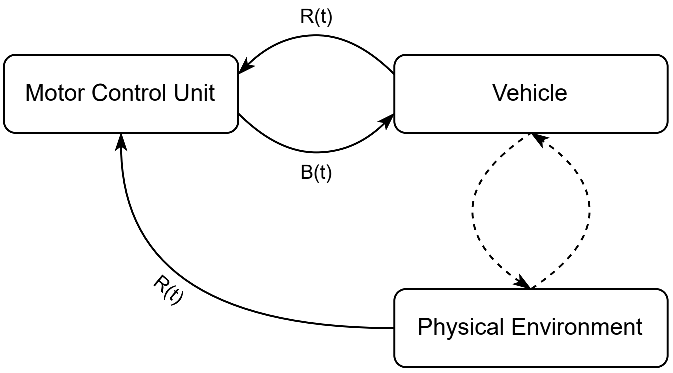

Fig. 5: A model of sports where the competition happens through a vehicle proxy and is based on the physical environment.

Vehicle based sports such as bicycle racing, sailing, motorsports and other are subject to the model.

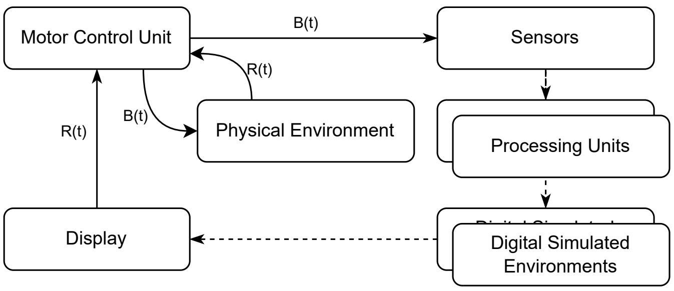

Fig. 6: Hybrid model of sports where competition is simultaneous in multiple environments.

Hybrid competitive environments can be characterized by combining both physical and simulated environments. In such cases an athlete would be required to optimize multiple environments in parallel.

C. Mathematical foundations

Observed and measured signals can be viewed as an individual spectral profile of a sport. Furthermore such profile can be subject to analysis with existing digital signal processing (DSP) techniques. Later frequency analysis of cognitive and physical functions should differentiate the sports into different categories based on objective measures.

$$f_{rules}(t, [MCU_i], [RE_j]) = [r_k(t)] \tag{5}$$

5: Function of rules f_{rules} depicts the limits of a sport function. There are minimal and maximal values that are allowed by the rules of a sport, otherwise an athlete can be disqualified or receive a reprimand. Function f_{rules} takes time, a vector of $MCUs$ and a vector of REs as a parameter and maps these signals to a vector of values depicting the amount of times a condition was met, $i \in \{1, ..., n\}$, $j \in \{1, ..., m\}$, $k \in \{1, ..., o\}$.

$$S_{sport} = (f_{rules}, [MCU_i], [RE_j]) \tag{6}$$

6: Sport can be viewed as a tuple containing a function of rules, a vector of athletes, and a vector of referees, $i \in \{1, ..., n\}$, $j \in \{1, ..., m\}$.

In the presented view of sports it is possible to state that if $sport_0 \in (\mathbb{R} \mapsto \mathbb{R})^n$ and $sport_1 \in (\mathbb{R} \mapsto \mathbb{R})^n$, such sports can be compared directly and are within the same wider category of sports as presented in Subsection II-B. Otherwise if $sport_0 \in (\mathbb{R} \mapsto \mathbb{R})^n$ and $sport_1 \in (\mathbb{R} \mapsto \mathbb{R})^m$ where $n \neq m$, we state that such sports are within different wider categories and can only be compared with respect to their common dimensions.

III. Summary

Using the proposed framework should allow decomposition and categorization of any sport by verifying sources of signals that have to be processed and functions of competition within the environment.

Maximizing the functions that are observed to be $P_{positive}$ and minimizing the $N_{negative}$ should be viewed as an objective contribution towards victory. Viewing sport as a signal, and ultimately through available data, can help to provide quantifiable and objective means for scoring and assist referees to minimize the error and provide fair competition. Moreover, our theoretical approach can be used to decompose the training process of any sport by means of computation. This could be used in transferring training methods from similar sports.

The lack of physical activity is often cited as a counterargument for proper esports classification. According to the World Health Organization physical activity is defined as "any bodily movement produced by skeletal muscles that requires energy expenditure." [55].

Any psychological activity or movement that is more than idle thought or rest can elevate energy expenditure through chemical reactions required for information processing. It is worth noting that contrasting the sum of energy expenditure used in the process of training and practice against the idle energy expenditure, might be a better indicator for verifying whether the activity can be classified as a sport.

The argument that physicality in chess is irrelevant to the final result of a move is unwarranted. Grasping and moving a piece on a chessboard within the time limits requires the movements to be fast and precise in over-the-board competitions. Factors such as latency and missclicks do not happen in the game's physical version but are present when playing online. In this regard, the environment differentes online chess and over-the-board competition. [14] Attempting to declassify various activities as sports is therefore incorrect, and we stand against devaluing emerging sports. Our views stand in contrast to the views of some scholars [56].

A. Limitations

We recognize that our work is not without limitations. The proposed theoretical model requires computational validation.

Measuring, processing, and embedding data in the latent space can uncover the similarity of sports, as has been done in other venues of research [57–61]. Despite providing examples of sports categories that showed contrast between known sports in various environments, we might have omitted some specific sports and their models. Future research should define more sports categories using our theory. Moreover, we are aware of other possible formal representations of sports which might be based in different mathematical foundations. Therefore we are open to updating our formal representation after further investigation.

IV. Conclusions

The goal of our work was to define esports by extending the available sports definitions, and to provide a novel modular theoretical framework for sports categorization based on signals and environments. Based on our aims and research questions, we reached the following conclusions:

- Our definition of esports extends the existing definitions of sport.
- Our theoretical model for sports categorization can incorporate esports and other previously unrecognized sports in various environments.
- We have shown that sport can be viewed as a multidimensional signal and is subject to computational analysis based on measurements.

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