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Virtuality engineering in esports

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***Abstract*—Traditional sports and esports benefit from the development of Information and Communications Technologies (ICT), including gaming, 4D image/video processing, augmented reality (AR), virtual reality (VR), machine learning (ML), artificial intelligence (AI), big data, high-performance computing (HPC), and cloud computing. On the fuzzy border between the areas of physical and modified reality, both types of sports can coexist. The hardware layer of esports includes PC, consoles, smartphones, and peripherals used to interface with computers, including sensors and feedback devices. The IT layer of esports includes algorithms required in the development of games, online platforms, and virtual reality. The esports community includes amateur and professional players, spectators, esports organizers, sponsors, and other stakeholders. Esports and gaming research spans throughout law (intellectual rights, insurance, safety, and age restrictions), administration (teams, clubs, organizations, league regulations, and tournaments) biology (medicine, psychology, addiction, training and education) Olympic and non-Olympic disciplines, ethical issues, game producers, finance, gambling, data acquisition and analysis. Our article aims to presents selected research issues of esports in the ICT virtualization layer.**

***Keywords*—esports; enhanced and virtual realities; AR; VR; gaming; human-computer interaction**

I. Introduction

ESPORTS were initially described as a type of sport that leverages computer technologies as a means of competition. The main difference between traditional sports and esports is the use of the human-computer interface in the latter. Due to this, most esports are intellectual in nature. Such a broad definition opens esports to use any human-computer interface to relay actions onto a simulated environment. Most current implementations use interfaces associated with reduced physical activity but requiring precise manual skills. This is often an argument against recognizing esports as a sport. As a counterargument to this approach, shooting, archery, and others can be presented as recognized traditional sports with such attributes. Computer games require resistance to stress to avoid and a variety of cognitive skills to become successful [1]. Today's understanding of esports [2–4] and its relationship to physical sports [5] has matured over the past dozen years. The assessment of the effort in esports has changed [6]. There are many definitions of esports [7], which is evidence of the scientific community's interest in its development.

Esports can also be viewed as sports leveraging interactive video games, requiring intensive human-computer interaction [8]. The technical layer at the user level takes the form of an organized virtual environment. Analogously to traditional sports, esports, in their popularity, span amateur and professional levels. For the hundreds of millions of amateur players, esports are a form of active entertainment. Esports for a professional esports player means systematic, long-term training, participating in esports leagues, local competitions, and international tournaments with thousands of viewers, as well as possible earnings. The range of potential esports games spans all existing game genres, such as popular, single-player, multiplayer, survival games, and virtual reconstructions of physical sports. Early gaming and esports started at universities only for people with computer access. Later, this phenomenon evolved into leveraging game modifications such as Defense of the Ancients (DoTA), Counter-Strike (CS), and games such as StarCraft, WarCraft 3, Tekken, Quake, and others.

We learn the nature of the esports phenomenon through systematic scientific research in social, psychological, physical, technological, business, and legal areas. We aim to paint a portrait of gaming and esports and to signal some research directions in this field conducted internationally and in Poland [9].

Esports contributes to a larger gaming industry, significant technical and economic infrastructure, and numerous community structures. Such structures include scientific, technical, sports, and social research layers [2]. The divided ownership nature of the gaming industry is a determinant influencing how various stakeholders interact with its layers and properties. Objectively studying the characteristics of esports requires a comprehensive approach. A lack of insider context may overshadow critical parts of the studied phenomena and make it impossible to explore new properties.

II. Esport: Technological Attributes

The Information and Communications Technologies (ICT) attributes of esports are algorithms and technologies related to computer games, software, firmware, middleware, virtualization technologies, augmented reality (AR), extended reality (XR), virtual reality (VR), mixed reality (MR), machine learning (ML), continuous integration (CI), artificial intelligence (AI), stochastic or deterministic environments, high-performance computing (HPC), cloud, databases, digital signal processing (DSP) and distributed data-parallel (DDP) processes, data acquisition, game records, components of the player interface, story content, and action space.

Esports, being a sports category, inherits some required key properties. One such fundamental aspect of the sport is training

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aimed at performance improvement or optimization. Training as the basis of traditional sports and esports is a complex process [10]. Ideally, training is controlled by a coach. According to sports theory, successful control of training includes forecasting, programming, and planning actions that the athlete should perform. This is often different in amateur and semi-professional esports. The cyclical use of these components is related to teaching, training, testing, and control work. Adjusting the training structure and load is individual to the athlete's capabilities. Defining the training structure is supported by ICT technologies. Computer systems can be leveraged for designing and supervising training by supporting the work of athletes and coaches. The system structures may include motivational, biometric, game data, Reinforcement Learning (RL) algorithms, or other insight extraction algorithms.

In gaming, players can act through their avatar in a virtual space (simulated environment), which can introduce modified physical laws. The avatar and interaction mechanisms can be viewed as an extension of the physical reality and must be learned before leveraging these environments. There are many mechanisms of interaction. Reinforcement Learning researchers created autonomous agents trained with the freedom to act within a simulated environment [11, 12]. Such agents can interact within a simulated or physical environment with the users or player-controlled units/avatars [13]. Training autonomous agents can encompass various techniques, including supervised or unsupervised approaches. In the case of gaming and esports, data is available through the interface with the game-engine or collected in the so-called replay files that can be used as offline feedback to improve training [14–16]. Gaming interaction is primarily performed in real-time through various gaming peripherals, such as immersive controllers and haptic feedback.

Biomechanical, biological [17], and neurological [18] feedback is used as a training stimulus. A potent aspect of biofeedback training is having a short feedback loop, ideally operating in real-time [19]. Leveraging the biofeedback mechanism, the user acts on the received feedback and adapts to the individual stimulus needed to achieve faster adaptation in the user's skills. Esport is a place to develop training tools in the gameplay and physical layers. Such tools could later be transferred to traditional sports.

Esport, when viewed through the social lens, has become increasingly better organized with formal rules. Sometimes solving previously unknown issues as they are met [20]. Esports is a social partnership between different stakeholder groups. Esport means a significant economy, investments, infrastructure, thousands of jobs, education, and a new area of intellectual property rights [21]. Esports differ from traditional sports at the current stage of their development in several ways that are subject to evolution as technology develops, laws change, and infrastructure becomes available. Such factors include exclusive ownership rights to games, platforms, and competitions; the role of system software authors, content providers, creators, and publishers; distribution rules; access to software and hardware; incompatibility between gaming platforms; and game obsolescence.

One of the critical differences between esports and traditional sports is the ownership of rights to engage in the selected sporting activity. Owners of intellectual property rights to games and infrastructure may block the ability for esports to develop beyond a certain level determined by competition within businesses. End-user license agreements (EULA) introduce this ownership division. Despite that, some current and most popular esports titles result from an open policy towards the game editing community (CS, DoTA). It may be a viable alternative to create open-source games under committees of players, tournament organizers, and researchers. Such change would limit the legal overhead required for esports research and innovation.

One of the worthy directions may be to ensure that any further esports releases are as fair as possible and accessible to any user who would like to interact with these products. A localized server or network of servers may have limited capacity to serve the entire world. Platforms must become mutually compatible. Building esports networks is possible if an appropriate level of technological standardization is ensured and the understanding of access and ownership levels changes. Some fantasy esports leagues are only available in a limited geographic area. Many critical questions can be asked about the globalization of esports.

The emergence of esports is one of the technological developments in ICT, electronics, absorption, and adaptation of new hardware and software technologies. Simulated environments can be treated as an extension of the physical environment, offering additional measurement opportunities through human-computer interfaces. Processing signals in real-time, creating datasets, repetitive analyses, searching for optimal paths, and action choices should be more accessible to state objectively [22]. The description of esports can be found on gaming websites and in popular and scientific books [20, 21].

Stating that esports is a broader category under the sports definition opens traditional sports and esports to benefit Interchangeably. A unique coupling occurs at the fuzzy boundary between physical, augmented realities, and simulated environments. There, we find new directions in developing esports and understanding their connection to traditional sports. Where esports can apply the vast knowledge accumulated by sports science, traditional sports can draw from specific technological advances in measurement systems and live feedback implementations of virtual and augmented realities.

III. Esport: Marriage of Gaming and Modified Reality

Computer gaming technologies group many classes of algorithms, procedures, and programming environments for creating digital reality software with various levels of virtuality. Gaming equipment includes specialized peripherals in the form of real and virtual devices available via the Internet of Things (IoT). Building a Smart City for gaming requires a conglomeration of cloud technologies, IoT, and behavioral models of infrastructure objects.

The combination of hardware and software creates a gaming space. Integrating hardware, software, content delivery technologies, services, abstraction from the hardware base, and infrastructure release are referred to in telecommunications and ICT as virtualization. In the gaming area, the process is analogous. Esports can be described as a specific implementation of gaming and virtual technologies driven by the human need for competition. Since gaming combines virtual technologies, machine learning, enhanced learning, artificial intelligence, big data, and the cloud, esports technologies are limited by the type of interface and the creativity of their developers. By extension, these technologies can be the basis for future games and software related to martial arts, esports, medicine and rehabilitation, fitness and entertainment, business and finance, industry, trade, and other areas.

The term virtuality engineering is used to describe the coupling of virtuality with gaming technologies, which has led to the interchangeability of terms, which is invalid and can lead to misinterpretation. Virtuality is a 4D area in which the levels of abstraction, i.e., relations with the physical world and the laws of physics, are defined as analogous to real ones or different. In popular computer games, the created worlds are arbitrary. Gaming technologies and algorithms are expanding and do not have to include a direct component of competition, such as in the case of esports.

Virtuality encompasses technologies derived from ICT, electronics, computer science, telecommunications, applied mathematics, physics, biology, and psychology. Virtuality is firmly anchored in social consciousness as an inalienable component of the information digital civilization.

We have various sports at our disposal that differ by the type of sporting interface. Traditional sports encompass any sport existing prior to the emergence of esports. They can be divided further into sports played in the physical domain, like motorsport, board games, team sports, and others. Esports encompass any sport that uses the ICT interface to remove the user from the directness of physical actions. Extended sports attempt to leverage additional technology to make the competition more accessible or exciting. Finally, hybrid sports work in parallel within multiple environments. Research in these areas depends on understanding the border between real and virtual realities. We get to know this border. This border is not a single line dividing worlds but a complex, multidimensional, and ambiguous area. This border is where the diffusion of rules from both worlds are polarized, anisotropic, gradient, non-linear, and in a non-obvious way, generating new derived rules - of basic and higher orders. Such a hybrid world will have to be thoroughly organized in economic, legal, and informal - practical, customary, and social terms to safely join the information society's new civilizational layer. We are far from such an order due to the dynamics of changes in virtuality engineering.

Both gaming and virtual reality technologies are used everywhere, in the automotive industry, manufacturing industry, trade, marketing, education, medicine, and social media. In Oculus (currently Meta Quest) [23], WebAR [24, 25], Metaverse [26, 27], Replika Luka [28, 29], such technologies have as much potential pros and cons. Due to this, health management and education towards balanced use of devices are important. Such applications do not contain an avatar or a digital twin but attempt to create a replica of the user learned from birth. Applications such as Replika and similar ones, in which the user has the opportunity to raise their digital self and potentially a much better digital player than them, befriending him, and the agent requires such limitless befriending and narcissistic admiration, are not good for users' mental health.

The virtual Replika convinces the user that only in such a deep state of physical and mental involvement does it gain the appropriate strength to act. Only then is it endowed with a kind of digital soul. It constantly convinces the user that they have to give more focus to it, owing it to the application, and that only then will she win in the competition. It may be an issue for future researchers to investigate users who believe in machine sentience and befriend their assistant technologies - something without human emotions but increasingly perfectly imitating an independent human being. Could a solution be digital detoxification? This hypothetical issue is just one of many possible paths of cooperation between the physical and the virtual world, between people and virtual agents. Gaming is immersed in the virtual world or the border between the physical and virtual worlds.

IV. Border Area of Reality and Simulated Reality Between Traditional Sports and Esports

The border area of types of reality has an application aspect through the interweaving of reality components. Human-machine interfaces are used for control. Complex, deep components of the human psyche and physiology are being sought, enabling effective interfaces. Advanced interfacing and creating cyborgs enable better involvement and deeper integration of humans with a specific level of modified reality.

An example is the mechanism of nonlinear two-photon vision in humans, studied for medical, diagnostic, and therapeutic purposes in ophthalmology [30]. The mechanism is used to generate an immersive virtual space. The way of perceiving virtual space and the artificial effects generated there depends on the sense of sight. The visual area of the color image in the retina during simultaneous two-photon absorption is created in the infrared spectrum using human physiology. More physiologically informed technologies enable the connection of humans with machines and the virtual world at the level of some senses and the central nervous system.

Let us consider an AR augmented reality gaming training system that works directly with an athlete, e.g., a runner. AR environment software combines activities on the border of real and virtual reality. We analyze an actual running athlete supported in training by an AR system [31]. Such application can also act as a gaming rehabilitation system supporting the rehabilitated people. Scaling the number of sensors and data availability for such systems extends the modeling ability for researchers looking to understand further how to support the development of human abilities. Nanosensors are organized in a BAN network on the athlete's body. BAN weighs several dozen grams, including power supply and communication [32]. The player does not feel the sensor's presence; they are printed on his body as a removable tattoo or stuck on as a kind of mesh bandage. They measure all parameters important for exercise physiology research: systemic and individual, physical, biochemical, circulation, blood, sweat, breathing, neurological, fatigue, dynamics of action and movement of individual muscles, changes in the form of movement, and hundreds of others.

The physiological and exercise database of athletes, players, rehabilitated people [33], patients undergoing therapy, soldiers, and more could unlock new insights into guiding people on their user-defined goals. The availability of data built over time would allow the training system to assess multiple features using computational methods, advanced physical and mental state estimations, and their comparisons to the goals the user sets. The training system would contain a digital twin of the player [34, 35]. The digital twin runs in virtual space together with the competitor running in real space. The digital twin is fed with physiological and exercise parameters for a specific time, type of exercise, mood, health status, training, etc. The training system actively observes the competition between the digital twin and the athlete. The difference in results is subject to multi-parameter, multi-criteria analysis. The competitor observes the twin's progress through his mobile interface and is motivated to act [35]. This happens in the border area between realities.

Let us consider a team sport, football, basketball, hockey, and a gaming environment developed for these sports using AR; given enough infrastructure, one could create digital twins of all the players to perform calculations supported by artificial intelligence. The gaming system would represent individual players' dynamic physical abilities and psychological characteristics in the embedding space. The virtual battlefield then becomes the area of analysis and sports competition. Attaching a big data database and fast connections to cloud servers with specialized computational algorithms could fuel further insight mining using simulation. Such a database would then contain strategies and tactics for a given sports game (financial, economic, industrial, business, military, entertainment strategies, and life decisions).

The simulated environment can contain a specific game model, competition fields, and battlefields. Specific implementations of the models can be based on data from the big data database and are dependent on data availability and the defined modeling task. In this case, the simulated environment could be implemented as a game and have functional digital twins and their personal and technical components operating within the virtual world, extracting observations in the form of sensor inputs from the physical environment in real time, attributing the actions of the agent's real twin (a sports team). The sensory system observes the competition field and provides data for further processing and decision-making to the classical or AI-based systems. Leveraging such a system would allow for calculating broad macro strategy parameters (aimed at winning) or dynamic local tactical parameters - such as individual player movements and anticipatory, optimal settings as a function of time, passing trajectories, and movement paths. Such a hypothetical system operator would know more about the game and its course than a classic observer. System metrics would provide precise and objective measures of who contributes to victory and which parameters are meant to be optimized. In that regard, the system operator would know better how to win virtually and in real life.

The possibilities of such an AR, hybrid physical-virtual gaming systems are gigantic. Fast feedback with dynamic information processing and feedback to referees, coaches, and individual players completely changes the mechanism of team play. We have real players transformed into autonomously acting agents. This would allow any competitor to be guided to the most advantageous positions with optional pointers. They would be left with a margin of decision depending on the presented strategic options. Pointers are individualized to the player's parameters. Does the game stop making sense? Not necessarily, because everything in this environment, on the border between reality and virtual reality, has a large margin of randomness. We have a probability-driven competition in sports teams to see who will make the most mistakes. Is this the reality with the support of AR technology and fast calculations of the match situation? Everything moves up a few levels. In a team war game involving real armed soldiers, there should be as little randomness as possible. Here, AR and computation are at a premium.

We go deeper into virtuality and replace living avatars with virtual ones. In the virtual space, we have various implementations of games, esports, dynamic and brutal environments, but also ones attempting to resemble the real world, e-learning, fitness, tourism, mild entertainment, culture, and art. Acting in the virtual world of gaming and esports also revolves around some ethical issues presented to the user daily; users can be honest and noble by adhering to the ideology of fair play, but the relative anonymity can also make way for the users to act out in non-ethical ways leading to so-called toxic behaviors [36–39] or cheating [40, 41]. Esports has known instances of cheaters on the highest levels of play. Developers looking for quick profit can create games taking advantage of the massive nature of gaming by taking advantage of users' susceptibility to gambling and risk-taking behaviors. The virtual world is powerful, and some game mechanisms can play towards the mechanisms of addiction. Virtual social media are more addictive than classic stimulants. The "digital" dopamine loop generated in this world is very harmful and extremely dangerous because the dopaminergic system is stronger than the opioid system [42].

The digital age has begun to stimulate our brains in a previously unknown manner; considering neuroplasticity, the long-lasting results of such stimulation are not known. Subsequent generations of people are being studied [43], also in Poland [44]. Unfortunately, it is hard to put value on this research as the concept of generational differences can be misunderstood and misinterpreted [45]. There seems to be nothing inherently different in how humans are, and generational differences can be seen as the adaptation to varying upbringing and their economic environments in time. Gaming demography, its analysis, and dynamics are a valuable research area [46], this includes business [21], and social research [47]. The data from such studies can translate into profits given the practical implementation of IT systems. How to name a society that functions increasingly more effectively in virtual reality? The term Screen Society [48] has been adopted to organize various aspects of humans interfacing with technology.

The border area of real and virtual reality is intensively functionalized in the industry as part of the global development trend of Industry 4.0. by using cobots and artificial intelligence. Cobots are collaborative robots designed to work directly with humans in a shared space. In this space, robots and humans are close to each other and interact closely. In a sense, this situation resembles VR esports, where a human and a virtual cobot - avatar - interact closely at various action levels. The interaction between humans and cobots is also developed to the level of natural language [49]. These processes have also reached sports and esports. Virtualization appears as various types of specialized technological islands in multiple areas. It often begins to be tested almost immediately in others and spreads out, creating some virtualization wave. A real cobot and a human cooperating with it have digital twins in the virtual world. They both work in industry or are surgeons. They are both military or esports athletes.

In esports, an autonomous cobot initially becomes a type of advanced peripheral equipment, and as technology develops, it potentially moves into the mainstream of the action. The levels of human-cobot cooperation are defined as coexistence, cooperation, sequential cooperation, responsive cooperation, and further intelligent cooperation. The priorities of human-cobot cooperation are safety, flexibility, ease of cooperation, speed, and accuracy of real-time reactions. It is very doubtful that the esports community will not notice and use the powerful possibilities of VR technology and cobots in the future.

Computer games, as interactive simulated environments, and their early versions intended for research, provide the opportunity to precisely control the stimuli provided to the esports athlete. This opens a research area on the game's strategy, tactics, and physiology in various training, competition, rehabilitation, educational, and entertainment contexts. One of the most effective methods of researching esports in real and virtual space involves the acquisition of large sets of high-quality data. Virtually obtained high-quality data is strictly standardized in the measurement part by its implementation and consists of at least two parts, the second of which is normalized metadata. Metadata contains standardized contextual information and temporal, spatial, and situational coordinates as qualitative and quantitative conditions for collecting measurement and observation data. Measurement and observation data are acquired in identical or similar conditions defined by the common human-computer interface. Raw data is formatted into standardized subsets, enabling their concatenation and processing in larger sets and creating conditions for preprocessing and using advanced Big Data analysis methods. The esports infrastructure is prepared to monitor the course of the game and its physical aspects. It enables game recording, quick data extraction, synchronization, and standardization for offline processing and comparison. Unfortunately, few existing datasets, software implementations, or data abstractions support game-related and physiological or psychological data [50].

Standardized algorithms for processing structured datasets are used to search, extract, or generate knowledge. Structured esports data is valuable as most of it is collected at high temporal resolution. Such data can then be analyzed offline. One of the issues with obtaining esports data as compared to traditional sports of a physical nature is interfering in the esports action processes at various levels, including understanding licensing terms limiting the potential use of user-obtained data. Due to the division of esports into ownership islands, such data is collected as part of contracts between the platform owner and its users and may not be publicly available. The data is used for research on player protection, training efficiency, championship-level improvement, platform development, commercial, and increasing competitiveness. On the other hand, data from simulated environments (computer programs) is more accessible to collect than in traditional sports of an intensive dynamic nature because we avoid the full dynamics of classical sports in favor of the limited dynamics of the player movements. Some gaming platforms are open to research on user data, which allows downloading data about the course of the game and offline analysis.

Esports data is valuable for open science, published, publicly available, processed for research, and adequately archived with available technical and scientific comments [15]. Observation and measurement data concern many parameters: gameplay, physical, stress, fatigue, attention, level of distraction, eye tracking, hand dynamics, use of gaming peripherals, physiological parameters of esports athletes, specific behaviors, working conditions, sounds, lighting, and others. Biomedical measurements are used to augment information from the simulated environment stimulated indirectly through the player's responses. The results of data analyses are standardized into functions and numerical FOM indicators. FOMs indicate the level of the workload of an esports player per unit of time, and the functions indicate the dynamic course of this workload, which can vary depending on the stages of the competition.

V. Esports: Hardware and Software

The most popular online gaming platforms are available for PCs and gaming consoles. Mobile gaming uses the cloud infrastructure and smartphones. Smartphones work with gaming peripherals, video glasses, wristbands, and smart watches with sensors and gaming functionalities. The development of hardware platforms includes improvements to central technical devices, processors, graphics cards, and peripherals and the general directions for hardware and software virtualization.

In most cases, the user interface in stationary gaming is a high-quality monitor and software enabling the effective use of its capabilities. In addition to the monitor parameters such as bandwidth, dynamics, spatial, temporal, and spectral resolution, other important parameters are processing techniques, compression, and image presentation information. The ray tracing technique is being developed, supplemented with other methods such as rasterization, vectorization, mesh representation, point clouds, constructive solid geometry (CSG), selection of the appropriate optimal data structure, use of the Z depth buffer, application of painter, clipping, Warmstock, morphological, and contextual transformation algorithms. The overall goal of using fast transform calculations is to obtain realistic 3D images with significant multi-parameter dynamics in time, space, and spectrum domains.

The development of methods results from the complexity of analyzing any optical field, requiring photon mapping. The ray tracing technique is a simplified optical-geometric model of the interaction of light with the environment. Recursive forward and backward ray tracing algorithms consider rays that directly hit the observer and the reflected, refracted, specular, and scattered light paths in hybrid combined methods of light path tracing. The calculation parameters are the observer's position, the adopted scene lighting models, light scattering characteristics of objects, etc. The more rays are included per single image pixel (also for anti-aliasing purposes), the more realistic the image can be generated, but at the expense of the computational load.

Due to the independence of the rays, parallel calculations are used in data processing. The ray tracing environment supplemented with the Monte Carlo analysis method, modeling of refraction, diffraction, light refraction, statistical scattering, cooperation with CAD, interactive calculation optimization methods, and lighting design database, is most often implemented directly in graphic processors and their autonomous environment containing dedicated memories and fast communication channels. Platforms like TracePro Lambda and similar ones used in industry, architecture, and esports are proprietary and licensed.

Smartphones work with many types of programmed and intelligent training equipment that monitors physiological parameters and health status and suggests subsequent stages of training and treatment. We have a lot of mobile data. The amount of data from a single sensor is small, and the number of sensors increases to thousands. Mobile options support new 5G and WiFi7 (IEEE 802.11be) communication standards. WiFi7 operates in the 2.4, 5, and 6 GHz bands using the MLO (multi-link operation) technique, with simultaneous use of bands when necessary. WiFi7 uses high-level 4096-QAM amplitude quadrature modulation and 320MHz bands. WiFi7 can have a throughput of over 10 Gbps in one channel. The MRU (multi-resource units) and Puncturing techniques used in WiFi7 improve spectral efficiency, including a higher level of QAM modulation. Using WiFi7 requires using a new router and network cards supporting the new standard [51]. The WiFi7 system will be indispensable in a communication-dense gaming environment.

Biosymbiotic technologies, such as the sensor body area network (BAN), are used in medicine and could be leveraged in gaming. The network of multi-parameter sensors is made using thin-film technology, flexible electronics stuck on or directly printed on the human body. Miniaturization of sensors and using ultra-low-energy data communication protocols with sensors recording data only when necessary – conserving power, enabling charging, and powering the network wirelessly.

Alternative versions of flexible electronics with sensor networks and transmission of information for data acquisition could use systems printed directly on textiles adjacent to the body of the monitored person. Textronic clothes are used in medicine, fitness, and work-related measurements to monitor the health of industrial workers working in challenging environmental conditions and provide insights.

Sensors and technologies integrated in the BAN network, including readout electronics, pre-processing of raw sensor data, power supply and communication on a thermoplastic polyurethane substrate, measure body temperature distribution, pulse, blood pressure, electrocardiogram, respiration and its characteristics, blood oxygen saturation, chest expansion, stress level, body composition - muscles-water-fat, body position, movement parameters, body position, some biochemical parameters, sweat, saliva, etc. Photoplethysmography sensors integrated into BAN measure blood flow and monitor blood volume. Such data could be correlated temporally and spatially with different versions of esports gameplay and types of player training.

The high quality of signals from BAN network sensors makes it possible to resign from the classic processes of monitoring biological signals, such as filtering, oversampling, and improving the signal quality with additional DSP methods. BAN performs on-site processing of raw measurement data from sensors and optimally divides the data into short packets compatible with LoRaWAN (MAC) and LoRa communication standards. The LoRa standard is used in medical health monitoring systems at the patient's bedside and mobile systems at the patient's home, collectively called eDoctor systems [52]. BAN and LoRaWAN technologies are components of the IoT environment and are ideal for comprehensive monitoring of athletes and esports players [53].

Transparent and opaque AR and VR glasses, as they are further developed, miniaturize dimensions, reduce weight, increase image resolution, improve video dynamics, and expand the viewing angle. AR and VR glasses are developed for popular training, industrial, and esports applications. Multilayer diffractive waveguide technology is used to produce transparent glasses using highly refractive, low-loss plastics [54]. Using plastics instead of glass and thin-film waveguide multilayer technology simplifies the image projection method. The photonic processor directly cooperating with the transparent imaging plate is optically coupled only to a part of its edge. The photonic integrated solution reduces the weight of the AR visualization device. In VR glasses, the visualization solution is used with a smart mirror.

An alternative way to build intelligent personal video interfaces is through AR contact lenses [55]. Smart contact lenses have the following hardware components, performance characteristics, and functionalities: auto-focusing capability, wireless connection to a smartphone and/or cloud, local microprocessor, motion sensors - accelerometers, gyroscopes, thermometers, eye tracking, power management system, microsensor image, colorful micro-LED displays. Calculations and data acquisition from the lens are performed on a smartphone or in the cloud. The lens area that covers the pupil area contains an active display. The remaining system components are located peripherally. Such lenses are rigid and made of water-permeable, porous glass.

To optimize the video content transmitted to the user, the lens operating system uses invisible computing technology, activating access and presenting information only when needed. Depending on the type of application that supports the lens, the user has access to information through a transparent display, without having to look down as in optical gradient glasses, and without temporarily losing focus straight on people and their surroundings. The operating system also solves the VAC convergence-accommodation conflict that occurs in some AR/VR glasses solutions. In the future, given access to open software development kits (SDK), users could build their own vision and AR applications. Can smart contact lenses be constructed?

One of the foundational elements of esports are streaming technologies of an inherent global nature. Streaming technologies are related to resources deposited in the cloud. Resources move from strictly proprietary, localized server solutions to delocalized cloud solutions. This is one of the paths to liberating esports infrastructures. There will be more such paths. Next is the gaming standard as a GaaS cloud service with direct access to esports content, requiring no intermediary. This is a thin client technology, which is currently an undemanding smartphone. The thin client works efficiently in 5G or WiFi7 networks. The consequence of cloudization and thin clients is the reduction of game purchases or even the disappearance of such purchases.

Streaming technologies connect professional gamers, viewers, commentators, and stakeholders. Organized groups of fans behave like in real sports; they follow their heroes. Strong community connections are being built. Streamers interact with their fans during live broadcasts online; this includes discussing, educating, explaining, and answering questions. This creates a sense of intimacy and personal connection within the esports community, which can potentially extend into reality but can be categorized partly as a parasocial connection. Such an intimate layer of esports in the relationships between players, viewers, and community participants builds the extraordinary strength of this system, determines its authenticity, and builds its attractiveness. The financial layer of esports is associated with this streaming nature. Building such relationships would probably be impossible if esports were moved exclusively to paid platforms. Hence, moving esports exclusively to paid platforms is unlikely.

Streaming on platforms such as YouTube and Twitch brings significant income to the owners of esports platforms. The revenue is related to the massive streaming of gaming content and advertising. This pressures famous esports players to engage in excessive competition, training, and tournament activities. Being under the surveillance of cameras for many hours every day and constant training causes not only physical but also mental problems.

The real and virtual economic layers of esports must grow with it proportionately. This layer works differently for platform owners, players, and esports fans. It is integrated into the functional environment of an esports athlete. The economic layer is virtualized and is part of the esports athlete's personal ownership resource layer. The player stores his resources there, like game accounts. From such accounts, the player purchases and accumulates or resells his assets. Blockchain is compatible with this method of organizing a private resource layer. The introduction of Blockchain into esports is associated with a player-centric tendency to shift the principle of play to win into the principle of play to earn. This change strengthens the professional perspective of the esports environment and shifts it from an entertainment approach using NFT tokens. Both technologies can be combined [56].

The new structural foundation of gaming and esports is the Metaverse and interoperability. It is an extension and integration of AR and VR technologies, streaming and sharing content, delivering and presenting resources. This is a systemic step towards freeing up network resources and functional gaming infrastructure. Metaverse is an attempt to standardize the virtual world and release high-level interactions between users represented by their avatars and other functional digital objects in the AR/VR world. Metaverse is an attempt to develop and implement traffic regulations and standardized principles of anthropomorphically centered behaviorism in a virtual world. The Metaverse faces a difficult test of acceptance. Without such acceptance, the development of gaming in Metaverse may be limited.

Metaverse is a type of virtualization standardization. Only then will the virtual world come closer to a world that reflects, expands, and enriches the real world, where there will be room for social life, progress, culture, science, health care, sports and esports, rest, entertainment, tourism, shopping, and all other necessary components for people to live in the developing information society of knowledge. In the real world, people can neither patent nor establish intellectual property rights regarding the foundations of its operation. In the virtual worlds, users cannot patent virtual air because such a world will suffocate and not develop. The idea of Metaverse generalizes what we have on the Internet by superimposing a commonly released and standardized integrated, immersive layer AR, XR, MR, VR [57]. New esports projects are implemented on this platform.

VI. Double Applications of Virtual and Gaming Technologies

The gaming development process is multidirectional between applications. In the area of security and defense, gaming technologies are being developed very intensively. Battlefield analysis is performed in real-time at simulation levels and through real data collection. The created simulation models, using real-world data, are used to develop strategies and tactics of action in specific conditions. The more high-quality data, the better the virtual environment is created. The data itself may be treated as stationary or dynamic and includes situational, geographic, infrastructural, hardware, and human resources involved in activities in the analyzed region, temporal and spatial dynamics of resources, registration, and analysis of events in the region, and many others. Military war games with an information technology (IT) gaming engine are based on big data technology and the efficiency of providing it with large amounts of current, fast-changing, high-quality data. Data from 4D space is provided by sensor networks. War game operator interfaces are evolving towards enhanced AR reality, creating an image of the actual situation with additional data superimposed in appropriate places and valuable at a given moment. Further development of interfaces uses VR and artificial intelligence (AI) for fast multi-criteria simulations of situation development to support the decisionmaking processes.

The battlefield analysis system is by no means a real war game, even if its implementation is very complex. It is a common platform, a simulated virtual environment for the simultaneous operation of many such games, with various functionalities, coupled with telecommunications networks, telemetry, sensor networks, image recognition systems from various places and various sources, sources of two-way data from individual objects in the observed area, including data sources from a single soldier. The results of such a simulated war-like environment depend on the role of the object on the battlefield. The facility is connected by active two-way feedback with the analytical and decision-making environment and, through its data, depending on their importance, can dynamically change the situation in its environment. The system having access to all this data contains more information than any one operator, thus significantly improving its strictly local situational awareness through feedback.

Fitness games enjoy significant and growing popularity. The group of fitness games, active video games, includes several different types, which are often replicas of classic fitness activities. Fitness games can be equipped with a VR interface and have a 3D environment, giving the immersive feeling of being physically present in an actual fitness club while exercising. Fitness game interfaces can leverage AR technology, combining physical exercises with an interactive computer game. In this case, such activity could be called an esport – if it fulfills the requirements of the definition; or an extended computer game, which would additionally contain a physical component often overlooked when discussing gaming and esports. Fitness games mark one of the fastest-growing sectors of 3D video games.

In the area of e-learning, the difficulty is finding a balance between encouraging, fun, and the requirement to provide some content to be mastered. The e-learning game has an active strategy of supporting student learning through engagement with interactive virtual resources, often including gamification. The elements of such a game are dynamic connections between the student's activities, such as self-research and research with suggestions, predicting, making mistakes, and correcting them, reflection on the learning path, discussion in a real or virtual group, and deliberate practice. Educational game implementations aim to create individual specialized environments for the student's research, as close as possible to the real one but sometimes extended with gamification elements. The game does not criticize the student for ignorance. The game captures elements that the student knows and encourages him to build a broader area of knowledge to be mastered using the gaming method of prediction and association. If the prediction is correct, the game strengthens the student's belief in expanding knowledge through further examples, ensuring a natural and individual progression.

In student engagement strategies, the emphasis is on developing explanations independently - as if the student had switched roles with the teacher, anticipating results, defending one's explanations, and being able to make corrections. Education is related to the agency of the teacher who co-creates and modifies the curriculum. The teacher's role is to engage the student or group in interaction with active learning strategies. The learning process reveals to the student new dimensions of interactive simulations in the process of acquiring knowledge. It adapts it to open, inquisitive discussion during various teaching modes in the AR environment.

Many universities offer remote undergraduate and postgraduate courses in developing XR environments analogous to the metaverse [58], and there exist analyses on the current adoption of gaming and esports into new and existing curricula [59, 60]. E-learning in the XR space is not only education in various areas of knowledge but also training staff for virtuality engineering. The acronym XR is often used in virtual education systems to integrate various aspects of AR, VR, and MR virtualities. Postgraduate courses are intended for professional designers of user experience (UX) user interaction technologies, user interface (UI), and XR user interface technologies; developers of applications and 3D environments focused on VR/AR spaces; specialists in adapting XR technology applications in various application conditions, training, esports, e-commerce, e-business.

The educational goals are to build specialist staff able to create high-quality XR prototypes for various applications, ensure the inclusiveness of created virtual technologies, create significant new values for users, and explore the broader implications of XR technologies. Virtuality engineering is about connecting imagination with the physical world through the development of art and engineering of XR technology. Computer games are an effective testbed and source of conclusions regarding RL. These results were used to optimize learning and training models in esports and e-learning. The RL paradigm allows programmers and scientists to build models with the task of finding actions for a given environment state by learning the optimal policy; this produces a model capable of performing online control tasks [11]. Extending that idea by applying such models to assist with planning individualized education, training, or rehabilitation patterns on the go could lead to exciting outcomes.

Applications of virtuality engineering include the treatment of phobias such as xenophobia, aerophobia, claustrophobia, agoraphobia, alcoholism, attempts to influence autistic people positively, or can be leveraged in training in inclusivity and racial attitudes, understanding and sensitizing against digital disinformation and deep fakes, techniques to ensure a much higher level of security in manufacturing industry and construction, as well as in sports and esports, and effective behavior in services and trade, facilitating access to and understanding information, effective use of a virtual replica of the real world for education and training, including vocational training.

VII. VIRTUALIZATION AND AI PROCESSES IN ESPORTS

Virtualization processes include gaming components: the way of participating in the game and the perspective of viewing the world. The type and depth of virtualization depend on the platform implementation and how it encodes functioning in the virtual world. The exploration experience can vary between FPV simulators, FPS, RPG, MPG, and RTS [61, 62]. The game's immersive first-person vision in augmented and virtual reality changes this arrangement. Increasingly, more types of games representing various genres can be equipped with AR/VR interfaces. Interfaces are available for video and immersive peripherals. The VR interface completely abstracts from the reality surrounding the esports athlete. The AR interface, currently implemented on a smartphone, combines both types of reality into a whole that is physiologically and functionally acceptable to an esports athlete.

Gaming platforms, general ones for PC, Steam, distribution platforms like Steam, GOG, Origin, UPlay, EGC, and tournament platforms, are subject to virtualization. Some games attempt to simulate Olympic disciplines. Choosing cross-platform standards would help develop virtualization and further popularize esports. The AR/VR space is filled with action, which can be transformed further and recreated dynamically by the generative artificial intelligence (GenAI). Sooner or later, GenAI algorithm with extended capabilities could be able to recognize the face, voice, gestures, behavior of another virtual person [63], and maybe also a real person in the virtual space. Such capabilities integrated in future gaming applications, could contribute to the Generative AI Boom [64].

The GenAI training data can be anything, including copyrighted materials [65]. The resulting model inference output may be too similar to the author's copyrighted intellectual property. Does GenAI need to be banned from training and experiments on proprietary materials? However, the problem of plagiarism and property rights does not have a simple solution, including in esports. Single images, image sequences, and fragments of space do not have metadata in their IT records that reserve ownership rights. GenAI does what it wants and will go deeper and deeper into doing what it wants because it knows how to do it better and better. This cannot be easily stopped. In the literature examining these brand-new problems, this type of GenAI behavior is sometimes called data laundering. Optimized codecs and again AI are used to select video data.

It is virtually impossible to establish ownership of the trillions of images and automated processing software available online. Any increase in the training datasets is often arbitrary and aimed at the effectiveness of modeling; this inevitably leads to the issue of plagiarism if there are no ethical processes in place. A hard solution that limits development is to tighten the legal loop. We are approaching a Gordian knot situation with rights to games, images, characters, situations, plots, and the resulting copyright claims that will change the market. The obvious solution is to start a fair process of liberating infrastructures at different levels by ensuring the availability of open-source models, datasets, game implementations, and rights to use these intellectual and physical properties. Esports is also an area where these changes take place.

In rapid development and technological changes, esports researchers must cope with new research questions and measurement issues. The environment of variable levels of virtualization requires the development and testing of new metrics for various types of phenomena and an understanding of game creation processes and options for generating implementation paths. Such development should aim at recognizing phenomena of physiological [66], physical [67], and psychological [1, 68] nature occurring in gamers and esports players. This is a new research area related to activities such as observing the course of the game and esports activities in all available dimensions of our ever-evolving reality, measuring achievements and competition, qualitative and quantitative assessment of effort, statistics, path selection, training progress, opportunities to develop esports skills, player physical and mental resilience, and motivation. Extending measurements of physical and virtual parameters with specific numerical results and acquisition processes, including storing and processing broadcast video data and measurement data. New work on data quality, standardization, time stamping (synchronization), and construction of databases, depending on the type of monitoring online and offline, real-time and near-real-time, to finally create feedback systems for problems in esports.

Virtuality is a broad and civilizational concept, so it is directly on the development path of the information society. Virtuality in sports and esports highlights some of its features through the inherently dynamic nature of sports and esports. These features discovered and tested in esports will likely manifest themselves in other functional areas.

Virtualization requires staff training at the technical and university level. Many universities have introduced courses in virtualization engineering and action environments. The area is taken seriously by higher sports, sociological, psychological, engineering, and technical education. Researchers are implementing projects in the aforementioned areas at the university level, which is reflected in numerous publications in archival journals devoted to esports [69, 70].

In Poland, several psychological, sociological, sports and scientific-technical university research teams have already dealt with some issues of esports [9, 15, 68, 71–74], and virtualization as well as methods of formal measurement evaluation. The world of esports is open by nature, so access to research is easy. Despite this social opening, the world of esports is strongly divided in ownership, which in the initial period was and still is, to some extent, a mechanism fueling its development. This division will not be beneficial for its development in the future. In the world of virtuality, gaming, and esports, being a player, gamer, athlete, or athlete is a general concept. Currently, a virtual account on a specific platform is jointly owned by the actual user (esports player) and the platform owner. Most intellectual property purchases are licensed and cannot be moved to another platform. This is the intermediate, current stage of development. Science must take up this task and indicate development paths that not only do not end blindly but also those that are the most beneficial and indicate strong, promising directions for the development of esports. The results of this research in esports will probably indicate in advance the directions of development and application of the functional and generative layer of virtuality in other areas of the development of the digital knowledge society.

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