一般社団法人 電子情報通信学会
THE INSTITUTE OF ELECTRONICS,
INFORMATION AND COMMUNICATION ENGINEERS

信学技報
IEICE Technical Report

A Prospective Study About Enhancing Effect of VR in Soccer Training

César Daniel Rojas Ferrer† Itaru Kitahara†† Yoshinari Kameda†††

Department of Intelligent Interaction Technologies. Graduate School of Systems and Information Engineering.
University of Tsukuba. 1-1-1 Tennoudai, Tsukuba, Ibaraki, 305-8573, Japan.
E-mail: † s1620853@u.tsukuba.ac.jp ††kitahara@iit.tsukuba.ac.jp †††kameda@iit.tsukuba.ac.jp

Abstract: In elite football soccer, the quest for new training methods in order to improve performance is never-ending. Specially in recent years, the pace at which technology is advancing have created a situation where more athletes are incorporating novel technology to their training protocol, and Virtual Reality is one of the key technologies. Even though employing Virtual Reality for physical training is not new, the approaches employed so far have been plagued with problems due to technological limitations. Now, with the advent of mass consumer VR products and rapid advancement of the technology supporting such devices is opening new levels of refinement and possibilities. Thanks to this tendency, we are able to design a VR Soccer Training system that offers the possibility for both coaches and players to re-experience countless times previous matches inside VR from both their point of view as well as their adversary's with just a pc and a Head Mounted Display. By such means, in this work we focus our efforts in analyzing the enhancing effect of VR in helping the players develop their spatio-temporal awareness, crucial in team-based sports for knowing the best location to pass the ball with high success rate in a way that could be only realizable with virtual reality. Furthermore, we also aim for finding the proper implementation that allows us to employ previously captured displacement data for creating new hypothetical in-game situations inside the VR simulation, so that the athletes can achieve a new level of visualization training with the expected improvement in their overall performance on the pitch.

Keywords Virtual Reality, Movement analysis, Spatio-temporal analysis, Football

1. Introduction

Virtual Reality (VR) systems have advanced at a vertiginous rate in recent years thanks to the conception of mass consumer products such as the Oculus Rift, HTC Vive, Samsung VR, Playstation VR, etc. Even though most of those products are clearly intended for entertainment purposes as the main target, there is also a market for this technology in various fields such as scientific, industrial, medical, educational, artistic and of course, sports related applications [1]. Even though this type of technology has been in the spotlight since the late 90s due to its potential applications [2], until just a couple of years ago they were highly expensive, and only a select group could afford the equipment needed for the development of applications, relegating VR experiences to a small niche. But this situation has been changing recently at an impressive rate with the appearance of the devices mentioned above.

Not only the price has gone down, but also the portability of the systems themselves, giving the chance of deploying a VR solution in a matter of minutes in a variety of locations, like for example in the locker room or the side of the pith in a soccer field, with just a laptop and a Head Mounted Display (HMD). This environment offers the possibility of experimenting with new approaches to sports training by deploying this technology with the athletes even on site if needed.

In this paper we discuss the enhancing effect of VR in soccer training and how it can be realized by developing the spatio-temporal awareness of the players. Instead of discussing the technical implementation deeply, this time we rather focus in the elements that should be taken into account in order to realize an effective training framework.

In soccer training, there is a long history of video technology, especially in the last decade soccer video analysis has attracted much research, where a wide spectrum of possible applications has been considered such as verification of referee decision, tactics analysis, automatic highlight identification, video annotation and browsing, content based video compression and automatic summarization of play [3], but in the case of visualization based training, using the orthodox video training approach in comparison to Virtual Reality Training seems to have some limitations that are inherent to the technology behind it, and test data in related studies has shown indicatives that when it comes to psychomotor skills training, the subjects that employed VR training outperforms the ones that use Video based Training, suggesting that the former one is a better training medium a priori [4].

Furthermore, the importance of spatio-temporal awareness in team based sports is recognized as a core element of the game, but surprisingly there is a sensitive lack of tools that help players to train that ability in a controlled, qualitative way. In soccer analysis tools, typically the positional information is extracted by setting high definition cameras around the pitch, and tracking the players in a per second basis, delivering the coordinates for being employed and complemented during a post-processing step where the data are annotated with additional information manually or semi-automatically. Even though the player's positional data generation process has a lot of development, comparatively the analytical tools for transforming such information into useful tangible application is lacking and underdeveloped. The research on analyzing the obtained movement data itself is scarce, and professional teams seem to be demanding new solutions in this aspect [5]. In VR we see a unique way to fill such void.

Now, in relation to already existent VR training systems, they seem to be limited by scope and affixed to the concept of just reproducing pre-conceived patterns of movement (see next section). This limits the potential of VR technology by constraining its possibilities, consequently reducing its final benefit in our opinion.

Based on this facts, we feel compelled to propose a novel soccer training system based on VR, that offers a robust tool for spatio-temporal awareness development, match planning and visualization training, such as the one we are going to introduce in the present work.

2. Related Work

2.1 Spatio-Temporal Awareness in Soccer

Like in any team-based sport, spatio-temporal awareness is crucial for achieving a high performance since in collective games knowing when and where other players are located is vital for making the best decision for the next pass, dribble or shoot.

Although research and development is scarce in applicability of available spatio-temporal information to game analytics, there are notable exceptions such as R. Nakanishi et al. [6] who applies the concept of dominant region, described as "a region where the agent can reach faster than any other agents" to RoboCup Soccer, where they employ the spheres of influence of each player in order to predict the outcome of certain actions, evaluating the suitability of the current strategy, making possible to predict a success or failure of passing by real-time calculation based on the agent position, velocity and direction of each agent.

There are techniques applied to soccer analysis that employ spatio-temporal information to applicable visual representations useful for coaches and players, such as the Playing Area Subdivision [7]. Since player trajectories and event logs can be considered low-level representations and can be challenging to work with, a way to deal with this issue and make it more significantly representative is to discretize the playing area into regions and assign the location points contained in the trajectory or event log to a discretized region. By subdividing the playing area into regions, such that each region is dominated in some sense by a single player, for example by the player being able to reach all points in the region before any other player.

2.2 VR for Psychomotor Skill Training

Good research has been done related to VR and its varied applications in the past decade, showing that VR is a tool which can benefit many fields in training [8]. Even though our research will focus mainly on its application to soccer training, it is worth mentioning a few works that focus in studying the impact of VR on psychomotor skills, such as rehabilitation where certain types of patients constantly require repetitive movements with the help of a therapist [9], in such cases VR offers an alternative for providing the guidance needed for the exercises.

Another approach in the medical field uses VR extensively for training physical motions of medical students [10], preparing them for complex task like surgical procedures. In a related study focused on laparoscopic surgery, by tracking the movement of the instrument and correlating that with the virtual tasks, a detailed analysis of how well the task has been completed, rather than simply how quickly it has been done, could be produced with a VR simulation, and proved that experienced surgeons outperform younger ones by measurable, objective criteria [11]. That kind of assessment would be almost impossible in a non VR environment, since is harder to get detailed and constructive visual feedback related to specific visual-spatial skills. This application of VR shows that this technology can be also applied successfully for task/performance assessment and not only on training based in task repetition.

Pioneering work in the past, centered in analyzing the effect of Virtual Reality in psychomotor skill training in contrast to video training, demonstrated better learning transfer from virtual reality [12]. Which means, after learning athletic movements (in this particular referenced study tai chi) from either virtual reality or video, subjects later on performed better in the physical environment after learning from VR. In another experiment from the same work, learning from VR was approximately 25 percent more effective than learning from video. Another work employed a system that analyzes images to capture participant posture during a golf swing in order to provide feedback and consequently help him to improve his technique [13].

2.3 Visualization Training in Sports

The domain of Sports Psychology has evolved in a way that now is possible to see common practices among teams all over the world based on a series of techniques such as relaxation, psychophysiological assessment, biofeedback, neurofeedback, cognitive restructuring, imagery and simulation. Among this elements, the ability to control thoughts, arousal, and attentional focus appears to be the common denominator in the concentration behavior of winning competitors, employed in order to obtain better performance and help the athletes overall to keep focus and concentration during a competition [14].

An exemplary case of the aforementioned concepts applied to soccer with success is the former 2006 World Cup winner team, the Italian national team utilized a number of biofeedback and neurofeedback techniques framed in a concept known as the "Mind Room"[15]. They used the principle derived from sports psychology of relying in biofeedback and neurofeedback to assess and teach the athletes to maintain appropriate breathing, relaxed muscles, coherent heart rhythms and dominant alpha brain states. Details on the Mind Room remain secret, but it has been well analyzed and identified by experts four components well documented in sports psychophysiology. In resume, in order to outperform the rivals and keep a peak performance, the player needs to stay calm, alert, and focused on the goal which requires special preparation considering the highly stressful environment they find themselves in quite often during an important match. For achieving that, the Italian players were reported to use meditation, physiological relaxation, and visualization techniques to enhance their relaxation, alertness, and focused responsiveness on the field.

3. Spatio-Temporal Awareness of the Players

By analyzing the existing research previously cited, we are convinced that a different approach is required in order to realize an effective training method that may allow the athletes to develop further their talents in a way that haven't been implemented so far. Although all of the studies previously mentioned showed promising results, they all offer either a rigid experience, relying mainly on playback of a previously recorded action without much room of further customization once the action has been defined in the pre-recording process, or rely in too abstract and ambiguous elements to improve performance.

In this paper we discuss a new approach for realizing the enhancing effect of VR in soccer training by developing the spatio-temporal awareness of the players, and in the following sections we analyze some of the key elements that should be taken care of for maximizing spatio-temporal awareness training results in VR, finalizing with the necessary visual space perception elements to complement the VR training experience.

For realizing this system, we employ player's displacement data previously captured with panoramic cameras for reproducing their moving patterns inside the VR simulation. The displacement data itself, is captured by carrying out player's positional tracking with K2 Panoramic video cameras placed in the stadiums and with the help of Match Analysis services and its proprietary software Mambo Studio [16] for the post processing and analysis of the data. Mambo Studio offers full player's statistics, profiling and positioning with which we can extract each player's trajectory information, employing it to our advantage while building the simulation. To put it simple, each trajectory is a sequence of location points, and these can be used to extrapolate the basic movement geometry of a player at a given time-step into our VR simulation. Similarly, the geometry of key events (when a goal happened for example) can be inferred from such data.

The resulting positional coordinates of the players extracted from the video footage has one second interval between each known position, leaving the blank trajectory information between seconds to be filled by employing computer graphics interpolation techniques such as Catmull Rom Spline in order to achieve a smoother movement inside the simulation.

4. VR Implementation

In order to help players to develop their positional awareness, we reproduce the match inside our simulation employing Unity 3D as the selected development environment, given its versatility as a game engine and the native support of Oculus Rift, the selected HMD. The reason for this choice it the availability and easiness of deployment of the system setup in both outdoor and indoor environments with relatively lightweight equipment, easy to use be the players and coaches in a variety of situations and locations.

4.1. Spatio-Temporal Awareness in VR

In order to develop the spatio-temporal awareness of the players, we take advantage of the full immersive capabilities of the Oculus Rift in order to help both the player and coach visualize from a first person perspective the full dimensional information available in a given event during the game. By seeing the other players relative position as if he (the user) were re-playing the game, it becomes possible to analyze the effectiveness of game decisions such as passes, shoots and overall movement based on the player's particular field of view. Furthermore, it could be possible to enhance the decision making analytical aspect by integrating spatio-temporal related techniques to the simulation, such as the one that will be discussed next.

4.1.1. Approximate Player's Dominant Region

Thinking about the unique potentialities of VR as a medium for training, it offers the chance to visualize in situ the relative position of each player while enhancing the information with analytical data that couldn't be accessed during live training, or poorly visualized by traditional means such as the standard drawing board commonly employed by coaches for reviewing team strategy.

One possible approach could be by adapting to VR the concept proposed by R. Nakanishi et al. [6], which states that the region where a player can reach before any other rival can be calculated by knowing the time, trajectory and speed of each one of them in a given moment, such as the dataset received from Match Analysis in our system. By employing such data, it could be possible to represent the safest locations to make a pass by adding using visual cues in the simulation that represent each player dominant region, meaning that the zones in the pitch not covered be the rival's area of influence are safer to make a pass.

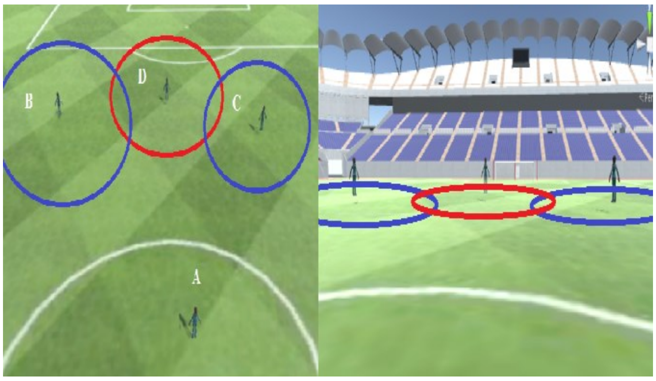

Fig 1: On the left side, the overview of each player dominant region, on the right the first person view from the perspective of player A.

In figure 1, the concept of Approximate Player's Dominant Region (APDR) is shown, where the circles around each player represent their respective dominant region in that moment. On the right image, it can be observed from the bird-eye point of view the player A and both the companion and rival's ADPR, with which he can foresee the areas to make a pass with lesser success rate in the overlapping sections of player's B and C with D. On the right, the same scene is viewed from first person view, in this case player's A view as the user with the HMD would, being capable to analyze spatio-temporal information in a way that he couldn't without VR.

This also offers the possibility to measure how much of the ADPR of other players can be observable from a first person perspective in a real game, how much is the limitation of the field of view of each player and how much information is lost to him from his blind spots. All of this can be better appreciated in VR, since the HMD simulates the head rotation and overall field of view of the players.

4.1.2. Displacement Data and Defensive Unity

In a Soccer game, the so called principle of defensive unity which is related to the positioning of off-ball defensive players in order to reduce the effective play-space of the opponents has a critical impact in the match outcome [17]. It has been suggested that in order to achieve a high degree of success in this principle, it is vital for each individual player to have a clear understanding of his position and the position of his opponents [18]. Based on this, we decided to focus in the correct representation of the player's position inside our VR simulation for offering an effective medium for training based in this particular concept.

4.2. Visual Space Perception

The sense of immersion is a key element in VR, which means that the user must feel he is in presence of an accurate representation of the world. Researchers are still working to understand some fundamental issues including the mapping between real space and its mental representation (visually perceived space) [19]. But existing research on the element of dimension and scale [20], proved that subjects rely on apparent size when making depth comparison using a HMD, and suggested that humans use relevant visual cues from their body's position to judge depth and distance. Therefore, we considered the best approach to realize dimension and scale representation in our simulation, while also keeping in mind the importance of the correct position of the user in relation to the VR world representation.

4.2.1. Dimension and Scale

One of the many merits of choosing Unity as the developing platform is that it offers the possibility of a correct spatial representation inside the simulation; where by default one Unity unit is equivalent to 1 meter in real life. This gives us the option of making real height custom made player models and stadiums.

As seen in the Figure 2, if we know the real measures of a given element then it is possible to translate that information inside Unity, therefore the player models would also have a similar physical proportions compared to their real counterpart as well as the pitch size, and the stadium and its elements can be built by following FIFA standard measures [21]. This could also offer valuable information to users in various situations, like for example in the case of a corner kick, a taller attacker can score easily with a header, therefore he requires a tighter man marking.

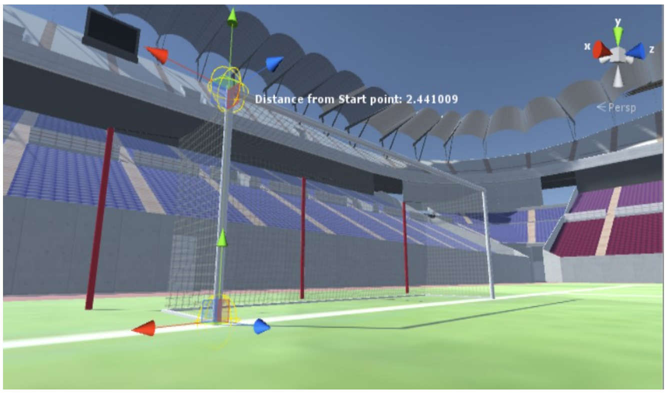

Fig 2: Goal Post height measured with the Unity units to meters' conversion tool. The real standard size is 2.44m as stablished by FIFA, just like in the picture.

By being able to tune the simulation with dimensional details such as the relative height of each player, we can provide a more cohesive experience, filled with useful data to be employed during VR training sessions.

4.2.2 Head Mounted Display and Camera Height Calibration

So far we have described how the real life height equivalence is transferable to Unity. But we must keep in mind that the end user will experience the simulation through the Oculus Rift HMD. Therefore, there are some details that we must keep in mind if we really want to fine tune the experience and make the dimensional data as accurate as possible. When it comes to the Oculus Rift, the point of view will be that of the position that we set of the player's camera inside Unity. If we know the particular value of the player 's eye height, then we can tune it to that particular player, but in average the cam should be fine by being placed about 10 cm below the tip of the head if we consider that, for example in a population with an average height of 1.70 m then the average height of eyes is 1.60m (as a matter of fact, that is the average height worldwide) [22]. Once the players point of view is set, the system is ready to be used by players to experience the virtual match simulation. Below we see a figure depicting the workflow for the system.

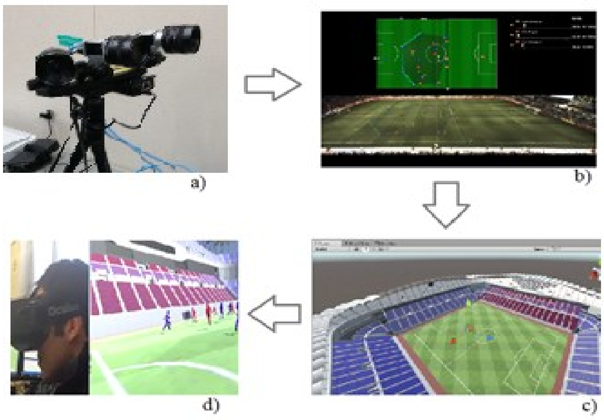

Fig 3: a) Panoramic K2 Cameras placed at the stadiums capture the action. b) The displacement and players profiling is extracted and analyzed with the help of Match Analysis. c) The displacement data is exported and represented inside Unity 3D. d) The user experience the Match from a first person perspective from both teammate and opponent point of view.

5. Conclusion and Future Work

In this paper we discussed a new approach for realizing the enhancing effect of VR in soccer training by developing the spatio-temporal awareness of the players, and we analyzed the key visual space perception elements to achieve this, such as dimension and scale and head mounted display and camera height calibration.

With the advent of mass consumer Virtual Reality technology, there is currently a considerable rise in VR experience production in a wide range of fields in both quality and quantity. But there is still a perceptible lack in practical applications that could offer the possibility of truly seeing what the user foresees inside his mind. In the future, we want to further tune the proposed system, make possible the representation of useful spatio-temporal data, the Approximate Player's Dominant Region, and be able to use the obtained data in constructing hypothetical situations that could unfold in a future match.

We aim to integrate core tactical planning elements in a VR game drawing board fashion, which coaches could employ for letting their players know the strategy for the upcoming game by giving form to his ideas in our VR solution, showing in a perceptible way what he thinks could be the movement patterns and strategies of the adversaries, allowing both players and coaches alike to actually see their opponents moving and behaving with their real biomechanical characteristics, and be better prepared both mentally and physically for the action.

This work was supported by JSPS KAKENHI Grant Numbers 25280056, 15H01825.

References

[1] S.R. William, and A.B. Craig. "Understanding virtual reality: Interface, application, and design". Elsevier, 2002.

[2] C. Youngblut. "Educational uses of virtual reality technology". Institute for Defense Analyses, 1998.

[3] T. D'Orazio,M. Leo "A review of vision-based systems for soccer video analysis". Pattern Recognition, Elsevier, 2010.

[4] E.C. Hmilton, D.J. Scott, J.B. Fleming, R.V. Rege, R. Laycock, P.C. Bergen, S.T. Tesfay, D.B. Jones. "Comparison of video trainer and virtual reality training systems on acquisition of laparoscopic skills". Surgical Endoscopy and Other Interventional Techniques, Volume 16, Issue 3, pp 406-411, 2002.

[5] J. Gudmundsson and T. Wolle. "Football analysis using spatiotemporal tools". Computers, Environment and Urban Systems, 47:16–27. ISSN 01989715. 2014.

[6] R. Nakanishi, J. Maeno, K. Murakami, and Tadashi Naruse. "An Approximate Computation of the Dominant Region Diagram for the Real-Time Analysis of Group Behaviors". In Proc. 13th Annual RoboCup International Symposium, pages 228–239, Graz, Austria, Springer. 2009.

[7] J. Gudmundsson and M. Horton. "Spatio-Temporal Analysis of Team Sports - A Survey." CoRR abs/1602.06994 n. pag. 2016.

[8] J.N. Bailenson, N. Yee, J. Blascovich., A.C. Beall, N. Lundblad & M. Jin, "The use of immersive virtual reality in the learning sciences: Digital transformations of teachers, students, and social context". The Journal of the Learning Sciences, 17, 102-141. 2008.

[9] M.K. Holden, "Virtual environments for motor rehabilitation: Review" Cyberpsychology & Behavior, 8(3), 187–211. 2005.

[10] N. E. Seymour, "Virtual reality in general surgical training". European Surgery, 37(5), 298–303. 2005.

[11] N. Taffinder, C. Sutton, RJ. Fishwick, IC. McManus, A. Darzi. "Validation of virtual reality to teach and assess psychomotor skills in laparoscopic surgery: results from randomised controlled studies using the MIST VR laparoscopic simulator." Technology and Informatics 50. Medicine Meets Virtual Reality: Art, Science, Technology: Healthcare (R)Evolution. IOS Press. 50:124-30.1998.

[12] J.N. Bailenson, K.Patel, , A. Nielsen, R. Bajcsy, S.Jung , & G.Kurillo, "The Effect of interactivity on learning physical actions in virtual reality.Media" Psychology, 11, 354–376. 2008.

[13] A. W. B. Smith, & B. C. Lovell, "Autonomous sports training from visual cues". In Proceedings of the Third Australian and New Zealand Conference on Intelligent Information Systems (pp. 279–284)., Sydney, Australia. December 10–12, 2003.

[14] V.E. Wilson, E. Peper, & A. Schmid, Training strategies for concentration. In Williams, J.N. (ed). Applied Sport Psychology: Personal Growth to Peak Performance, 5th edition. Boston: McGraw Hill, 404-422. 2006.

[15] V.E. Wilson, E.Peper, D.Moss. ""The Mind Room" in Italian Soccer Training: The Use of Biofeedback and Neurofeedback for Optimum Performance". Biofeedback. Vol. 34 Issue 3, p79-81. 3p. 2006.

[16] Match Analysis. "Mambo Studio". Software Application, 2016.

[17] J. Castelo, "Futebol: A Organização do Jogo". Soccer Organization of the game. FHM Edicaos, Lisboa. 1996.

[18] G. Machado. M. Padilha. R. Santos. and. I. Teoldo. "Positional role influences soccer tactical performance". International Research in Science and Soccer II, Routledge. Chapter: 3, pp.21-29. 2016.

[19] J. M. Loomis and J. M. Knapp, "Visual perception of egocentric distance in real and virtual environments," In L. J. Hettinger and M. W. Haas (Eds.), Virtual and Adaptive Environments, pp. 21–46, 2003.

[20] C. Armbrüster, M.Wolter, T,Kuhlen, W.Spijkers, B.Fimm. "Depth perception in virtual reality: distance estimations in peri- and extrapersonal space". Cyber Psychology & Behavior 11(1), 9-15. 2008.

[21] FIFA, "Laws of the Game 2015/2016". (n.d.), from http://www.fifa.com/mm/Document/FootballDevelopment/Refereeing/02/36/01/11/LawsofthegamewebEN_Neutral.pdf. Retrieved June 14, 2016.

[22] G. Caprara, E. Virdia, A. Pane, M. Agostiano, L. Baracco. "Guidelines to overcome architectural barriers in cultural heritage sites", II edition, revised and updated, Ministero per i Beni e le Attività Culturali, Gangemi, Roma. pp.52, 2011.