Title:
Goalkeeper Simulator for Amateurs and Young Students with Disabilities

Authors:
Greta Baronchelli, Politecnico di Milano
Giulia Castiglioni, Politecnico di Milano
Leonardo Comotti, Politecnico di Milano
Ian van Ham, Politecnico di Milano
Sara Arlati, STIIMA, CNR
Mario Covarrubias, Politecnico di Milano

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Abstract:
This study explores the use of Virtual Reality (VR) in sports training and inclusion through the development of a goalkeeper simulation game. Designed to provide an immersive and adaptive training environment, the game was tested with 15 students with disabilities from the ASPOC association, highlighting its potential for inclusive sports engagement. The VR system allows for personalized difficulty adjustments and facilitates participation by individuals with mobility limitations, as it can be played while seated. The project underscores how VR can enhance accessibility in sports training, offering a novel approach to both skill development and rehabilitation

Introduction:
The Goal Keeper simulator game is, as the name suggests, a Virtual Reality game focused on mimicking the action of a goalkeeper. An incentive for the creation of this game is the desire to recreate the training environment of a football goalkeeper in virtual reality. This would allow for a new training regiment to be created allowing for training in the off-season of the sport. In order to have a meaningful impact, the training must accurately mimic the motions and habits that the real sport requires. Furthermore, the possibility to calibrate the difficulties according to the level of the player by modifying some parameters such as the speed of the ball, the force of the shot and, in a minor part, also the trajectory of the ball, allows to target it towards the specific tasks that need to be trained. To better emulate real conditions, the game is set in a "real" soccer stadium, also background noises are added to better recreate the environment. Another application of this game is for rehabilitation of patients with disabilities. Indeed, the game can be played entirely while sitting down and only requires the movement of the hands. This would allow wheelchair-bound patients to experience playing sports.

Kulpa et al. [2] demonstrated how, in soccer training, the VR methodologies can revolutionize goalkeeper training by simulating dynamic scenarios, such as varying wall configurations during free kicks. By tracking real-time movements and providing immersive visuals, VR enhances the player's ability to respond to realistic game situations in a controlled environment. This has practical implications for improving decision-making,

reaction time, and spatial awareness, making VR a valuable tool for refining skills and preparing athletes for competitive performance. Further studies from Shimi et al. [3] and from Vignais et al. [4] examined the critical role of cognitive abilities in soccer goalkeeping, focusing on attentional networksalerting, orienting, and executive controlusing immersive virtual reality (VR). Participants performed a goalkeeping task in VR and completed tests measuring attentional and inhibitory control, including the Attention Network Test and Whack a Mole task. The findings revealed that all three attention networks significantly contributed to performance, with inhibitory control also strongly correlated to success. These results emphasize the importance of cognitive skills in soccer-specific tasks and highlight the potential of VR training to enhance attentional abilities and decision-making for improved real-world goalkeeping performance.

To create a realistic virtual training environment for athletes a variety of hurdles must be overcome. An athlete's response to an opponent's action is largely based on the moments leading up to the action rather than solely the action itself. During a football penalty kick, the goalkeeper is carefully studying the kickers run into the moment of the impact with the ball. Based on the information they receive, it allows a split second more time to make a decision and corresponding action. To unlock the full potential of VR training it is essential to create an accurate animation model for the players to ensure the correct goalkeeper response to these actions. Bideau et al. [1] used a motion capture system to create a realistic animation, data from 12 professional handball athletes during a standardized throw were recorded. The skeletal models that were created were then simplified and averaged to create a master model. The model was then tested with professional handball goalkeeper; by modifying the trajectory of the skeletal model, the goal keeper's response was highly influenced. When the skeletal model was unmodified the keeper performed very well. By adjusting the trunk rotation angle, or wrist position during the release the goal keeper's accuracy was greatly reduced. This study showed the importance of creating an atomically accurate model so that the training matches the real play condition.

Development of the VR App:

When starting the game, the main page is a menu that allows to access all the other levels. Each level, from first to fourth, is developed with an increasing difficulty, further descriptions will be given in the following paragraphs. Each level is designed to have three initial lives that are reduced by one every time a goal is scored, while a point is given for every saved goal; once all the three lives are spent due to mistakes of the player, the game automatically returns to the main page to start a new level. The other two buttons in the main menu are the Academy one, which allows to try each level, and the Penalty one. The Academy option allows, starting from the first level, to try all the levels in order of increasing difficulty. Each time 5 points are reached, the game automatically switches to the next level. Three new lives are given at the beginning of every new level. The Penalty button instead simulates penalty kicks.

Scripts and game logic:

In the following paragraphs the scripts that were used to develop the game will be described.

Main Menu

The main menu, shown in Figure 1, is controlled by the script `UIMainMenu`. It contains all the buttons present in the Main Menu (Level 1, Level 2, Level 3, Level 4, Academy, and Penalty). Each button, when clicked, recalls a `SceneManager` public class that is what actually allows to change the scene and so the different levels. The scene is automatically reloaded every time all lives are lost in order for the player to start a new game.

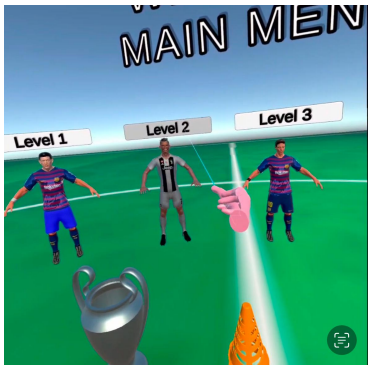

Fig. 1: Main Menu and use of hands to interact with it.

Level 1

When clicking on the Level 1 button the first level loads. This is the easiest level of all, no special features were added and it was left on purpose as easy as possible just to allow the user to understand how the game, and the virtual reality works. It is the level suggested for people approaching the game, or virtual reality, for the first time. An example of the graphic interface is shown in Figure 2.

The level starts with a ball being spawned at a slightly variable distance and location from the goal. The first spawn of the object is controlled by a function that initiates the level and has no other purposes. After the first spawn of the ball, the game is completely controlled by the script linked to the ball. After the first ball is spawned it is shot towards the goal with the function `AddForce`. The vector that controls the `AddForce` function has a range of values that is randomly chosen from a set of values that was carefully calibrated for the ball to aim at the goal. Some shots were intentionally calibrated to let some balls go outside the goal itself to make the game more realistic and to better emulate real life conditions. Indeed, in a real life environment, it is important to evaluate the trajectory of the ball and to assess whether or not the ball aims at the goal. The most interesting part of this script is the big if condition at the end; this is what allows to understand what happens to the ball after being shot. This if cycle is what distinguishes what the ball collides with and, according to that, what happens to the game:

- if the ball collides with the player's hands the `GameManager` public class is recalled and the score is updated adding one point to the total score that is displayed on the screen for the player to see it. Two additional actions are performed in this case: the disappearing of the ball, with a delay of a couple of seconds, and the spawning of a new ball to make the game restart. The delay in the disappearing action was added to make the game as realistic as possible and to give the player the visual input of the save, indeed, the ball is able to bounce on the hands of the player and to change the direction before disappearing;
- if the ball collides with the out zone (planes that surround the goal and the goal structure itself), the ball is simply instructed to disappear and a new one is respawned. Also in this case a little delay is applied to the disappear function to give a more realistic aspect to the game. No points are given to the player in this case;
- if the ball collides with the goal, a life is subtracted from the total and the ball disappears, then the remaining amount of lives is checked. If the total reaches 0, it means that all the initial lives have already been used, the game goes back to the Main Menu so that the user can choose another level. If instead the remaining lives are more than zero, the life counter is updated, still using the `GameManager` public

class, and a new ball is respawned to make the game go on.

Fig. 2: Example of basic level of the game, the virtual hands are shown to help the user in the save.

One additional variable, really useful for the purpose of the game, is the Boolean `_col` variable, this is used to avoid that multiple collisions are detected between the first collision and the moment the ball disappears, which happens with a delay of a few seconds.

Level 2

The second level, like all the following ones, is for the most part similar to the previous one. Still, as the player enters the game a ball appears; in this case the force seems to be given by the animation of a soccer player kicking the ball, a frame of the animation is displayed in Figure **??**. This animation was acquired with the Captury system, but further descriptions will be given in Paragraph **??**. What actually happens in the game is thanks to a synchronization between the animation and the application of the force, furthermore, in this case a randomized spin effect was given to the ball. Thanks to the spin effect of the ball, and to the use of the `MagnusEffect` the ball is able to describe a curved trajectory in the air to emulate some peculiar shots that can be performed during a game. This function uses the spin and the force applied to the ball to compute the proper trajectory so that the physics of the launch reflects the real ones. This was made to try and emulate the most real conditions possible. One problem that can arise while using such animation is that the ball does not reflect what can be deduced from the position and from the actions of the soccer player since the animation used is always the same. This can be a problem for high level goalkeepers that use the movement of the opponent to try to predict the final position of the ball. For this reason, multiple acquisitions of the action should be recorded and implemented in the game according to the force given to the ball.

Academy

As briefly explained in Paragraph **??** the Academy option allows to test all the levels, starting from the first one and moving on towards the fourth, for a limited amounts of points (5) after moving on with the following level. To obtain this a boolean variable (`_acc`) is set to `true` when the Academy button is selected in the Main Menu. The first level is then loaded, the ball is spawned and the game starts. The scripts used for each level are the same that have been described above, what has been omitted in the descriptions given so far is the presence of an if condition in each of the scripts that checks the score value; if the score reaches 5 the next level is loaded, while if the life count reaches 0 the user is redirected to the Main Menu as for all the other levels. The life count is restored to 3, or 5 in the case of Level 4, each time a new level is restarted; this was specifically done to allow the user to have more chances in actually reaching the end of this training.

When the last level is completed, the game goes back to the Main Menu, and any other level can be selected. What has been fundamental in the coding of this level, is to set the (_acc) variable back to `false` when the Academy experience ends, this is to avoid that the variable remains set to `true` repeating the experience every time any level is selected.

Testing:

The testing phase involved two primary groups: students from the Politecnico di Milano and athletes from the Vittoria Junior Soccer Team, a female soccer team based in Milan. These groups provided valuable feedback on the usability and realism of the VR goalkeeper simulation. Also, 15 students from the ASPOC association successfully tried the application, demonstrating its accessibility and effectiveness in promoting sports inclusion. The participants were introduced to the hand-tracking system and the game mechanics before engaging in various levels of difficulty. Their feedback, gathered through a System Usability Scale (SUS) survey, indicated a generally positive response, with particular appreciation for the immersive experience and the intuitive interaction with the virtual environment.

The subjects were asked to try the game according to their desire, they were briefly instructed on how to interact with Virtual Reality without the use of controllers of any kind. Once they were confident, they were asked to select any level they wanted and to play the game for some time. The suggestion was to start with Level 1 to build confidence with the game; after that, they were left free to explore the game as they liked. The main difficulties in this part were found in understanding how to interact with the Main Menu. In fact, this operation was found to be the most difficult part of the game by many users. After they were satisfied with the trial, they were asked to fill in the System Usability Scale (SUS) protocol on a Google Form, answering both the standard questions and two additional ones concerning their previous soccer experience: subjects were asked if they had ever played soccer and if they played in the role of a goalkeeper. The results are displayed in Figure 3.

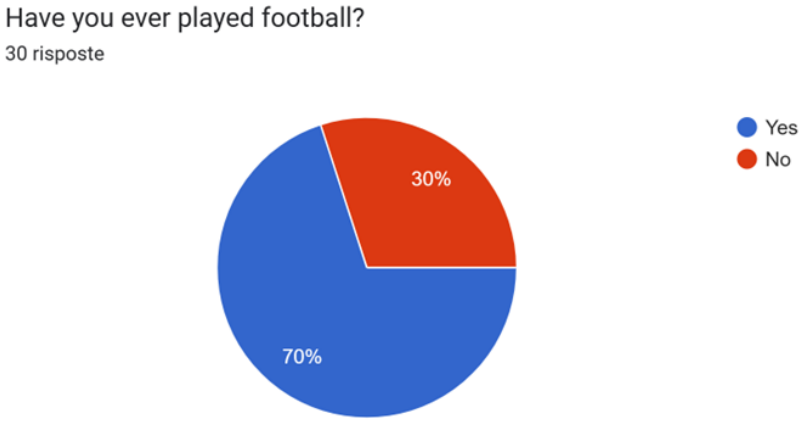

Fig. 3: Results of the SUS Survey. Of the people who played soccer, 26 percent also played as a goalkeeper.

The results of the survey show that the software is user-friendly and can be navigated easily by new users. This is highlighted also considering the answers to the question "I would imagine that most people would learn to use this app very quickly". In fact, most of the users agree strongly with this sentence. So, even if some troubles may be present at first (especially considering the previously mentioned problem of the selection

of the game level), they can be rapidly solved simply by playing to get more used to the VR's logic. Good feedback was also given considering the integration of the various functions of the app, its consistency and the assistance needed to make the all game user-friendly.

Conclusions:

In conclusion, the Goalkeeper Simulator is a Virtual Reality game designed to replicate the experience of a football goalkeeper, providing an immersive and adaptive training environment. The project aimed to recreate real-world conditions through motion capture, realistic stadium settings, and customizable training parameters tailored to individual athletes' needs. The System Usability Scale (SUS) survey conducted during testing confirmed that users found the application engaging and accessible, with only minor difficulties related to the initial learning curve of hand-tracking interactions.

Beyond its technical achievements, this project highlights the broader impact of Virtual Reality in promoting sports inclusion. By eliminating physical barriers and allowing participants to engage with the game while seated, the application creates opportunities for individuals with disabilities to experience sports in a way that may otherwise be inaccessible. Notably, 15 students from the ASPOC association successfully tested the application, further demonstrating its effectiveness in fostering inclusive participation. The ability to adjust gameplay difficulty makes the simulator suitable for users with different physical and cognitive abilities, reinforcing its potential as both a training tool and a means of social integration through sports.

References:

[1] Bideau, B.; Kulpa, R.; Arnaldi, B.: Virtual reality applied to sports: do handball goalkeepers react realistically to simulated synthetic opponents? In Proc. of ACM SIGGRAPH International Conference on Virtual Reality Continuum and its Applications in Industry, 8, 210–216, 2004. http://doi.org/10.1145/1044588.1044632.

[2] Richard Kulpa, F.M.; Argelaguet, F.: Virtual reality sport. 33rd International Conference on Biomechanics in Sports, 2015.

[3] Shimi, A.; Tsestou, V.; Hadjiaros, M.; Neokleous, K.; Avraamides, M.: Attentional skills in soccer: Evaluating the involvement of attention in executing a goalkeeping task in virtual reality. Applied Sciences, 11(19), 2021. ISSN 2076-3417. http://doi.org/10.3390/app11199341.

[4] Vignais, N.; Bideau, B.; Craig, C.; Brault, S.; Multon, F.; Kulpa, R.: Virtual environments for sport analysis: Perception-action coupling in handball goalkeeping. International Journal of Virtual Reality, 8(4), 4348, 2009. http://doi.org/10.20870/IJVR.2009.8.4.2748.