Title:
Inclusion of People with Disabilities in Virtual Reality Archery Training

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Abstract:
Virtual Reality (VR) has emerged as a powerful tool for enhancing training and skill acquisition across various domains, including sports. This study presents the development and evaluation of a VR archery simulator designed to teach fundamental techniques and provide a realistic training environment for users. Unlike existing archery VR applications, which are primarily focused on entertainment, this project emphasizes skill-building through a structured three-phase approach: a guided tutorial, targeted training exercises, and a semi-realistic simulation.

The VR application was developed using Unity and tested on the Meta Quest 3 headset. The interactive system includes a physics-based bow and arrow mechanism, immersive environmental elements, and dynamic challenges such as moving targets and wind effects to simulate real-world conditions. Additionally, the system is developed by students with disabilities (18 to 25 years old), promoting inclusivity and accessibility in VR-based sports training. A usability assessment was conducted with 18 participants using the System Usability Scale (SUS), yielding an average score of 86, indicating strong usability and effectiveness in teaching archery fundamentals. Furthermore, 14 students from the ASPOC association tested the system, providing valuable feedback on its accessibility and user experience.

Findings suggest that VR-based training can improve archery skills by offering a controlled and engaging learning environment. The application provides an accessible alternative for beginners and potential use for athletes in need of off-season or rehabilitative training. Future developments will focus on enhancing haptic feedback, refining graphics, and integrating adaptive difficulty settings to further personalize the user experience.

Introduction:

Related to VR archery experience, a lot of simulators have been developed in the last few years. However, the majority of them are thought as entertainment without the concrete goal to be used to specifically train the sport in consideration. Some examples that can be found are "Archery Pro" by SavySoda [5], "Arrowhead-Medieval Archery VR" by kilogrames [3], or "Backyard Virtual Archery" by MISSING

GAME STUDIO [6], which by the way intend archery not as a sport to learn and progress into, but mainly as a game or arcade competition. A positive aspect of the diffusion of such games is the increasing interest in the development of items and tools that can make the virtual experience more realistic: an example is the "Artemis VR Game Bow" by Wonder Fitter [2], a physical bow equipped with compartments for VR controllers and a piston that simulates the shooting of arrows. This type of equipment could also be applied to more technical applications, like the one presented in this work, to enhance haptic sensations of the users and create a realistic experience.
Concerning the state of art about archery in virtual reality, few articles and journals were found during the research, even though this topic is taking more importance as demonstrated with the previous examples. Silviu Butnariu [4] in his article developed a prototype of bow, composed by a simple frame, electrical motor, sensors and a system of pulleys, interconnected with the virtual reality through a channel, in order to strengthen the haptic interface during shooting. In the experiment the Oculus Rift DK2 was used and a simple medieval landscape was bulit in Unity. Depending on the drawing of the physical bow (rotation angle of the pulley due to the bow string) and on the direction of headset, the arrow was shot in the virtual world at different distances. Additionally, the prototype gave the possibility to change its weight and the length of the draw in order to simulate different categories of bow.
As it is possible to notice from the various topics of the articles just reported, a VR application completely dedicated to teach the fundamentals of archery sport in a simple but refined way is difficult to find. For this reason in the following paragraphs all the steps taken to develop a virtual reality app able to teach the basics of archery are presented.

Methods:
The VR application was built using the software Unity (Version 2022.3.44f1) in collaboration with Visual Studio 2022 to write all the necessary scripts in C#. For the creation of the items present in the game several packages were downloaded from the Unity Asset Store, as reported in the following sections.
The Meta Quest 3 was used as head-mounted display to try and develop the application.
Concerning the testing of the VR app, a pool of 18 subjects was tested and the usability of the system was retrieved by the SUS protocol (System Usability Scale) ideated by John Brooke in 1986 [1]. The questionnaire was sent as a simple Google Form and all the responses were easily collected in a linked Excel file to better work on the final results.

Development:
For the development of the application, the different components have been created separately and then integrated together. The main components are the bow and the arrow, the targets, and the user interface elements; their development will be described in the following paragraphs.

0.1 Bow

The development of the bow started with the download of the model from the internet, that must be without the string; in fact, to properly represent its bending behavior when pulled, the string is created by means of a line render each time a scene is uploaded, thanks to the "Bow_string" script. To permit the right positioning of the arrow, a "XR Socket Interactor" on the "Midpoint visual" has been used, this component will be explained better in the following paragraph.

0.2 Arrow

The procedures followed for the development of the arrow are strictly related to the different phases of the shooting process; in fact two slightly different types of prefab were created: one used to manage the

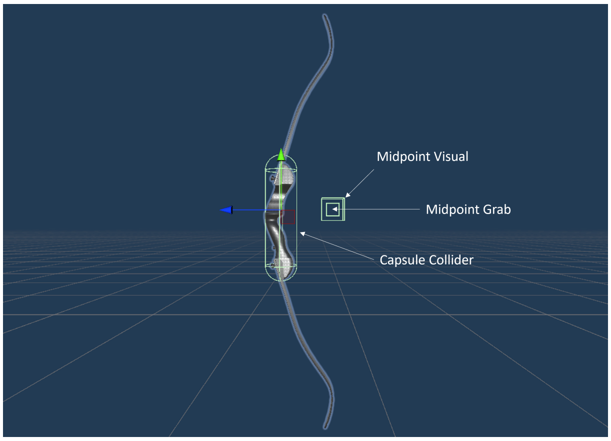

Fig. 1: Bow components.

loading of the arrow on the bow ("Arrow_start"), the other to handle its release and flight ("Arrow_fly"). In order to make the flight of the arrow more real, a rotation that follows the direction of the velocity vector is imposed to the arrow while flying. In this way, the arrow flies following a parabolic trajectory; this process is possible thanks to the "Arrow_rotation" script assigned only to the "Arrow_fly" prefab. To better clarify, the main difference between the types of arrow prefabs is that the first type isn't subjected to gravity and it is kinematic, meaning that it isn't affected by forces; in contrast, the second type feels the gravity and is affected by forces, both fundamental for the flight of the arrow.

0.3 Targets mechanism

In the game two types of target have been chosen. One is a classical outdoor round bale target with three wooden legs, called "Target ground" (Figure 2). It is divided into ten different rings, colored two by two in white, black, blue, red, and yellow. The other one, called "Target fly", has the same traditional target face, but is unconventionally suspended, and it is able to move horizontally or vertically in the space, at different speeds. The motion of this last target type has been made possible thanks to two specific scripts, one responsible for the horizontal movement, called "MovingTarget", while the other one was responsible for the vertical movement, called "MovingVertical". Thanks to public variables the range of motion and the speed can be adjusted in the development phase. These targets are 3D models downloaded from Turbosquid and Free3D, specific websites that allow to download for free their models in the correct .obj file format and together with their .mtl files. In order to make the experience more realistic, also the sound effects are fundamental. That's why every target has an audio source component linked with the script related to the score. Inside this script, specific code lines are used to find the audio associated to the target and reproduce it whenever it is hit.

Simulation scene

In the 'simulation' scene the main goal was to let the user challenge himself in a test that resembled real shooting in a more complete way. To do so, the distance between the user and the single target present in the scene is increased respect to the 'training' and the effect of the wind is introduced in order to influence the behavior of the arrow during the flight.

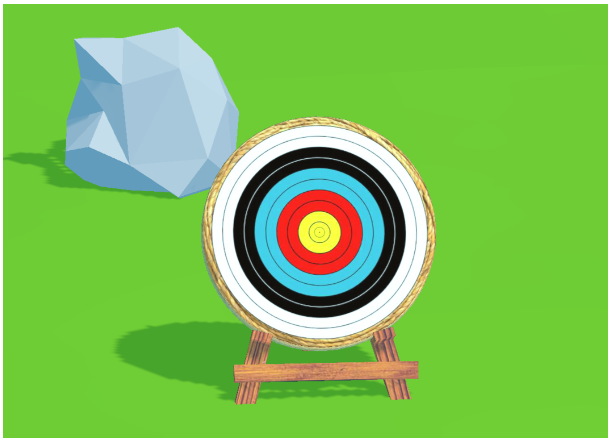

Fig. 2: Target example.

A directional wind zone of Unity was used to create the air moving with the addition of some particle systems to visualize it. To make it more realistic, the direction and the intensity of the wind were randomized through a script that each twenty seconds changed casually the force ("WindMain") and the direction ("Transform") of the zone within defined ranges. Moreover, it was necessary to replace the script "Arrow_controller" with a further one ("Arrow_controller_wind") to apply to the bow in order to make the flying arrows react to the wind, because only particle systems are affected by it in Unity. This script simply added in the function "ReleaseArrow" the detection of the intensity and direction of the wind at the shooting instant, and then applied a force with the same magnitude and direction to the component "Rigidbody" of the arrows just instantiated. Eventually, to let the user visualize easily the behavior of the wind, a flag was developed and put as child of the wind zone to follow the same rotation. The flag was built by simply applying a cube object with changed dimensions (cloth) to a slender cylinder (pole). The component "Cloth" was also added to the flag in order to animate it as moved by the air.

Concerning the landscape, different items of the same packages used for the 'training' scenes were chosen: winter-themed terrains, trees and rocks were included in the scenery to trigger sense of quiet and concentration on the actions to perform and conditions to consider (Figure 3). Moreover, the particle system resembles the snow moved by the wind, giving stronger realism to the landscape. Also in this scene bow and arrows were placed as the cases cited before, and the partial and total score were displayed just above the target.

The 'simulation' is thought as the last step to take in the experience of the archery application in order to apply all the former learning to a semi-realistic situation.

Fig. 3: Simulation scene.

Testing:

To understand the potentiality and lacks of the developed VR application, a pool of 18 people was tested. All the subjects never performed archery as a professional sport before, so they were considered as beginners and their age ranged between 18-56 years old. The protocol was based on making each subject try the application in all its parts, with the possibility to receive help and suggestions from the developers, and then compile a questionnaire related to the experience. The questionary relied on the SUS (System Usability Scale) protocol introduced by John Brooke in 1986, that is generally used to measure the usability of a product or system in a reliable and inexpensive way [1]. SUS is composed by ten statements (more precisely the ones showed in Table **??**) whose answers can range from 1 (strongly disagree) to 5 (strongly agree). The total result of the questionnaire is calculated using the following process: for even statements (2,4,6,8,10) the answer is subtracted from 5, while for the odd ones (1,3,5,7,9) a value of 1 is subtracted from the answer; the resulting contributions of each statement are summed together and eventually multiplied by 2,5. The final score ranges between 0 and 100, describing an increasing level of usability and ability of the system (Figure 4).

Concerning the VR app, the average value of all the polls was taken as evaluation parameter for the scale. It returned an overall score of 86, that could be considered an acceptable result because over the scale 70. This result indicated a very good usability of the application and reflected the thought behind the development of the project: to realize a simple and available method to introduce users to archery and train them on the basic theory and movements.

The statements that returned the most controversial answers resulted to be the first ('I think that I would like to use this system frequently') and the fourth ('I think that I would need the support of a technical person to be able to use this system'), showing that some part of the participant reported low interest in the topic of archery sport or found difficult to approach for the first time to the virtual experience and its commands. This two points should be taken into account to improve the assistance to the player and enhance the curiosity towards archery.

Naturally, the estimation of the application's usability must take into consideration the low amount of users that were tested and consequently account for the possibility of a different result from the one previously displayed. Moreover, the alternative to test the VR application on a pool of athletes that regularly train themselves in archery could bring to other insights: as reported in the first part of the report, the idea to use the app also for athletes that need to keep training during specific health or physical conditions can be considered. However, if the level faced in the VR application matches the required one for higher ability should be tested.

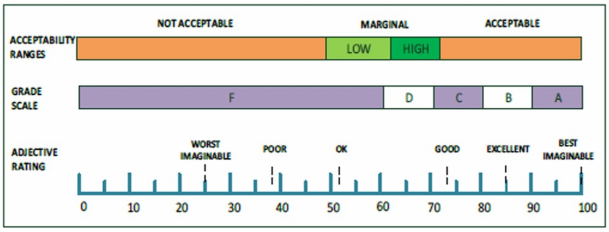

Fig. 4: SUS score scale evaluation.

Conclusions:

The development of this VR archery training system highlights the potential of immersive technologies to bridge accessibility gaps in sports training. By integrating inclusivity into the design process, this project not only enhances skill development for individuals with disabilities but also sets a precedent for future innovations in adaptive sports training. The positive feedback from usability testing reinforces the system's effectiveness and encourages further improvements to maximize its real-world applicability. Moving forward, expanding the application to include additional accessibility features and refining training modules will ensure a more comprehensive and engaging experience for a broader audience. This initiative underscores the significance of VR in fostering inclusive and effective sports training methodologies.

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