Title:
VRocky: A VR Boxing Simulator for Amateurs and Young Students with Disabilities

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Abstract:
VRocky: A VR Boxing Simulator for Amateurs is an immersive virtual reality (VR) application designed to make boxing training accessible, engaging, and safe. Developed using Unity, the simulator provides an interactive gym environment where users can explore boxing techniques through lessons and mini-games. By integrating the learn-by-doing approach, the application enhances motor skills, cognitive abilities, and physical fitness while making training entertaining.

A key feature of VRocky is its potential for inclusive sports engagement. The application is designed to be adaptable for people with disabilities, particularly individuals with motor and cognitive impairments, by allowing customizable training intensities and learning paces. Studies have shown that VR-assisted boxing training improves upper extremity function, balance, and cognitive abilities in stroke patients, making this application highly relevant for rehabilitation and adaptive sports programs.

The VRocky simulator was tested by students with disabilities (18 to 24 years old) from the ASPOC association, providing valuable feedback on its usability, accessibility, and engagement level. Their experience highlighted the potential of VR in enhancing physical activity and cognitive training for young adults with disabilities, reinforcing the importance of inclusive design in sports technology.

Beyond rehabilitation, VRocky promotes sport for inclusion by enabling individuals of different backgrounds, skill levels, and physical conditions to participate in boxing. By eliminating concerns about physical contact and injury, the simulator makes boxing more approachable for amateurs, children, and people with disabilities, fostering equal access to sport.

Introduction:
Boxing is a worldwide phenomenon entertaining thousands of fans. Besides the critics that can be moved to the violence involved in this sport, is undeniable, and demonstrated ([1], [2], [3]), that boxing training has countless benefits, both from the physical and mental point of view. In this article, we exploit the possibility to apply the VR technology to this sport, in order to involve amateurs and children in such healthy activity without the inconvenience of being hurt: in this way more and more people could get closer to this beautiful sport and train themselves while having fun. To accomplish this task, an

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interactive boxing-related VR video-game has been created using the *Unity* software: the game consists in a stimulating and interactive environment where the user is enticed to explore a virtual gym where he can follow short lessons about the correct boxing's techniques and then apply what learned in four different mini-games. Since the basic idea behind the architecture of the VR application is the possibility of exploring in freedom the environment, users are free to find out and try new things about boxing, but especially to learn more because driven by their curiosity (this approach of learning is more active than classical frontal lessons, and further explanations are presented in Chapter **??**). Moreover, the learning is reinforced by the so called "learn-by-doing" mechanism proposed by the mini-games; this represent also a good way to make physical activity in a fun and entertaining way.

Besides VR applications, articles highlight that also a simple boxing training is a good way to improve motor skills both for impaired patients or for users with partial disabilities ([2]), and also for healthy subjects that want to stay in shape ([1]). Considering what present in literature, therefore it seems a good idea to develop an interactive boxing video-game that would require the user to develop both his cognitive and his physical skills. In this context, it has been developed a VR application where a boxing environment is recreated and that is explicitly meant for amateurs (thus for people who know few about boxing) and even for children. Thanks to this application they could empower their cognitive skills by memorizing moves and their combinations in an interactive environment, which requires to focus on lessons chosen directly from the user while background music plays. In addition, the players could also practice the learned movements and could stay active by playing with all the mini-games and the challenges present in the application, which would stimulate and entertain the player while using the application. Finally, besides all the positive and healthy benefits of this type of training, another goal of this virtual environment is to bring people closer to such a beautiful sport as boxing, which is often victim of prejudice and unfairly labeled as "violent". Getting people in touch with boxing as a game can be a "win-win" situation both for the users and for this sport: in fact, the user could improve its cognitive and physical skills, while boxing could grow as a healthy, inclusive and entertaining movement.

Development of the VR App:

1. Navigation and architecture of the game:

The VR application starts with the player inside a boxe gym, which is purposely created to replicate as realistically as possible a real boxing training environment. As in all the virtual reality environments, the player can move freely in all the virtual ambient: thus, he could go up and down the ring, or he could look around and choose to listen a specific movement's lesson, or also to play at one of the four mini-games (and much more besides).

In particular, one fundamental feature present in the application, is a "Canvas Menu", which is equipped with three buttons: "Play", "Quit" and "Option". The "Play" button allows to start the interactive virtual reality experience going on with the exploration of the overall game: in fact, if pressed (thanks to the ray interaction from XR controllers) it shows four "Activation-Cubes" all around the whole gym environment, those permit to start the four games associated to each of them (the cube-game relationship and the activation of the games will be explained later). The "Quit" button is the one that simply closes the game, so it ends the whole VR application. Instead, the third button (at top-right on the "Canvas Menu") is an additional optional feature that, if pressed (by clicking the controller's frontal button when its ray hits the button "Option", as done for the previous two buttons), it opens a second menu-layer in the "Canvas Menu", where the player can choose between three different levels of difficulty for all the "mini-games" present into VR application, and then go back to the precedent menu-layer. Hence, supposing that the player wants to play a certain and a specific mini-game, on the first screen of the "Canvas Menu" he has to set the right and wanted level and to press the button "Play", after which

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the "Canvas" disappears and four "Activation-Cubes" appear around the gym.

2. Implementation of the VR environment:

Creating a realistic and engaging environment for the user is considered a critical development step for video game fabrication. With this perspective, a realistic boxing gym has been created from scratches in order to better model every single feature and object present in a real gym. The gym contains a ring that has been 3D modeled through the use of the software *Autocad Inventor* and imported as an FBX file (generated thanks to *Autodesk 3ds Max* software) in the *Unity* project. This ring is the fundamental feature of the environment because it is the place on which all the mini-games take place (when activated according to the mechanism described in the previous chapters). Also the four mini-games have been created from scratches in different *Unity* projects (in which a simpler implementation and test could be performed) and then imported in the different game's scenes as "Prefabs" (a more detailed description of the games and of their development will be provided in the next chapters). Most of the features and of the *Unity GameObjects* present in each game have been created as 3D models by using, again, the software *Autodesk Inventor*: real boxing pads and toolkit have been taken as references in order to be as realistic as possible in their modeling. Moreover, stick-like obstacles and boxing gloves have been appositely designed in order to implement some objects that have to be dodged during the games, making them more engaging. Once again, the choice of adding background music aimed to improve the experience of the user. A general view of the aesthetic of the gym can be seen from Figure 1 presented below.

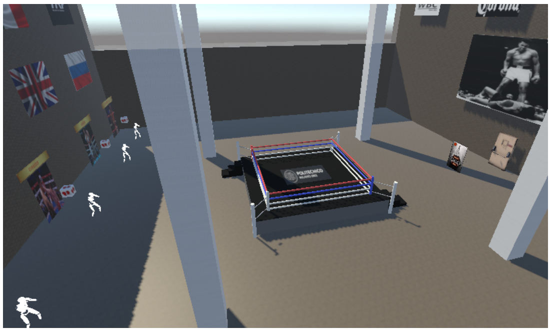

Fig. 1: General view of the gym.

3. Boxing lessons:

As anticipated in the introduction (Chapter **??**), the Lessons' aim is the one of excite curiosity in the user rather than imposing him mandatory tutorials about each single correct boxing techniques. To accomplish this task, the five basic movements of boxing (Guard, Jab, Cross, Hook, Uppercut) have been registered by using the apposite cameras connected to the *Captury Live* software (Figure 2). Each movement has been repeated twice by an expert for each recording: the first trial has been performed slowly (in order to show all the little characteristics of each movement), and then the second trial has been realized at normal speed (to show also the correct velocity at which the task should be performed).

Once the Lessons' FBX files has been generated by *Captury Live* software and imported in the main scene of the VR application, the animations that drove them have been put "in-loop": in this way the user can carefully look at them for all the time needed and up to when he feels confident about the learned movement. In addition, as mentioned in the previous paragraphs, a short vocal explanation of each movement has been registered and loaded as a *Unity Asset* to the *Unity* project. Behind each animated *Captury Live*'s built-in avatar, a cube customized with the *Unity Particle System* and a picture

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Fig. 2: Frame of the Recording Procedure.

have been placed. The idea is that the player can constantly look at the movement (which is reproducing "in-loop"), and that when he touches the cube he can hear to the vocal explanation, so the effective "lesson".

Finally, for aesthetic purposes and to increase the immersive power of the VR application, pictures of professional and legendary boxers are placed behind each cube and Lesson's area, together with golden banners containing the name of each cube's relative movement. In Figure 3 is presented a general view of the implemented Lessons' area.

Fig. 3: General view of the Lessons' area.

Testing and System Usability:

In order to verify the usability of our application a SUS questionnaire (System Usability Scale) have been asked to be compiled to a pool of volunteers that have already tested the implemented VR application. The System Usability Scale (SUS) is a standardized and widely used tool for measuring user's perception regarding the usability of a product or of a digital service. In other words, the SUS helps us understand whether our application is easy to use and satisfying to the user. What has emerged from our survey is that the game is very engaging and, generally, easy to use. In fact, the SUS Score - updated at 2025/01/15 - of the application is (85.75 ± 13.44).

Some remarks were done about the initial canvas: an improvement to it could be adding a text annotation also above the button dedicated to the level setting, in order to make the possibility of setting the difficulty-levels more clear.

Games were generally considered entertaining, challenging and easy to understand.

Also lessons have been appreciated, with some remarks of translating them in English (this should be necessary to permit to a wider basin of user to use the VR application).

Most of the users would recommend the game to third people, which is a fact that we consider extremely positive.

In addition, by collecting the ages and the professions of the users that tried the VR application, it is possible to conclude that its development and architecture is understandable and usable by all players of all ages and connected to different working/academic sectors and fields.

By collecting all the constructive criticism, as developers we found some aspects to be improved in order to allow to have a better game's experience. Some of the suggested improvements could be the addition of text annotations and banners around the scene (to make the game self-explanatory without the need and the presence of a coach, so to increase the "self-usability"), the realization of "smoother" and more fluid transitions between different game's scenes and, finally, the complete translation of the game in English -thus the recording of vocal lessons from English professionals. In fact, regarding this last weakness, it must be said that the registration of the lessons have not been made by professional vocal actors, therefore the current choice of the Italian language was made in order to give the best possible performance: involving professional boxing coaches and voice actors would surely give huge improvement to the game both from the sporty and artistic point of view.

Apart from these few and marginal remarks, we consider the results of the SUS questionnaires extremely positive: this fact testifies the quality of the developed VR application.

Conclusions:

The VRocky boxing simulator has proven to be an effective and engaging tool for learning, training, and entertainment. Through its immersive VR environment, users can practice boxing techniques safely while enhancing their motor skills, reflexes, and cognitive abilities. The application was designed with inclusivity in mind, making boxing accessible to a wide range of users, including amateurs, children, and individuals with motor and cognitive impairments. A key validation of the simulator's effectiveness came from 15 students with disabilities (aged 18 to 24) from the ASPOC association, who successfully tested the application. Their feedback confirmed the usability, engagement, and accessibility of the VR experience, reinforcing its potential as a sport-for-inclusion tool. Beyond entertainment and physical training, VRocky also holds promise for rehabilitation and adaptive sports, with future developments aimed at integrating AI-driven movement analysis, personalized training programs, and multiplayer functionalities. Ultimately, VRocky represents a step forward in inclusive sports technology, breaking down barriers to participation and redefining boxing as an educational, accessible, and empowering activity for all.

Future Developments and Works:

A significant improvement, also in terms of future market potential, would be the creation of a community of users who can play together in the same environment. This would require the creation of multiple servers to avoid the overcrowding of the initial gym, where all players would enter once the game is launched. The individual and single mini-games will remain independent sessions and "played" into independent scenes for each player, but the main scene's gym environment could be developed as an interactive and shared space. Even if this seems a challenging improvements to be implemented, some commercial applications already present on the market allow to share the same VR environment with different devices (like *VIROO*).

The implementation of a cloud-based VR application (as the one presented above) will also open up the possibility of implementing a multiplayer mode. Specifically, when and if this implementation will be realized, players would be paired based on their *average score*, which could be computed from the average of the scores achieved by the player in previous VR sessions or into the different mini-games. Then, after having paired two players, they would be transported to a new "shared" scene, for example in a scene where they will be placed on the same boxing ring, where the multiplayer fight could be conducted.

During this fight, a realistic real-time score and "remaining-lives" displacement - similar to the *Virtual Sparring* one - could be realized.

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