Design and Virtual Studio Presentation of a Traditional Archery Simulator

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ABSTRACT

In this paper we describe the design of a virtual reality simulator for traditional intuitive archery. Traditional archers aim without a target figure. Good shooting results require an excellent body-eye coordination that allows the user to perform identical movements when drawing the bow. Our simulator provides a virtual archery experience and supports the user to learn and practice the motion sequence of traditional archery in a virtual environment. We use an infrared tracking system to capture the user's movements in order to correct his movement. To provide a realistic haptic feedback a real bow is used as interaction device. Our system provides a believable user experience and supports the user to learn how to shoot in the traditional way. Following a user-centered iterative design approach we developed a number of prototypes and evaluated them for refinement in sequent iteration cycles. For illustration purposes we created a short video clip in our virtual studio about this project that presents the main ideas in an informative yet entertaining way.

Keywords

VR archery, 3D interaction, interactive sport simulation, user experience, user-centered design.

INTRODUCTION

Virtual Reality (VR) nowadays is used for training some sports or at least for entertaining the user with believable, but non-realistic simulation. From the beginning of VR system development, sports played an important role as an application area of VR [15]. The challenge in many sports is the training of motion sequences and their perfection like, for example, shooting, fencing or archery. Thus, the advantage of a VR simulator is the athlete's independence from other athletes and from the required space or environmental conditions. However, a system that provides for a realistic or at least believable user experience should fulfill three requirements: a set of natural interaction techniques with multimodal feedback, appropriate behavior simulation and a positive user evaluation of the system. Based on these requirements we built a VR simulator for traditional archery. Traditional (or instinctive) archery is an outdoor sport with increasing popularity (see Fig. 1). In opposite to FITA target archers (the Olympic sports discipline), traditional field archers aim without a conscious sight picture or additional means like peep holes, releases or stabilizers. Good shooting results require an excellent arm/body-eye coordination that allows users to perform identical movements during the shot. To hit targets at unmarked distances the archer relies on his experience to subconsciously measure the distance and move the bow correctly. In opposite to target archers this intuitive action allows to shoot moving targets at unknown distances. For novice archers these movements can only be practiced with the advice of an experienced trainer who continuously controls and corrects the archer's movements.

Goal of our project is a VR simulator that allows novices to learn the correct basic movements and experience the positive feelings usually associated with this activity. A 3D avatar provides assistance by explaining the necessary steps to position, anchor, and draw a bow. Wrong user actions are detected and corrected instantly. Experienced archers could virtually visit archery courses and practice archery in a simulated outdoor environment. The development followed an iterative user-centered design approach. We built a number of prototypes and evaluated them with different techniques. Preliminary results indicated a believable archery experience of our VR simulator.

Fig. 1 Traditional archery in a real outdoor environment. The picture shows Toren Mikat, the German Vice Champion for Longbow in 2009

RELATED WORK

In this section we review some related work on sports simulation both for training and entertaining purposes. Simulation techniques and the use of digital media allow to analyze sports activities by measuring and visualizing user parameters and to extend the basic concepts of selected sports by augmenting them by digital content.

A good example of the latter is exertion interface as proposed by Floyd Mueller et al. [10]. They developed a number of exertion interfaces for sports over distance, table tennis for three, FlyGuy (flying with a hang glider) etc. These interfaces enable persons to interact sporting with each other with remote social bonding. Compared to our system most of these exertion interfaces do not try to simulate the real activity but modify the game experience to cope with the spatial separation of the involved users. We want to provide a believable experience close to a real archery experience.

Multon et al. developed a VR training system for gymnasts to simulate gymnastic aerial motions in an interactive environment [6]. Users can test new figures and their motions for better performance and beginners can test complex motions without being in danger. The Virtual Football Trainer supports training of playing football in a CAVE [7]. A student team at University of Michigan developed the VR simulator that allows analyzing the player's movement and to practice tactics independent of environmental conditions or additional players. Similar to these projects we want to provide selected immersive cues to increase the user's presence. Another requirement is the design of two modes for novice users and intermediate / expert archers.

There are different approaches for virtual archery where movements are used that more or less mimic real archery. The success of the Wii console showed that intuitive interaction is superior to advanced graphical representation, especially in the area of sports simulation. Nintendo Wii Sports Resort contains an archery application (Target archery), which is played with the Wii Remote Plus and Nunchuck. Drawing the bow is simulated by distance between the controllers and the arrow firing by pressing the button. The interaction does not afford haptic feedback, but mimics the motion sequence of drawing a bowstring. The archery game of the Sony PlayStation offers a slightly better simulation of the archer's actions. The player uses the new PlayStation Motion controllers as interaction device and the eye-toy camera recognizes the movements of the user. Indeed, the application admits an adaptable posture of the bow; however, also here the haptic feedback is absent.

A pragmatic input device for archery games is the Virtual Archery Bow by Thomas Foo [4]. He attached a Wiimote to a real bow and simulated the pull-off by an elastic strap. This comes closer to the real experience but the strap only provides a weaker draw weight compared to a real bowstring. The Virtual Archery Bow simulates the arrow release only by triggering the fire button and does not consider the acceleration of the string. Archery with realistic haptic feedback is provided by TechnoHUNT, a commercial interactive archery simulator to shoot virtual quarries using a real bow and real arrows [8]. The system includes a tracking system to give feedback on arrow velocity and shot placement. But the system presents only video sequences and there is no immersion or real feedback. Moreover, the indoor shooting of a real arrow with rubber blunts requires large safety zones. TechnoHunt is for the experienced archer only and we want to provide support for novice archers. We want to provide realistic haptic feedback by using a real bow as interaction device because our users should feel realistic draw weights (around 30 lbs) and the sensation of arrow release but without firing a real arrow in our lab environment. An approach for a VR archery-training simulator has been developed by two students of the Aalborg University [9]. They used a bow with reflected markers as interaction device within a CAVE environment. They detected the shot by the spatial relations of the marker and calculated the flight path for the arrow. The user could practice only target archery in a virtual environment. In our simulation we focus on traditional archery in a simulated outdoor environment.

DESIGN PROCESS

We used an iterative prototyping approach to develop the VR archery simulator. It consists of three principal phases, each with appropriate evaluation techniques. Due to space limitations we describe the general process very briefly [3]:

(1) **Static Phase:** Brainstorming with text fragments / scribbles. Textual scenario description with personas, storyboard and sketch prototype. Internal evaluation by team members / Expert reviews
(2) **Animated Phase:** Video sketch and video prototype of partial / complete functionality. Qualitative evaluation with possible user groups.
(3) **Interactive Phase:** Implementation of an interactive prototype, which may evolve from the non-interactive video. Not yet implemented functionality can be simulated by a WoOz-Set Up (Wizzard of Oz). Evaluation with user groups may be qualitative or quantitative (task completion experiments)

The process description is not mandatory, i.e. it should not be followed like a cook recipe. It should be better considered as a set of tools that may (or may not) help the developer during the iterative design phases. This means that not every single step of the detailed description in [3] should be followed but the designer should select appropriate techniques based on the individual requirements of the project. However, the principal three phases should be applied. This is very similar to well-known design approaches in the area of digital media content creation or user interface design.

Requirement Analysis

Before the design process is initiated necessary requirements had to be identified in an analysis phase. We interviewed a professional archer (National Vice Champion for Longbow 3D Archery, 2009) to identify the most important factors for a believable archer experience. Additionally, we participated in an 1-day archery course to understand the different steps of an optimal shot and the special constraints of instinctive archery. With our experience we were able to identify how the VR simulator and the interaction techniques must be designed for a believable user experience. In particular, we need

- natural and haptic interaction with a real bow and draw weight. To minimize user distraction we use the bow also for interaction techniques to control the system menu,
- two modes that support novice users to learn the correct steps to shoot with a recurve bow and to provide archers with the experience to virtually explore an archery outdoor course,
- spatial cues like 3D stereo, viewpoint tracking increase the user‘s feeling of being in an outdoor environment, and
- advanced audio-visual representation of all scene objects to maximize hedonic qualities. This includes realistic animation of the 3D avatar and the virtual scene objects.

As a result of our requirement analysis we found that a simulation cannot replace a professional archery trainer and we decided to provide novices with a believable and entertaining archery experience that should provide hints to optimize their first attempts in archery. Instinctive archery suggests various techniques with different motion sequences to shoot, for example techniques with arm in holding position, push-pull method and swing-draw method. These sequences can be broken up into the following steps: stand, body setting, bow arm, string arm, slanting position of the bow, anchor, release, after hold. Our system provides user guidance by an animated 3D avatar that demonstrates these techniques based on motion-captured animation sequences (see Fig. 2 and Fig. 4).

We also decided to use advanced virtual reality techniques like spatial user tracking, motion parallax and user adaptive viewpoint control on a VR power wall and advanced 3D graphics and real images which allows us to create a semi-realistic application scenario of traditional archery. Based on the tracked user data we provide the user with hints on how to correctly handle the bow during the shooting.

Conceptual Design and Video Prototype

We started with a textual scenario description of the use context and defined two personas, a novice user that is interested in initially experiencing archery (primary persona) and an experienced archer who is interested in a virtual walk through an archery course (secondary persona). We created a set of static illustrations (scribbles, image composition sequence, see Fig. 2) of the basic user interactions. Team members and colleagues that were not involved in the project evaluated the illustrations. In the animated iteration phase a video prototype was realized that included the main functionality of the user interaction inside the virtual studio environment in our lab. This video prototype (Fig. 4, left) was evaluated by a professional archer in a post interview according to realism, look-and-feel, missing functionality, and user experience. Based on his feedback the development of the interactive prototype took place.

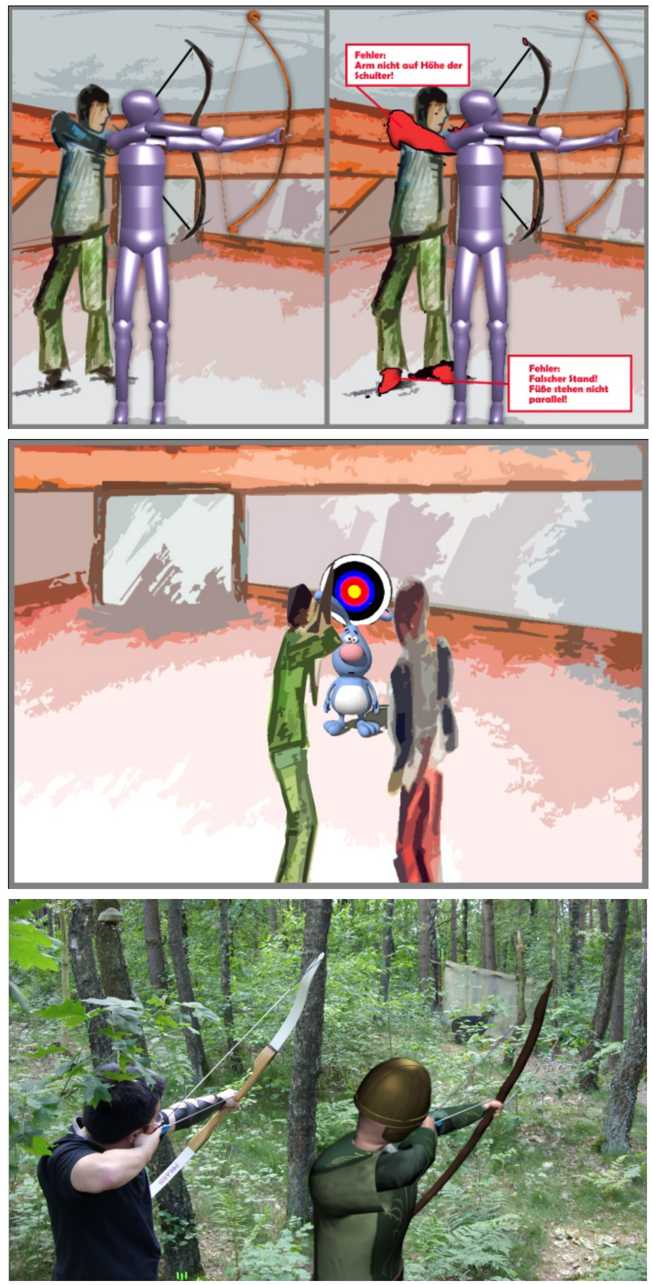


Fig. 2 Scribbles and image composition from sketch prototype.

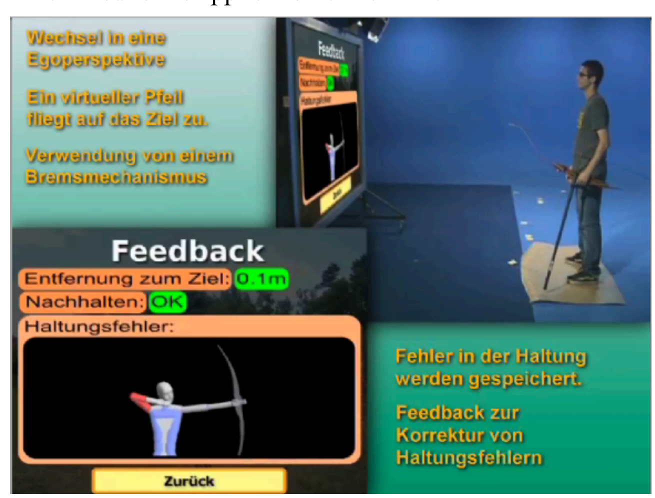
The current prototype provides two modes: beginner’s mode and advanced mode. In beginner’s mode the user receives a short introduction to traditional intuitive archery with the necessary handles (bow hand, string hand, string fingers). A 3D avatar demonstrates the entire movement sequence and the individual steps of the motion sequence (stand, body settings etc.) that have to be imitated by the user. During the performance the user's tracking data are compared with the available motion data of the avatar in the simulation. The user receives visual and auditory feedback if the movement is faulty, like, for instance when the user does not hold aslant his bow and head, a characteristic of traditional archery. If a coarse mistake appears during the user's motion sequence, the sequence is cancelled and the user has to repeat the action. The user must be able to execute the steps as a complete action. The better the archer performs the motion sequence the less assistance the avatar gives. The application provides an evaluation option where the user can check his hit rate and the given assistances of the system (e.g. head posture, anchor point inexactly). In the advanced mode the user selects his profile and is guided by an avatar through a virtual 3D archery course. The level of difficulty is considerably higher. The phases of the shooting are not brought forward here. If the archer has shot all arrows, generally three arrows per aim, he can check his statistics. In this mode fun and experiencing the virtual course comes to the fore. The bow is not only used for the shooting of virtual arrows but also as a selection device in the 2D graphical user interface of the application. The point-and-click gesture is realized with the bow, i.e. to select a menu point it is aimed with the bow. A short drawing of the bowstring signalizes the click and the user receives an acoustic signal too. Thus the user needs only one interaction device to interact with the archery simulation (see Fig. 3, top).

Implementation

We used a custom 3D framework that was developed during the projects [11][14]. The framework provides a flexible simulation environment with a plug-in system supporting a change of models and interaction devices during prototyping. The developed VR software environment consists of the following components: 3D visualization, tracking / IO configuration with IOtracker and physics simulation. The application scenario is designed for a virtual studio environment in our lab. The user stands in front of a power wall that renders the virtual archery environment for off-axis perspective projection. The user can move in front of the power wall freely (inside the tracking area) and the application adapts the field of view automatically to the user's ocular position. This is helpful in the 3D course to find a suitable firing position, like inside a real forest. With our virtual studio setup we can record the user's movements and place him in a virtual 3D environment in a postproduction. To get haptic feedback the archer uses a real recurved bow (length 62", draw weight 30#@28"[11]) that is equipped with "Bernie's Laz-Air Shot Trainer", a device that allows to dry-fire a bow without damaging it (see Fig. 10).

Fig. 3 Video prototype and menu selection with a bow.

The application consists of four modules: 3D world, animation of the avatar, motion tracking of the user and the calculation of arrow's trajectory. We modeled an outdoor archery course with three-dimensional targets (see Fig. 6) using pictures of an existing archery course and textured 3D objects of trees and plants. The animation of the avatar was recorded with motion capturing of a professional archer (see Fig. 5) and edited for the training assistance in the VR simulator. The user's motion sequences are recorded by the virtual studio tracking system and transmitted to the application via VRPN.



[11] 30#@28" denotes a draw weight of 30 lbs while the draw length is 28 inches.

Fig. 4 Video prototype with pose feedback.

The motion data has been mapped to user's avatar thus the application can provide a comparison of the motion sequence between the user's avatar and the trainer's avatar.

If the user releases the string a virtual arrow flight will be animated in the environment. With the tracked data of the bow position and bow expansion the simulation calculates a believable trajectory for the virtual arrow. Based on previous work on archery simulation [2] we adopt the mathematical model and aligned it to our simulation. This required a large number of design-and-test cycles. The creation of the avatar's movements was done using motion capturing technology. Instead of professional motion capturing systems used in film production we used a low cost system as provided by NaturalPoint's Optitrack. This system allows easily capturing the movement of human using IR cameras.

Fig. 5 Motion capturing process.

The recorded data can be analyzed and corrected using custom software provided by Optitrack. After that the mocap data is available in standard data formats and could be further processed using state of the art tools like Motion Builder and Maya (or other 3D animation tools).

Fig. 6 Virtual 3D outdoor scenery with target.

PRELIMINARY EVALUATION

We evaluated the current interactive prototype in a preliminary study using the web-based AttrakDiff2 questionnaire. AttrakDiff2 distinguishes between hedonic and utilitarian qualities of design [5]. Hedonic quality (HQ) measures how well a user identifies with a product and to what extent offering novel functions, contents, interactions and styles of presentation stimulate the user. Pragmatic quality (PQ) measures the traditional concept of usability, i.e., how well the user achieves his/her goals with the product. We selected 7 participants (5m+2f), aged from 19-30 years. All were unfamiliar with traditional archery but familiar with VR technology. After a short practical introduction we asked them to interact with the prototype for 10 minutes. The pragmatic and hedonic qualities were above average to good (see Fig. 7). However, we conclude that the usability of the current prototype has to be optimized in the next iteration, i.e. the tracking precision was not optimal. Further analysis indicates that the product was attractive and stimulates the user in a positive way. Although we could only test a prototypical version with reduced visual features and had only a small number of participants, the results encouraged us to finalize the implementation

Fig. 7 Preliminary evaluation using AttrakDiff2.

VIRTUAL STUDIO PRODUCTION

As introduction for the archery simulator as well as video example for virtual environments lectures, we did a virtual (TV) studio production. The story combines an indoor futuristic studio setting and an outdoor scene. An interested newcomer to traditional archery, played by a professional actress, gets an introduction by the project leader. The virtual avatar from the simulator becomes to live and gives further explanations and invites the newcomer to the virtual outdoor scene. There she tries out the simulator. Errors in position get visualized (see Fig. 8) and commented by the avatar. It is a live production with rendering of background and avatar at 50 Hz, which get combined perceptively correct with the video images from a studio camera. Main components of the virtual studio are a hybrid camera tracking system IS-900SCT (ultrasonic and inertial) and vizrt software. Main advantages of a live production are time reduced production time (in principle no post production necessary) and a homogeneous integration of virtual and real images. Camera operator and director see instantly the final images and can control better the production. Fig. 9 shows the preproduction step for video clip of the simulator that is shown in the futuristic studio. This video clip also contains real outside recordings.

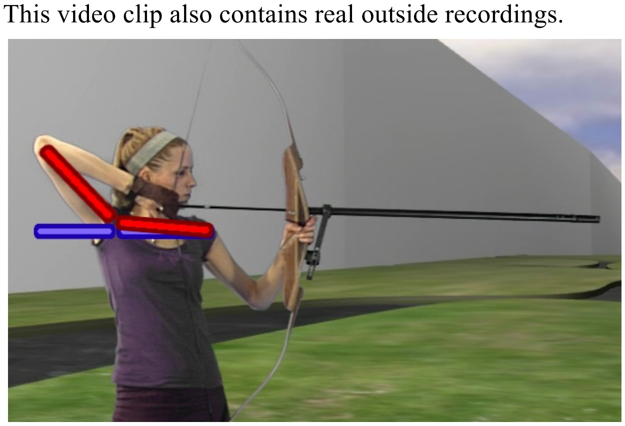


Fig. 8 Visualization of a pose error in the introduction video

The animation of the avatar was prepared in Maya using pre-recorded voice recordings and exported to virtual studio rendering engine. This implies predetermined movements of the avatar, but the rendering is live combined with images from the actress with arbitrary perspective view and timing. Another advantage of a virtual studio production in this project is the reuse of assets like the motion recordings for simulator, the modeling of the avatar and outdoor scene. All the data from the simulator could be imported into the virtual studio-rendering engine after a conversion step. The production pulls "naturally" the audience into the simulator (as well as the actor, see Fig. 11). Fig. 9 also shows some assets from the virtual set and a recording session.

Fig. 9 Virtual studio production.

CONCLUSION, LESSONS LEARNED AND OUTLOOK

The requirement analysis and the iterative design helped us to efficiently develop this complex system in a student project. From the interviews and archery course we learned to provide two modes for novices and experts and focus on natural interaction with a real bow. The detailed design phases from sketch prototype to video prototype to application prototype showed that emerging problems could be quickly discussed and solved. The internal evaluation of visual storyboards and sketch prototypes helped focusing on necessary application features and to keep the scheduled deadlines. The expert review of the video prototype convinced us to use motion captured animation and viewpoint tracking to provide a believable experience. The qualitative tests of the interactive prototype revealed that high quality outdoor scenery is needed and that the tracking system has to be optimized. The menu interaction with the bow was rated positively. We will also present the final video [13] production at the conference.

Further development should go into three directions: Enhancing realism by adding wind feedback, which was already applied within the research group in previous projects on vibro-tactile feedback [11]. Using markerless tracking [12], which is also easy to setup and to configure would allow general deployment and live feedback regarding human pose. Motion capturing gives realistic data sets, but requires necessary resources (time, systems, and man power). Other animations might be easier simulated using physical simulation engines, like Endorphine. Such a system would allow animations within the application in real-time according to the task or user behavior.

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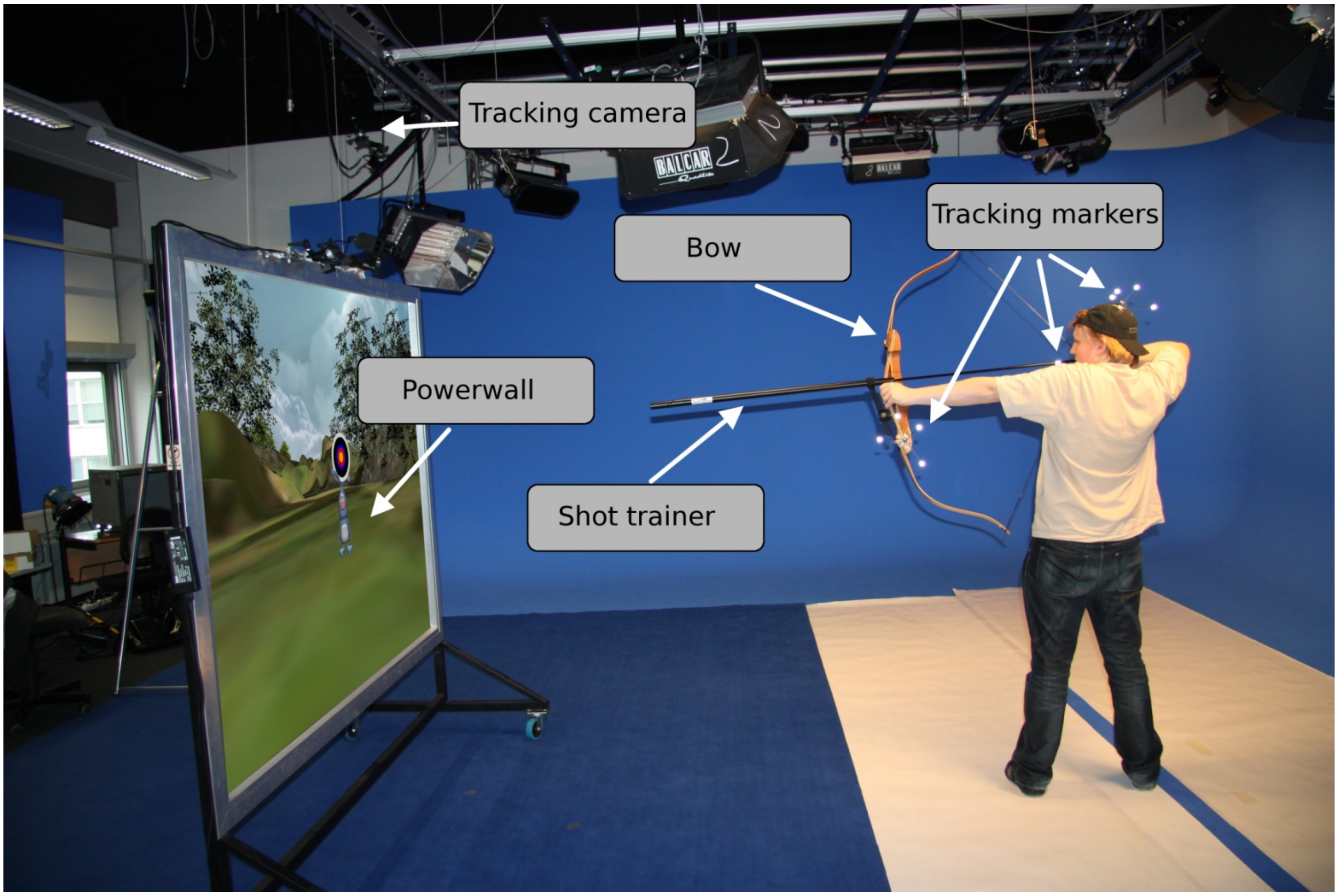

Fig. 10 Virtual reality simulator for traditional archery in a virtual studio setting.

Fig. 11 Introduction video with pulling in the actress into the simulator.