An Interactive Haptic System for Experiencing Traditional Archery

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Abstract: In the last decades, more and more virtual systems are used for various activities: training, explanation, simulation, or verifying different concepts. This paper presents a first attempt to create a CogInfoCom channel through which a Virtual Reality (VR) system communicates with a natural cognitive system (prototype and physical experimental system) in a way that improves human cognitive abilities to understand the way an ancient bow works and the sensations it exerts on the human body. This study proposes an immersive VR simulator for recreating the experience of shooting with 3 types of old bows, based on a customized haptic interface. The research focuses on optimizing the shooting experience by using the force characteristic measured from real replicas, as well as handling other important archery features such as the length of the draw or the weight of the bow. The results are mostly positive and the data collected demonstrates the adaptability and replicability of the developed solution, as the system is able to reproduce in VR any type of bow.

Keywords: Virtual Archery; Immersive VR; Haptic feedback; 3D interaction; CogInfoCom

1   Introduction

1.1   CogInfoCom and VR Technologies

The term of "cognitive entities" has emerged as the parallel evolution of people's cognitive capabilities with the resources represented by ITC, the phenomenon exploding to recent years with the X, Y and Z generations. The effects of this

phenomenon were detailed in [1]. As a component of development of technology in the last years, we can emphasize the field of Virtual Reality, which has entered into force in everyday life. Virtual Reality represents an artificial environment that is created with a mixture of interactive hardware and software, and presented to the user in such a way that any doubts are suspended. It is accepted as a real environment in which it is interacted with in a seemingly real or physical way [2]. This field has unlimited development possibilities and can be used in many areas of training or entertainment. A big problem is the way of communication between human and the computer, the transfer of data, but also the perception and understanding of the phenomena.

Cognitive infocommunications (CogInfoCom) is an interdisciplinary research field that has emerged as a synergy between infocommunications and the cognitive sciences. The infocommunication concept is an extension of telecommunications, with information processing and content management functions on a common digital technology basis. These include all types of electronic communications: fixed and mobile telephony, data communications, media communications, broadcasting, etc. [3-7].
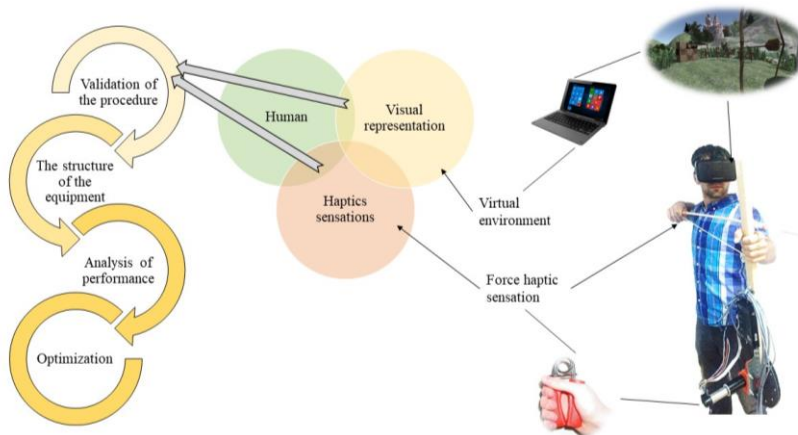

Figure 1
The concept of CogInfo in the use of VR equipment

Human mental capabilities are more flexible in adapting than material-energy capacities that operate artificial hardware, so new ways of interacting with information are constantly emerging. The concept of CogInfoCom has been identified with various levels and seen from many perspectives, especially to characterize the performance of new technologies where there is an interaction between man and machine [8, 9].

This paper addresses the analysis of a new communications channel that connects the user with the information systems as cognitive communication channels,

different from the classical ones. Our goal is to develop engineering systems for training using simulations in Virtual Reality. First, by using this type of application, it can reduce the cognitive burden of the user and, second, it may help to mitigate the effect of control instabilities and hidden parameters [3, 10].

In the ITC field, CogInfoCom solutions can be applied to determine the best parameters of the communication process (eg Human-Machine Interactions) [11]. There are concerns in the field of analysis of new communication channels: the subject of tactile perception of robot teleoperation [10, 12], production planning in virtual environments [13], creation of 3D workspaces for people with special needs [14] or analysis of the factors danger in building environments [15] using VR techniques, or even less tangible subjects, such as Crowdsourcing [16], pedagogy [17] or economic models, production and investment [18].

According to [4, 5, 8], in this paper we want to deal with the Inter-cognitive communication relationship. In other words, we are talking about information transfer that occurs between two cognitive entities with different cognitive capabilities, between a human and an artificially cognitive system – as determined by what is relevant to the application. In Figure 1 is presented the scheme of the CogInfoCom concept, with the model presented in [19] as the source of inspiration.

1.2   About Archery

Shooting with bows was one of the most common activities in medieval times, in both hunting and warfare. Different populations used different types of bows, among which we may mention the longbow and the curved bow, along with their respective extended developments. Both of them offer a unique archery experience in terms of precision and efficiency.

Today, archery is practiced as a sport [20] and it is seen more as a recreational activity than a productive one. Historically however, archery has been used in completely different contexts, such as hunting and warfare. The first bows were documented more than 10,000 years ago [21]. Since that time and until the recent development of gunpowder in the 14th Century (which rendered the usability of bows as projectile weapons to virtually zero), practicing archery gained popularity and expanded throughout all human-inhabited places.

Depending on the available materials and on the war strategies of each segment of population, bows specialized and diversified. Among the most important types of medieval bows, we can distinguish the longbows and the curved bows, each with its own subcategories (e.g. flat bows are included in the longbows category because the string doesn't touch the limbs of the bow anywhere except on the ending nocks [22], while horse bows are included in the curved bows category, since the limb endings curve away from the archer [23]).

One can notice the style differences around the world, as various populations developed different bow designs. In the Western hemisphere for example, longbows were often made of Dogwood or Hickory, exploiting the dense and fine-grained timber. In Western Europe, longbows were often made of yew. This type of wood allowed the Englishmen to make improvements to the original flat bow design, which survived only in cold areas such as the Scandinavian Peninsula, where yew doesn't grow [24]. English longbows could shoot as far and 250 meters, and at the moment of their introduction, gave a competitive advantage over the French troops. In the central part of Asia, nomadic tribes such as the Mongolians developed the horseback archery. They were using small curved bows, a type of weapon which also registered success with other Middle East cultures. Compared with the original D-shaped longbows, curved bows are easier to use (less strength is needed to shoot an arrow), and can store higher amounts of potential energy. They could send an arrow as far as 600 meters, but were light and thus, more fragile. Longbows on the other hand were easy to make, but hard to use.

The Japanese archers had a completely different shooting style, which was compliant with their war strategies, based on an asymmetrical bow called "yumi" [25]. As can easily see, archery evolved over centuries, differentiated cultures and ultimately influenced the history of humanity. However, the knowledge on such an important part of our history is not widely spread and is often disseminated by means of text information and exhibiting relevant specimens. Being a strongly physical activity, a much deeper knowledge could be shared instead by means of an interactive experience, something nowadays made possible by VR technologies. However, to the best of our knowledge, there are no VR systems able to recreate the physical experience of shooting with different ancient bows. This study proposes such a system, and focuses on 3 very different bows: an English longbow, a flat bow and a horse bow. Our aim is to develop a multimedia installation which can be used inside museums or at conferences and other related events, to document a piece of history which is important not only for experts and professional archers, but also for raising the awareness of the general public.

2   State of the Art

2.1   Archery in Virtual Reality (VR)

Archery has been introduced to VR in just a few prior studies. One of the first implementations tries to simulate horseback archery [26]. Although the users are not completely immersed, the interaction is obtained with the help of a real bow. A complex architecture based on five different processing units performs the

sensor fusion and provides the visual and haptic feedback to the user. The public warmly received the concept, although it lacked realism. A few years later, commercial entertainment solutions such as Nintendo Wii and Sony PlayStation implemented archery applications in their bundle. They work by tracking user's posture. The controls, however, lack the real drawing interaction, which is substituted with simple metaphor (press of a button). A more advanced commercial setup is the bow simulator from Techno Hunt [27]. Although it maintains the usage of a physical bow and the action of shooting with a real arrow, the non-immersive system is based on a flat screen, which has a negative impact on users' presence.

One of the most recent initiatives proposes a VR archery simulator based on a power wall and a real 62" bow [28]. The arrow is not released by the system, as the potential energy is conveyed into a pneumatic tube. The authors also exploited the system as to provide an archery learning experience in [29, 30], but due to several drawbacks, the overall assessment of the solution was only satisfactory. Learning archery was also presented in [31], were the authors tried to use the virtual environment as a platform for acquiring and improving archery skills. Another recent related work is presented in [32] dealing with the implementation of a crossbow into an immersive virtual environment. However, shooting with a crossbow offers a completely different user experience, which has little to do with the one offered by shooting with a bow.

2.2   Haptic Systems

Haptics is an essential part of VR. Although not as developed as others which are targeting more ardent sensorial channels served, e.g. by our eyes or our ears, it is foreseen that providing a haptic output will eventually become as important as rendering 3D scenes or providing ambient sounds [33]. Haptic interfaces offer users tactile information, by applying forces directly to their tegument. Thus, users can "feel" the environment, improving both their interaction and immersion. This translates in an increased sensation of presence, the goal of any VR application [34].

Haptics has several purposes. One of the most important which partially covers the subject of our research is virtual training. A large number of studies are using haptics to improve the physical and mental abilities of the users activating in the health industry [35, 36]. Training surgeons in fine medical procedures is among the most targeted subjects. Just a few studies target other areas; e.g. based on this technology, subjects can be taught to assemble complex products [37]. A specific subdomain of virtual training is the transfer of skills. There are numerous human activities which are on the verge of being lost, with only a handful of experts still actively pursuing them. With the help of the latest technologies, these can be recorded and transferred to others [38-41].

Haptic systems can be employed for assisting users in performing various tasks. Several papers target this subject; e.g. in [42, 43] users are assisted in operating a robot. Lots of studies propose systems which can assist people who are blind, or with a low vision capability [44]. Even in the automotive industry, assistive haptics may play an important role in the near future [45]. In entertainment, haptics resumes to the commercial systems described in the previous section.

3   System Design

The system was developed in cooperation with experienced researchers in the field of ancient archery from the History Museum of Brasov, Romania. Before starting to design the haptic interface simulating the bow, some of the authors have participated to an archery training course, to understand the bow shooting process. Moreover, we have interacted with several archery experts before actually designing the system.

3.1   Prerequisites

As a result, we have found that in order to reproduce as close as possible the experience of shooting an arrow with an old medieval bow, several factors must be analysed, such as the weight of the bow, the size and weight of the arrow, the length of the draw and the force needed to pull the bowstring (which it directly dependent on the coefficient of elasticity of the bowstring). The type of draw is also important. Moreover, the experience of shooting with a bow is highly dependent on the physical characteristics of each user, as the variable height and weight make a huge difference, not to mention that for some bows it is possible to shoot only with the right hand (or only with the left one).

Bow weight and dimensions: The English longbows typically weighted 1-1.5 kg and measured 1.8-2 meters on average, while the horse bows from nomad populations (such has Scythes or Mongols) weighted around 0.5-1 kg and were 1.2-1.6 meters long [46].

Draw weight and length: The draw weight is measured as the amount of force (expressed as a weight), which needs to be applied to the bowstring in order to bend the weapon to its full extent. The standard length one could extend the bowstring of an English longbow was 70 cm, but this could vary along with the bow. The draw weight was 30 kg on average. As for the horse bows, the draw length was longer, at around 80 cm, and the draw weight is measured between 40-70 kg [47].

Arrow features: Longbow arrows weighted between 50 and 100 grams, and measured between 60 and 85 cm, with an average of 76 cm [47]. Horse bow

arrows were a bit longer in length (between 80 and 100 cm). The length of the arrow was correlated with the aperture of the subject's arms (usually measured from the chest to the tip of the fingers).

After initial talks with several archery experts, the following general requirements were defined for the development of the VR system:

- Recreate the physical properties of old bows;
- Generate a realistic haptic feedback that allows to "feel" different draws of old bows;
- Immerse the user in a realistic audio-visual 3D environment, in order to provide an entertaining archery experience.

The longbow replica used in the experiment is 177.8 cm long, weights 1.3 kg and has a draw weight of 13.6 kg. The flat bow replica is 172 cm long, weights 1.2 kg and has a draw weight of 12.5 kg. The horse bow replica is 121.9 cm long, weights 0.5 kg and has a draw weight of 18.1 kg (Figure 2).

Figure 2
The horse bow, flat bow and English longbow replicas

3.2   Haptic Interface

The haptic interface is based on a MAXON EC-Powermax 30 electric motor and its corresponding digital motion controller (EPOS 70/10), with CAN bus transfer speed of 1 Mb/s, a value suitable to provide the haptic response. The draw length is measured by using a rotary encoder integrated in the electric motor. The motor was mounted on a wooden base, which is held by the user. At the end of the motor, we mounted a pulley with an outer diameter of 20 cm.

The kinesthetic haptic feedback is generated through wires. For a uniform winding on the tambour, and in order to avoid jams, the wire is guided through a mechanism composed of a wheel and a metal plate mounted next to the tambour.
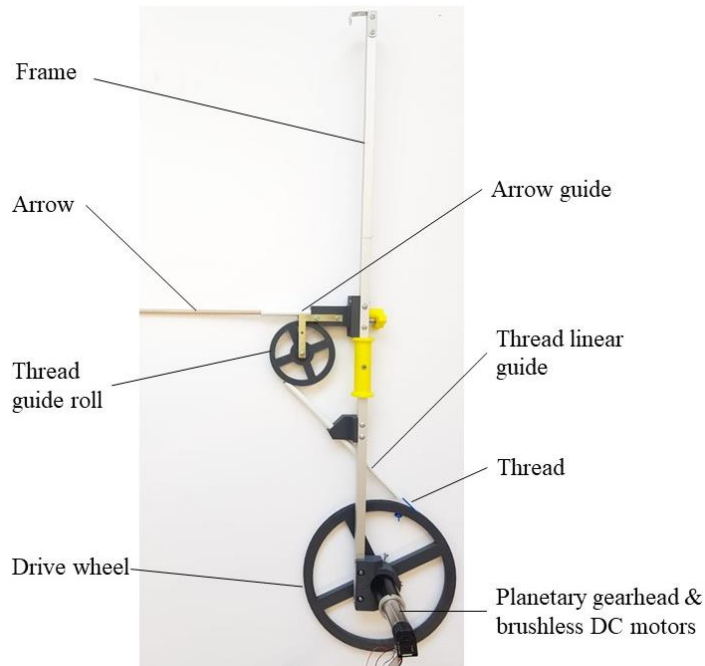
Figure 3
The developed haptic system

The kinesthetic haptic feedback is obtained by transmitting to engine's control module the corresponding power values necessary to obtain the required wire tension. When the user begins drawing an arrow, the haptic system creates the tension on the string by controlling the amount of electric current transmitted to the motors.

A control module developed in C++ allows the communication with the motor controller. The system enables users to manually adjust the weight, by mounting additional screws and nuts in the holes on the metallic plate. which is supporting the motor (Figure 3).

3.3   Force Feedback

In order to calculate the forces that will be perceived by the user via the haptic device, we had to measure each bows' properties under real working conditions. The elastic characteristics have been determined by means of experimental tests, using a Tinius Olsen H100KU dynamometer (Figure 4).

The 3 tested replica bows are equipped with a bowstring made of Dacron, a polyester material largely used in modern archery. Originally, bowstrings were

made of the sinew of large 4 legged animals (such as deer, horses and so on), animal skin, silk, cotton or other vegetal fibers. The main difference between Dacron and manual-made bowstrings is reliability [48].
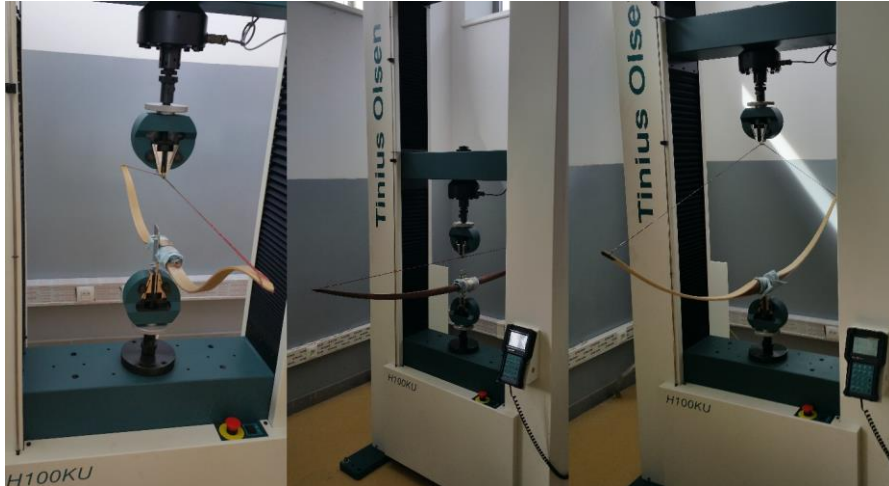

Figure 4
Measuring the elastic characteristic of the 3 bows

We assume that the measured values are similar to bowstrings made of natural materials. Each unit was mounted on a special fixed vise and the bowstring was hanged from a mobile hook. This was moved incrementally up to the maximum draw distance used to launch the arrow, which is measured up to 50 cm for both replica bows. While moving the hook, we recorded the force corresponding to the displacement, and thus computed the complete force characteristic for each bow. The results are shown in Figure 5. The elastic characteristics of the tested bows approach straight line graphs. Based on linear approximations, we can write the relationships of forces depending on bow deflection as the equation of a straight line:

$$F = a \cdot x + b \tag{1}$$

where F is the measured force corresponding to a draw value x *(mm),* with the real coefficient a presented in Table 1.

Table 1
Linear parameters

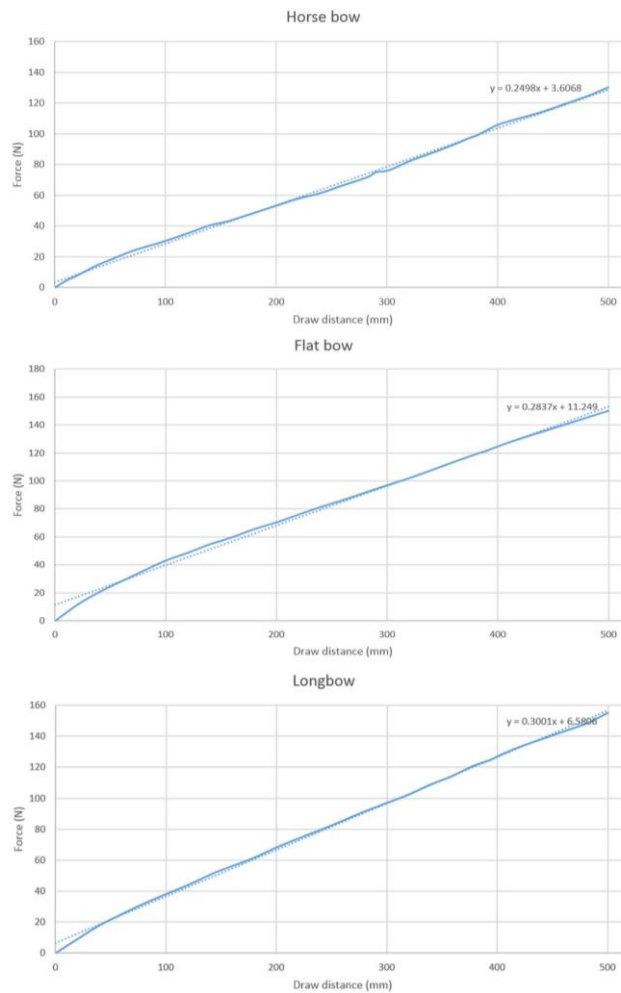| Bow type	a	b
Recurve horse bow	0,2498	3,60
Flat bow	0,2837	11,24
English longbow	0,3001	6,58

Figure 5
Characteristic graphs

3.4 Immersive VR Environment

In order to create a realistic and immersive 3D experience, we used the Unity Game Development Engine and the Oculus Rift DK2 head mounted display (HMD). Providing immersive depth cues via viewpoint movement is based on tracking of the user's head, updated by the coordinates received from the HMD's gyroscope. The haptic feedback algorithm written in C++ language as Dynamic Link Library (DLL) was imported to Unity3D. The complete system is presented in Figure 6.
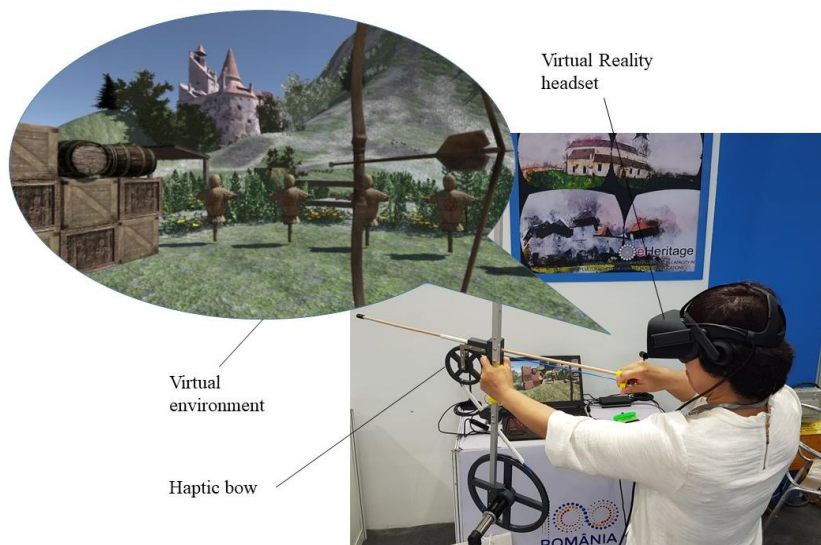
Figure 6
Complete working system in action and a view of the VR application

The trajectory of the VR arrow is calculated based on the potential energy equations presented in [49]. According to archery dynamics studies [50], only a certain percentage of the energy stored in the bow is transferred to the arrow itself (≈70%). The remaining 30% is discharged into the bow and transferred to the archer, usually in the form of vibrations. We have included this approximation in the distance calculus. The 3D environment uses the physics engine provided by Unity. The virtual bow is tied to the view point of the subject. The scene consists by several targets placed in a virtual environment with a rebuilt castle. The technology of virtual reconstruction of buildings that no longer exist is presented extensively in [50]. As soon as the user actuates the haptic system, the virtual scene is also updated.

4   Methodology

The overall objective of our study is to analyze the quality of the haptic device that simulates a bow in a virtual environment. We have tested the system with various occasions.

In the initial phase two experts, employees of the Museum of History from Brasov, Romania, have tested the system in two separate sessions. They were asked to answer to the questions presented below:

1)   What is your opinion on the Archery Haptic Simulator?

2)   Is the simulation offering a close-to-reality experience?

3)   From haptics point of view, were you able to differentiate between the 2 bows?

4)   What are the biggest drawbacks of the setup?

5)   How would you rate the shooting experience?

The overall system assessment is positive, as both experts enjoyed using it. The small difference in the force characteristic of the two bows was noticeable, and both experts confirmed the existence of different particularities between shooting with the virtual longbow versus shooting with the virtual horse bow. Moreover, both experts agreed the system provides a close-to-reality experience in both cases. The force characteristics are, however, much smaller than what would be normal in the past (expected, since both replicas have a draw-weight, which is approximately a third of the originals'). One of the biggest drawbacks was the lack of feeling of the bowstring. The shooting experience was warmly appreciated overall, which gave us grounds to proceed with the user study.

Many users tested the application during a cultural heritage workshop (Figure 7) within the Information Society 2016 multi-conference held at the Jožef Stefan Institute in Ljubljana, Slovenia [52] and presented at UE Open Day (Bruxelles, 2018) and International Cultural Industry Fair (Shenzen, China, 2018). The following research question was formulated: "Can a haptic virtual device which simulates traditional bows be developed in such a way that it offers a similar experience to the one offered by the natural process of archery?"

Based on the presented system, the simulation process presumes the completion of 4 phases:

(i) Setting up the haptic system input parameters: the custom bow weight, the elastic characteristic of the selected bow and the drawing length.

(ii) Preparing to draw an arrow: the user will perceive the spring force generated by the electric motor that actuates the wire. The tension on the string generated by the motor (eq.2) depends on the rotation angle of the wheel, which can be calculated by rewriting eq. (1):

$$F = a \cdot \alpha \cdot d \tag{2}$$

where α (rad) is the rotation angle obtained from motor encoder and d is the diameter of the pulley.

(iii) Launching the arrow: the operator will perceive the release of the string (which will wind back on the wheel) and a vibration on hand that holds the bow.

(iv) Updating the VR scene: the result of the interaction is updated in the 3D scenario.

Figure 7

The haptic bow at the Information Society (Ljiubljana, Slovenia, 2016), EU Open Day 2018
(Bruxelles, Belgium, 2018) and International Cultural Industry Fair (Shenzen, China, 2018)

5   User Study

Evaluating haptic systems is not a straight-forward task, yet there are plenty of
papers which deal with this aspect [53, 54]. We have designed this user study
based on some of the guidelines proposed in [55], a study in which the authors
thoroughly explain how haptic systems can be evaluated. We prepared and
conducted two test sessions: the first one - shooting with the 3 real bows; the
second – using the haptic device, adjusted with the 3 values of elastic springs of
real replica bows within the VR scenario. 20 respondents, aged between 19 and
62, have participated in the user study. 5 of them already had some experience in
using haptic devices. After conducting two sessions of tests, respondents were
asked to complete a questionnaire which followed a series of elements of
perception regarding the use of this equipment.

The subjective questions could be answered on a scale from 1 to 7. Before each
test, subjects were asked to focus on the use of each bow and to try to differentiate
them. They were instructed about the way people were using bows in the past. A
short story was also presented about each of bows, in order to increase their
interest. For both real and virtual bows, they performed 20 trials, separated in two
sessions, with a short break between them. The shooting results were not counted
as good or bad, and there was no time limit for performing the trials. All users
gave their informed consent in the beginning of the experiment.

The questions ask users how much they agree or disagree with the statements.
Also, the questions are separated in 6 categories: engagement, manipulability,
enjoyment, realism, usability and overall experience, in order to better assess the
interaction with the haptic device. The obtained values are presented below, based
on the questions from each category. Questions marked with "*" at their end were
expected to have negative answers. For the negatively stated items, we subtract
the user response from value 8.

5.1 Engagement

The following questions were asked in the "Engagement" part of the questionnaire:

(1)   I liked the activity because it was novel

(2)   I wanted to spend time to participate in the activity

(3)   The topic of the activity made me want to find out more about it

(4)   I wanted to spend the time to complete the activity successfully

(5)   I liked the type of the activity

(6)   The haptic application we employed captured my attention

(7)   I did not have difficulties in controlling the haptic application

(8)   I found the haptic application confusing*

(9)   It was easy for me to use the haptic application

(10)   The haptic application was unnecessarily complex*

The results processed in this section are presented in Figure 8. Users had a great involvement in the experiment and all of them wanted to successfully complete the tasks, both real and virtual. They reacted very well to both real and haptic bows, and they also found the application to be clear and easily understandable.
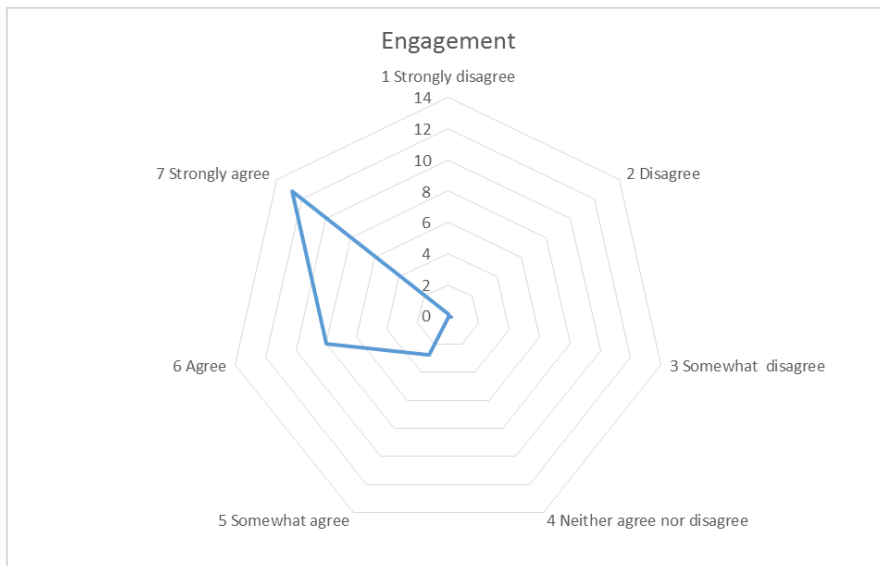

Figure 8
Engagement assessment

5.2 Manipulability

"Manipulability" was inspected based on the following questions:

(11)   I think that interacting with this haptic device requires a lot of body muscle effort*

(12)   I felt that using the haptic was comfortable for my arms and hands.

(13)   I found the device difficult to hold while operating the device*

(14)   I felt that my arm or hand became tired after using the device*

(15)   Fatigue level after 10 and 20 trials

(16)   I think the device is easy to control

(17)   I felt that I was losing grip and dropping the device at some point*

(18)   I think the operation of this device is simple and uncomplicated

In general, users were satisfied with the haptic device with respect to manipulability (Figure 9). They managed to easily use and control it. The operation of shooting was also simple and uncomplicated, and it was comfortable for arms and hands. The only problem reported by the users is related to the weight of the system, which was on average ranked between 3 (Somewhat disagree) and 5 (Somewhat agree). Due to the motor used, the bow's weight is a bit cumbersome for most users, especially for women. Being the first prototype, we aimed to first reproduce the functionality and the feeling of shooting, while further development will aim to fix the signalled issues.
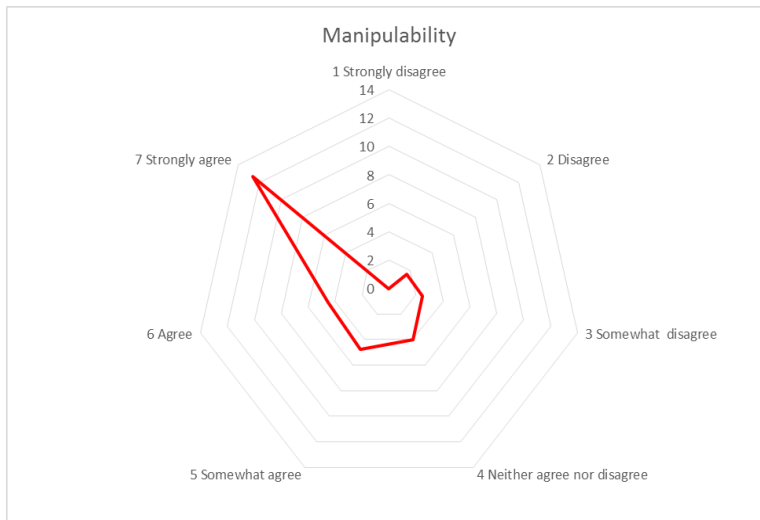

Figure 9
Manipulability assessment

5.3 Enjoyment

Enjoyment/excitement was assessed using the following questions:

(19) I enjoyed using the haptic device

(20) I found the haptic device unpleasant*

(21) I found the haptic device exciting

(22) I found the haptic device boring*

(23) By using the haptic device, I can understand how old bows where used in the past

(24) By using the device, I learn more about the history of bows

As one can see in Figure 10, most of the users were satisfied with the haptic device, described as being pleasant and exciting. They also learned new things related to the differences between the 3 different types of bows used during the experiments. A couple of users suggested including even more information related to the history of bows and their use in specific periods of time. A couple of them also asked for further use of such haptic devices, being really excited about using bows in virtual reality.
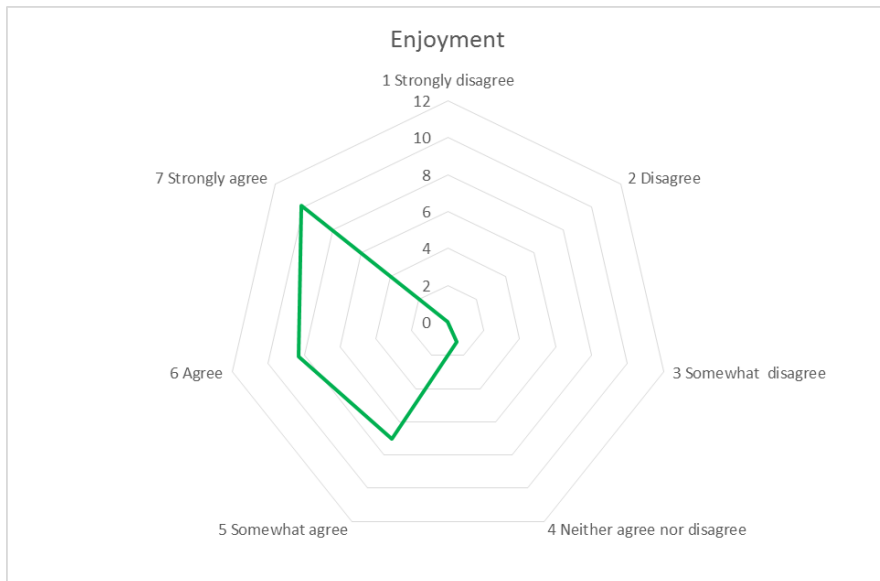

Figure 10
Enjoyment assessment

5.4   Realism

Here are the questions include in the "Realism" part of the questionnaire:

(25)   How realistic is the haptic feedback?

(26)   How similar was the feeling of bow shooting using haptic model 1 to that of real bow 1?

(27)   How similar was the feeling of bow shooting using haptic model 2 to that of real bow 2?

(28)   How similar was the feeling of bow shooting using haptic model 3 to that of real bow 3?

(29)   Choose the case with the best feeling? (not represented on chart)

(30)   Can you differentiate between 2 cases (haptic and real)? (not represented on chart)

After analysing the answers from this section, we can state that users were satisfied in general with the use haptic feedback, and they were also able to differentiate between the 3 settings according to the 3 bows proposed (Figure 11). The shooting feeling was similar with the real ones, but all of them stated that they can easily identify whether they shot with the real or with the haptic bow. We determined that users consider the haptic settings for made the second bow to be the most appropriated to the real one.
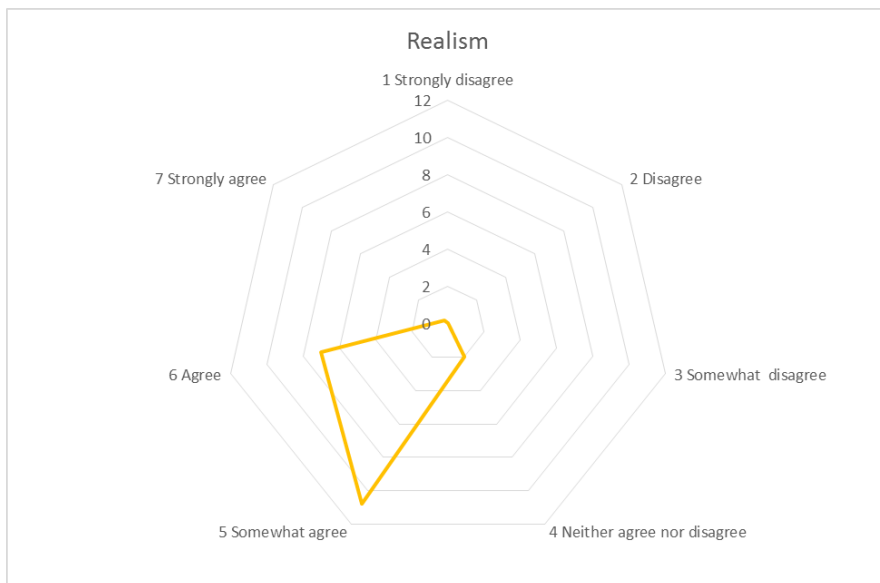

Figure 11
Realism assessment

5.5   Usability

Usability quantified based on the following:

(31)   I would like to use this system frequently

(32)   I found the system unnecessarily complex*

(33)   I thought the system was easy to use

(34)   I think that I would need the support of a technical person to be able to use this system*

(35)   I found the various functions in this system were well integrated

(36)   I thought there was too much inconsistency in this system*

(37)   I would imagine that most people would learn to use this system very quickly

(38)   I found the system very cumbersome to use*

(39)   I felt very confident using the system

(40)   I needed to learn a lot of things before I could get going with this system*

Users seemed to be confident about the use of such system (Figure 12) and they would like to reuse it in the near future. Using the haptic bow was an easy task for them and many consider it a step further to allowing everyone to use a bow without any safety concern. They also think propose paradigm is a very simple one. Everyone could easily use it, since none had to learn anything prior to the user study.
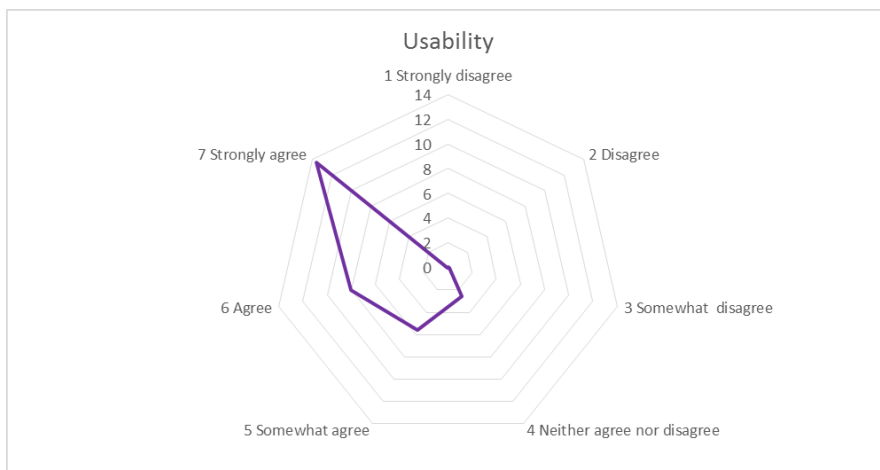

Figure 12
Usability assessment

5.6   Overall Experience

Finally, 3 questions targeted the overall experience:

(41)   Rate the overall experience you had during the experiment?

(42)   What do you like about haptic device?

(43)   What do you dislike about haptic device?

On average the experiment revealed that users were really satisfied with the use of virtual bows (Figure 13). They liked it since there was absolutely no danger when using the haptic device, but in general they were not too satisfied with its weight.

They also liked the fact that by using a single device you can actually simulate various bows only by loading a different software configuration. They were very satisfied to learn a couple of new things about bows and their history, and they also suggested to include a couple of more things within the application (gamification, social signals).
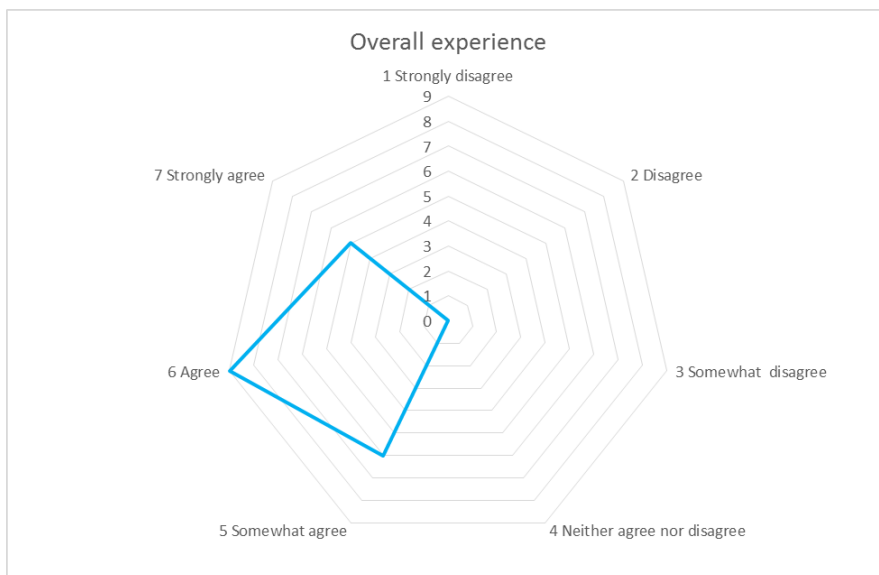

Figure 13
Overall experience assessment

Conclusions and Future Work

In this paper we identified some of challenges that occurred during the experiments based on VR systems and were commented on from a cognitive point of view. Regarding of data transfer and communication, it can be said that a

relationship has been established between the cognitive system represented by the user and the artificial system, represented by the Virtual Reality equipment.

We validate the concept of using an ancient bow in VR with the aid of two experts in archery from History Museum of Brasov. Furthermore, we propose a user study which assesses the success of the system.

We can mention a few highlights of our work: (1) we offer a solution to reproducing the experience of shooting a bow in VR; (2) the developed system can replicate the force characteristic of any type of bow; (3) we assess the degree of similarity of the haptic simulator with real replica bows; (4) a user study validates the system and shows that the prototype was well received.

Unlike classic bows, the force characteristic of modern compound bows has a negative gradient, meaning that it is harder to extend the arrow in the beginning or the drawing process. We will make a comparison between the experiences of shooting with old bows against using modern compound weapons.

An improvement of the experiment equipment will include a new haptic device that can simulate the energy discharged in the bow's limbs, passed through archer's hands (using a device such as buzzers).

By analysing all the obtained statements, we can conclude that users had a good experience in general with the haptic device and they would like to use it again in the future. The main signalled problem was related to the system weight. We are considering building a new version which will take care of this issue.

Acknowledgement

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