Multi-user and immersive experiences in education: the Ename 1290 game, based on the use of Microsoft Kinect and Unity

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Abstract

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Ename 1290 is a virtually reconstructed heritage application aimed to serve as an educational tool. With the emergence of media and interactive technologies like the Microsoft Kinect, users are now able to virtually explore and experience the reconstructed heritage environments and learn about the medieval world in a more exciting way. The present Ename 1290 application is designed in a single user mode of interaction and hence offers a very limited opportunity for social interaction, collaboration, and learning. In this thesis project, we have added a multi-user support in the present Ename 1290 application with real-time motion detection through the use of Microsoft Kinect and Unity. Moreover, this thesis also explores the design issues related to user embodiment in a multi-user based collaborative virtual environments, in particular a humanoid avatar for user representations through the use of Kinect. By collaborative virtual environment, we mean the current Ename 1290 application which offers a space for interaction and collaboration. Following this, we build a prototype which supports multi-user and showed how the design issues are addressed in the proposed system. We also hypothesize that the combination of Kinect-based multi-user collaborative virtual environment and educational live-action role play can provide a unique teaching and learning experience where users can learn through role-playing that is interactive and immersive. Evaluation of a collaborative virtual environment is a difficult task because it includes factors such as immersion, social interaction, communication, pedagogical practices and task involvements, etc. Finally, we proposed an evaluation framework aims to evaluate the technical, human, and pedagogical aspects of the proposed system. This evaluation framework is divided into four stages with each stage designed to address a specific evaluation goal.
### Acronyms and Abbreviations

<table>
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<th>Acronym</th>
<th>Description</th>
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<tr>
<td>ICT</td>
<td>Information Communication Technology</td>
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<tr>
<td>PAM</td>
<td>Provincial Archaeological Museum</td>
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<td>HCI</td>
<td>Human Computer Interaction</td>
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<tr>
<td>SDK</td>
<td>Software Development Kit</td>
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<td>VR</td>
<td>Virtual Reality</td>
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<td>AR</td>
<td>Augmented Reality</td>
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<td>VH</td>
<td>Virtual Heritage</td>
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<tr>
<td>Nu.M.E.</td>
<td>Nuovo Museo Elettronico</td>
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<tr>
<td>DVD</td>
<td>Digital Video Disc</td>
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<tr>
<td>LARP</td>
<td>Live Action Role Play</td>
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<tr>
<td>Edu-LARP</td>
<td>Educational Live Action Role Play</td>
</tr>
<tr>
<td>CVE</td>
<td>Collaborative Virtual Environment</td>
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<tr>
<td>ADHD</td>
<td>Attention Deficit Hyperactivity Disorder</td>
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<tr>
<td>IM</td>
<td>Instant Messaging</td>
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<tr>
<td>SMS</td>
<td>Short Message Service</td>
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<tr>
<td>NPC</td>
<td>Non-player Character</td>
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<tr>
<td>IR</td>
<td>Infrared</td>
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<tr>
<td>RGB</td>
<td>Red-Green-Blue</td>
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<tr>
<td>CMOS</td>
<td>Complementary metal-oxide-semiconductor</td>
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<tr>
<td>VGB</td>
<td>Visual Gesture Builder</td>
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<tr>
<td>Fbx</td>
<td>Filmbox</td>
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<td>UI</td>
<td>User Interface</td>
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1. Introduction

1.1 Motivation

Cultural heritage plays an important role in the understanding of our history, belief, customs, practices and social progress. For these reasons, it is important to preserve it and educate the public about our past. With the rapid advancement of technology, preservation, and presentation of cultural heritage has been significantly enhanced using computer graphics, virtual reality, information communication technology (ICT) and new interactive technologies, notably the Microsoft Kinect camera technology. There are many ways to educate and engage the public in cultural heritage, but one of the most popular is to allow users to interact with virtual worlds.

Ename is a historical site located in the city of Oudenaarde, Belgium. The remains of the Ename village in Belgium are still noticeable in the archaeological park but is difficult to understand and enjoy. A company based in Belgium called "Visual Dimension" [1] therefore started virtual reconstruction of the Ename village. Virtual reality and multimedia are the key components of the visual reconstruction and presentation. This technique is used to reach broader audiences and to help users to understand and experience the past in a better way. After many years of historical research, study and excavation the company reconstructed the abbey and the village of Ename as it was in the era 1290. This real-time visualization of Ename 1290 is used as a serious game for the educational department of PAM Ename (Provincial Archaeological Museum Ename) [2] as well as a virtual walk-through of the Ename village. Presently, only a single user is allowed to interact with the reconstructed virtual world (Ename 1290). The interaction and navigation of the Ename 1290 game is based on the user’s
gesture which is recognized through the use Microsoft’s Kinect. Although, the present application offers some experiences of interaction it still lacks the multi-user feature to support learning and understanding of the historical site.

1.2 Goal of the thesis

The primary goal of this project is to add multi-user support in the existing Ename 1290 application. A prominent feature of the Microsoft Kinect for Windows V2 is the capability of simultaneously tracking six people including two active people in detail. With this feature, we can add multiple users in the Ename 1290 application. To enhance the experience of immersion in the existing application, we will add 3D humanoid avatars. These avatars will replicate user’s body movements and will appear visibly in the reconstructed Ename 1290 virtual environment.

Ename 1290 game is also deployed as an educational game, and it is important to engage students in the game for a better understanding of the Ename village. Role-playing often takes the form of two or more people physically act out their characters in a scene. The communications and emotions experienced by the people playing in the scene are real which in turn creates a meaningful learning experience. With this thought in this project, we will introduce a novel approach where users can role play with each other as well as interact with the game through their embodiments. Finally, this is a multidisciplinary project involving virtual reality, human-computer interaction (HCI), sociology and psychology. Learning and understanding how to bring together these disciplines to solve complex problems faced in today’s technologically advanced operational domain is another goal of the project.
1.3 Research Questions

Along with the goals of the project, two research questions are formulated:

RQ1: What are the design issues involved in a Multi-user Kinect-based virtual environment?

RQ2: How to utilize the benefit of user embodiment and collaborative virtual environment to facilitate an educational role play and collaboration?

1.4 Hypothesis

Combining educational live-action role play with the Kinect-based multi-user collaborative virtual environments can provide a unique teaching and learning experience. By collaborative virtual environment we mean the current Ename 1290 application which offers a space for interaction and collaboration. Educational live-action role play could provide interactivity, communication, and feedback that are important to role-playing. Microsoft’s Kinect-based immersive virtual environment is not only able to simulate exotic settings, but it also provides user embodiment, motion detection, collaborative interaction and a sense of immersion.

1.5 Thesis Overview

Chapter 2 presents the background of cultural heritage, its digitization, two types of digital realities: virtual reality & augmented reality and virtual heritage. It also specifies the history of Ename and its virtual heritage interpretation.
In **Chapter 3**, the different theoretical backgrounds and related researches required for the project and specifically highlights different issues of user embodiment in a collaborative virtual environment are explored.

In **Chapter 4**, the virtual representation of Ename in the era 1290 is introduced. Interactivity and exploration in Ename 1290 are also discussed in this chapter. It further introduces Microsoft’s Kinect device, its working principle, application and research including Kinect Windows Software Development Kit (SDK) and Kinect version 2.

**Chapter 5** documents the creation of a humanoid avatar using Adobe fuse and Mixamo. Implementation details of adding of multi-user support in the existing Ename 1290 are introduced.

**Chapter 6** describes the design and development of the new proposed prototype and it also addresses how the issues highlighted in **Chapter 3** are addressed in the prototype.

The evaluation of the proposed prototype is discussed in **Chapter 7**.

Finally, **Chapter 8** provides the conclusion and the development limitations, and **Chapter 9** discuss suggestions for future work.
2. Background

This chapter introduces general concepts of cultural heritage and its digitization. Virtual reality (VR) along with its sister technology augmented reality (AR) used for showing digitized cultural heritage and the concept of virtual heritage are also presented. Furthermore, the historical context of the archaeological site Ename is described in detail. Finally, the chapter concludes with the presentation of the Ename virtual heritage and its virtual reality interpretation.

2.1 Cultural heritage and its digitization

Cultural heritage includes either intangible or tangible cultural heritage [3]. Cultural heritage is not only manifested from tangible cultural assets such as paintings, books, artifacts, monuments and buildings but also from intangible cultural assets. Intangible culture is a non-physical aspect of a particular culture [4]. It means the practices, representations, knowledge, rituals, skills, traditions as well as the cultural space associated with certain groups or individuals [5]. Although there are different categories of cultural heritage the conservation and protection is very essential. The preservation of cultural heritage not only gives us a better understanding of our history, it also helps us to remember our cultural origin.

Digital acquisition techniques of tangible cultural assets have become a new form of preservation. In today’s digital world, digital media are often used to preserve the cultural heritage and make it more accessible to a broader audience including students, researchers, and adults [6]. Libraries, museums, and academic institutions are extending their operations by creating digital collections of books, music, and painting, etc. For example, the National
Library of Norway has a program to digitize the entire collections of the library over a period of 20-30 years [6]. Moreover, with the advancement of 3D technologies, we can capture and represent buildings, sculptures, and monuments from all periods and cultures. One of the primary advantages of digitization of cultural heritage is that the digital world does not require to worry the physical deterioration of the artifacts. Furthermore, the electronic copies can be also accessed from different locations by many simultaneous users. In recent years, there has been an emergence of a new field called virtual heritage which uses electronic media to interpret cultural heritage to the public. More details on virtual heritage will be discussed in the next sections.

2.2 Virtual and augmented reality

Virtual Reality (VR) is a fully immersive computer-simulated 3D environment which can be explored and interacted with by a person. These simulated environments are usually experienced with VR helmets, head-mounted displays, wands and haptic devices like motion sensing gloves. Virtual reality is an advanced technology mostly used as a tool for education and training. VR simulators are routinely used for training pilots, doctors, and soldiers, etc. where they can develop their skills without fearing the consequence of failure. Learning in virtual reality is another application of VR as it’s immersive quality may enhance the learning by making it more exciting and interactive. In the gaming industry, VR is also gaining popularity and it’s size in the gaming market is estimated to reach USD 9.55 billion by 2022 [7].

Augmented Reality (AR) is a technology enriching the physical environment with digital information. Unlike virtual reality, augmented reality superimposes digitally rendered images onto our real-world surrounding environment in real-time. With the recent development of augmented reality technology, now using a smartphone augmented reality is easily accessible. For example, students can learn historical buildings when they install an AR application on their smartphone. They can view old buildings
of the past by superimposing them over the current day buildings from their smartphone’s camera.

2.3 Virtual heritage

Virtual heritage (VH) is expressed as a combination of cultural heritage and virtual reality which are presented through digital media [8]. In general, virtual heritage and cultural heritage have independent meanings: cultural heritage refers to the tangible cultural assets such as artifacts, buildings, monuments and objects with historical values whereas virtual heritage refers to the computer visualization of these artifacts and sites [9, 10]. According to Maria Roussou [8], virtual heritage involves the synthesis, conservation, reproduction, presentation, digital processing and display with the use of advanced image processing technology. Researchers and academics have developed many applications of virtual heritage for internal research purposes and industrial labs. Due to the cost of present VR technologies, development complexity, requirements of expertises and labor, etc., only a few applications are made available to the public spaces like museums and educational institutes. To extend virtual heritage from research labs to a larger public the educational, presentational and even recreational aspects must be emphasized [8]. However, many of the present virtual heritage applications lack such properties.

Many researchers and authors claimed that the failure of today’s virtual heritage applications is due to the lack of interaction with the content, those that do generally allow users to use the spatial navigation to tour through a virtual environment [8]. Mosaker even alleged that today’s VH environments lack a “thematic interactivity”, which means that the user navigates the virtual world without any objective or goal [9, 11]. Another important point is that the present virtual heritage demonstrates the advancement of the digital media technology, but on the other hand, it has failed to pay more attentions to the intangible part of the cultural heritage. Mosaker [11] surveyed users of two virtual heritage projects “Hellenic world” and Nu.M.E. “(Nuovo Museo Elettron-
ico)”. From her study, she found that visitors do not have the detailed information of ancient architectural styles. Instead, they are more interested in the human part of city life, which is something they can relate to [9]. Perfectly virtually reconstructed columns and buildings are impressive, but it doesn’t represent the everyday life of the people at that time. In the end, it gave a “sterile impression” to the visitors since the real world consists of many intangible elements. The incorporation of intangible elements in virtual heritage thus provides us a better sense of realistic impression and without a doubt, it will expand virtual heritage applications to more users.

2.4 **Ename historical context**

The Ename village is an important medieval trade settlement and a military center from around the year 1000. Ename grew very fast and turned into a center of power and international importance. By the time, they had two churches built: St.Salvator church and St.Laurentius church, “a harbor and a fortress”. For over half of the century, Ename was a major international trade and political connection along the western border of the Ottonian Empire [12]. However, its glory and importance were ended in the year 1033, when Baudouin IV, Count of Flanders captured the fortress of Ename [13]. The trade settlement was destroyed and the site was also demilitarized. In the year 1063, Baudouin V and his wife Adele of France founded the Benedictine abbey of Ename. The Ename abbey’s economy flourished and more farmers were settled in the village. The St.Laurentius church is turned into a pilgrimage church and St.Salvator church is replaced by an impressive Romanesque church. The abbey started to acquire more properties, and many of the old buildings were replaced with more decorated buildings with new gothic style. In the 13th century, the nearby woodland (Bos t’Ename) managed by the abbey was degraded so badly. The people in the village started planting trees and services to the abbey. This was recorded as the oldest act of forestry in Europe [13, 14].
In the later half of the 16th century, the abbey was severely damaged because of the religious wars. The buildings of the abbey have been seriously damaged and the church of St. Laurentius was also destroyed by the fire. In 1566, a revolt called “Beeldenstorm” [14] and the Protestant uprising (1572-1582) [13] were disastrous. The monks fled to Oudenaarde where they took refuge, and the abbey’s buildings were pillaged. However, at the beginning of the 17th century, the abbey and the village was rebuilt after the destruction. The abbey reclaimed its properties and became an institution of great splendor and dominated the lives of inhabitants. After 65 years, the abbey was confiscated and destroyed by the French Revolution wars.

2.4.1 Ename virtual heritage presentation

Today the village of Ename is located in the city of Oudenaarde (Province of East-Flanders) in Belgium (see Figure 2.1). Most of the archeological site is located on the medieval boundary between the French Kingdom and the German Empire [15]. The first archaeological excavation was carried out by Professor Vande Wallen between 1941 to 1947 [13]. The archaeological work did not resume at the site until 1982 when an intensive excavation and historical research was carried out on the abbey of Ename. The exceptional richness of archaeological data was revealed during the excavation. It therefore encouraged historian Jean-Pierre Van Der Meiren to develop the site into an archaeological park. In 1988 eight hectares of land was donated by Mr. De Boever to the city of Oudenaarde to develop the site into an open-air archaeological park further. A museum was opened, the old century St. Laurentius Church was restored, and the nearby woodland (Bos t’Ename) was also made accessible to the public [15].
2.4.2 Virtual reality (VR) interpretation of the archaeological site Ename

In 1997, the Ename 974 project was started with the support of the province East-Flanders [15]. The first visual reconstruction prototype of the Ename site called TimeScope 1 was installed at the site (see Figure 2.2) [13]. The new VR technology (TimeScope 1) gives visitors a 3D model of the Ename Abbey in ancient times through an onsite VR installation. Besides, a multimedia presentation offers additional information of the site and the people who lived there [15]. After the inauguration of the TimeScope 1, the Ename 974 project team started the excavation and restoration of St.Laurentius Church. This approach is very different to the TimeScope 1 approach because it uses internet technology. The camera images of the interior of the church, the results from the excavation and the restoration process were made to public on the internet and interactive kiosks [13]. In 1999 a new system called TimeScope 2 (see Figure 2.3) was inaugurated. This system not only highlights the standing monuments but also used to provide information of the Romanesque church while it is undergoing an extensive excavation and interior restoration. The TimeScope 2 system permits visitors to monitor the progress of the excavation and recovery efforts. An accompanied multimedia presentation explains the importance of the church and provides the rationale of various stages of the restoration process of the project [15].
VR reconstruction, multimedia presentation, and the daily work progress were made available through the TimeScope 2 system and as well on the Internet for different audiences such as school children, scholars, and adults, etc. After discovering the historical importance of the St. Laurentius church, much effort was put into the restoration of mural paintings. After the completion of the restoration, the Ename center team started to develop TimeScope 3 system. The team developed a storytelling system where it adapts to the interest and exploration of the user. The story based interactive system provides the historical importance of the old monuments, information about the excavation and restoration work to the public.
The provincial museum at Ename is very special among the other local museums because the museum uses computer controlled digital video disc (DVD), multimedia and VR technologies [15]. One of the most creative system is the TimeLine which uses a 3D reconstruction of a 3 by 3 km area over a 1000-year time span [13, 15] (see Figure 2.4). The interactive system offers a panoramic view of the selected area by touching the screen. The historical objects and archaeological objects are visually linked to the TimeLine reconstruction. Visitors can find information of the particular object through the TimeLine system, and can learn and explore the history of Ename through the interactive TimeLine travel setup. The reconstruction of each era is based on extensive historical research, study and excavation. The Ename 974 project is also made available through a website (source: http://www.ename974.org) where it provides international audiences and local publics regular events, new archaeological findings and new scientific and technological updates. This site also provides the virtual reconstruction of the old historical sites and a virtual walkthrough of the major part of the woodland (Bos t’Ename) [15]. The aim of this website is to raise public awareness of the importance of the old historical site, as well as to attract more visitors to the place.

Figure 2.4. The TimeLine display (Image courtesy of Visual Dimension)
3. Theory and related research

This chapter firstly gives a brief introduction to the research and the methodology chosen for this project. Then it presents the general concept of live-action role play and educational live-action role play. Following this, it describes the collaborative virtual environment and particularly the collaborative virtual environment for learning is introduced. Finally, user embodiment in a collaborative virtual environment and different design issues and techniques concerning user embodiments in a collaborative virtual environment are discussed in detail.

3.1 Introduction to research

Many games are used for educational purposes because they are suitable for transferring of concepts and ideas. Through games, students can learn a variety of essential skills such a critical thinking, problem-solving, teamwork, social skills and so on. There are literally more than thousand games available for students to play, but not all them are for educational purposes because educational games are often structured to reach certain pedagogical goals. Game-based learning is on the rise in many Western countries [16] because it provides a unique learning experience. Educational live-action role play (Edu-LARP) games in particular, emerged from the leisure activity of live-action role-playing is played as a game where students adopt their own character in a fictional setting. Edu-LARP is helpful while teaching a lesson and allowing students to explore and apply what the lesson has taught to them.

On the other hand, virtual reality with 3D interaction and real-time motion detection through the use of Microsoft Kinect
applications in classrooms is becoming very popular. In particular, virtual heritage applications provide students the opportunity to explore and understand ancient cultures in a way that books and online media are unable to provide. Educational role play is often missing or absent in such applications because most of them are designed to provide a single user mode of interaction. To facilitate educational role play in a virtual environment, one simple solution is to add multi-user and digital user embodiment. This will not only create a simulated environment but also helps educational role-play between two users feel real and immersive. This implies that the provided design will have an impact on how users facilitate educational role-play in a virtual environment. The creation of an appropriate immersive virtual environment, real-time motion detection through the use of Microsoft Kinect, digital user embodiment in a virtual environment could provide a new platform for educational role play as well as learning.

3.2 Methodology

The proposed study will first give a brief theoretical background of live-action role play, educational live-action role play, collaborative virtual environment (CVE) and CVE for learning. After that, we will identify and list different issues of user embodiment within a collaborative virtual environment such as presence, co-presence, identity, gesture and facial expression, location space and communication. Research on these issues of user embodiment in a CVE will inform the design decision of multi-user support in the Ename 1290 application through the use of Microsoft Kinect camera technology.

Following this, we will develop a prototype (see Chapter 6) that shows how these issues are reflected in the newly proposed system and how the system can be used as a teaching and learning tool that can be utilized by students and educators for educational role-playing lessons of the historical site Ename in the era 1290.
3.3 Live action role-play

Live action role-play more commonly known as LARP [17]. It is defined as a form of gameplay where participants (LARPers) physically act their characters within a fictional setting for an extended period. It is a storytelling system where players assume a role and serve as a character through action and interaction. LARP does not have a single source of origin. Instead, they are invented by different groups in Europe, America, and Australia. The styles, aims and ideals are different among these groups. For example, Nordic LARP aims more on immersion and most importantly there is no winning in their plays. LARP designers usually set the time, place and the environment. LARP is also a form of immersion where a participant’s character fits in the play and feels their presence in the game.

The “Carrousel” games are an early type of live role-play performed at the European Court [18]. However, the second birth of live role-playing occurred in Vienna in the 1920s when psychoanalyst Jacob Levy Moreno discovered the activity of improvised role-playing was therapeutic to his patients for treating their traumas; this has since developed into a method called “psychodrama”-[19, 18, 20]. Psychodrama offers a creative way of solving personal problems and issues raised by an individual or a group by providing a safe and supportive environment to alleviate the effects of emotional trauma. In a session of psychodrama, one client is selected as a protagonist and focuses on a particular problem. Different scenes or themes pretending a problematic situation are also created, and the protagonist explores new methods of resolving it, and other group members are also invited to support the protagonist in the scene by playing other important roles.

Besides the role-playing for therapeutic purposes, present-day LARP consists of two additional variants: Educational live action role-play and role-playing for recreation and entertainment [18]. Modern live action role-playing for leisure and entertainment originated from the existed reenactment groups in the United Kingdom and the United States for a long time. These groups focus on
the detailed study of the reenactment of historical events. For in-
stance historical reenactment groups like the Society for Creative
Anachronism. This group was founded in 1966 with the aim of
studying and recreating Medieval European cultures and their his-
tories. The society has grown worldwide and includes over 24,000
paying members as of 2014 [21] and with much more participat-
ing in events. Another origin of LARP was inspired by the de-
velopment of tabletop role-playing games in the late 1970s. The
current form of LARP was developed in the early 1980s mainly
influenced by improvised theaters. Today, LARP is a widespread
activity in the world especially in the UK and Scandinavian coun-
tries. It is a growing modern movement for people of all ages,
and every game consists of thousand participants, the game also
stretches the boundaries of the subjects explored.

The goal of educational live action role-play is similar to
that of therapeutic role-playing. The aim of educational live action
role-play is to help students understand a particular subject better
and helping them becoming more involved and develop their skills
for dealing problems and challenges. More details on educational
live action role-play will be explained in the next section.

3.3.1 Educational Live-Action Role Play (Edu-LARP)

Education in today’s world, should not only teach content but also
develop competence. Education must be upgraded to meet the
requirements of today’s world. Teachers need to have excellent
teaching, technological and competency skills to educate students.
They should use a variety of pedagogical methods and learn ma-
terials in a variety of situation where students are encouraged to
face real world problems and learn better. In recent years the in-
troduction of live-action role play as an educational tool has in-
creased dramatically and also received significant scholarly atten-
tion. Many schools, adult education programs, and afterschool
programs, have adopted this as a teaching method for both infor-
mal and formal learning.
Live action role-plays in an educational context (Edu-LARP) is a form of experiential learning in which students adopt their characters in a fictional scenario. Firstly, Edu-LARP is played as a game as it is fun and exciting. S.L. Bowman and Anne Standiford [22] suggested that intervention of Edu-LARP into the current science curriculum of a charter school in Los Angeles had a strong impact on students learning experience in Science by increasing interest, engagement, and perceived competence through gameplay and role enactment. Secondly, Edu-LARP provides an immersive experience where a new world is delivered to the participants. Many educators advocate the use of role-playing into the classroom as it leads to a higher degree of active engagement, cooperation, and participation [23]. In our traditional learning process, students are expected to receive and assimilate information from teachers [24, 25, 26], whereas game based learning provides a unique, shared, singular experience for each participant that is often lacked in the traditional learning structures.

Through Edu-LARP, students can acquire many skills such as cognitive, affective and behavioral [27]. One of the most important facets of Edu-LARP is that it promotes active engagement and social interaction. Young students in the current generation expect a high degree of interactivity as the result of constant exposure to the Internet and other digital media [26]. Edu-LARP excels at improving these skills because role-playing offers the benefit of “double consciousness” in which the player’s identity is relaxed while the role is enacted [27]. While in a role, students learn to examine and express perspectives of their characters and also offer peer to peer learning opportunities as a function of teamwork [27]. Additionally, Edu-LARP can help students with special needs to improve their self-efficacy and performance in the classroom. Hyltoft, a teacher at Østerskov Efterskole [27, 28] in Denmark explains these students need a more active, experiential and multi-modal approach. In their school, 15% of the students are with various disabilities such as dyslexia, attention-deficit hyperactivity disorder (ADHD) and have come from socially challenged homes. These students tend to learn better through educational role play.
While there are many ways to role-play but in the context of our study, role-play with a knowledgeable person is our primary focus. To have a good learning experience, role play against a partner who has a vast knowledge and expertise in the area of the skills to being taught is very crucial. The partner can be an educator or a facilitator, and the role of the partner is to guide and direct student toward their goals. Also, two students can role play with each other, and the educator can intervene when problem arise. As a role-playing partner, the educator can also improve social interaction skills of the students through real-time conversation. The “in-game” experience in an Edu-LARP is primarily obtained from a strong game design with pedagogical goals embedded into the characters and the game environment. In this study, we will not discuss different methods or strategies for such game designs as it is beyond our study. Our focus will be on how technology can play a role to create an enhanced or even ‘enchanted’ [87] reality experience and how to role-play in a virtual reality system supports social interaction and cooperation between a group of people. In recent years learning through virtual environment has become a new face of education. Today, virtual learning environments deliver the best aspect of a learning experience as it provides user embodiment, voice video capabilities and most importantly the ability to stimulate exotic settings such as a different time, a battlefield, a fantasy world or a futuristic world.

3.4 Collaborative Virtual Environments

In collaborative virtual environments or CVEs, information sharing is the central point. CVEs are simply virtual environments in which many users can collaborate and interact with a computational environment rendered by virtual reality technology [29]. Before we go deeper into the nature of CVEs, it is important to define what we mean by the collaborative virtual environment (CVE). CVE is defined as a “computer-based, distributed, virtual space or set of places. In such places, people can meet and interact with others, with agents or with virtual objects. CVEs might
vary in their representational richness from 3D graphical spaces, 2.5D and 2D environments, to text-based environments. Access to CVEs is by no means limited to desktop devices, but might well include mobile or wearable devices, public kiosks, etc.” [30]. CVEs are a subset of virtual environments as it offers a space for action and interaction. In CVEs each user is represented in the form of an embodiment or an avatar. They are free to navigate and communicate with other users using verbal and nonverbal communication. We will discuss more detail about user embodiment in a collaborative virtual environment in the subsequent sections.

The essential feature of CVEs is to provide an integrated, explicit and persistent context for cooperation that includes both the participants and the information that they access and manipulated into a single shared display space [30]. The design, development, and implementation of this kind of system is a complicated process, but it is also a growing area of research which involves lots of other disciplines such as sociology and psychology, etc. To support collaborative and cooperative activities, it is important that a virtual environment offers the means to access appropriate information as well as communication tools [30]. Following the above definitions, it has been argued that CVE has the potential to collaborate works, training, entertainment as well as learning when users are geographically dispersed [31]. CVEs allow people to come together virtually and engage social interaction in a virtual environment. Collaborative virtual environment technology has been used in application areas such as therapy, simulation, training, social entertainment, and marketing, etc. However, among the vast application areas of CVE our interest is in CVE for Learning.

3.4.1 CVE for learning

As education moves from traditional education to modern day education, there is an extensive use of computers, projectors, the internet and much more. Application of technology in education has been embraced by many schools and universities and has taken the
whole meaning of education to another level. In particular, virtual reality and interactive 3D solution for education have brought our current educational setting to another level.

An important area where CVE technology can aid the learning process is the presentation of environments that are difficult to access or places that do not exist anymore [32]. The Australian Great Barrier Reef is a natural wonder of our world. Refsland and his colleagues [33] created a virtual simulation of the Great Barrier Reef in a CAVE system, enabling many visitors to discover the reef through high-quality immersive entertainment without harming the actual environment. Another exciting project called Virtual Harlem [34, 35] a collaborative virtual reality (VR) tour of Harlem whose purpose is to allow students to experience the New York Harlem Renaissance and learn the historical context of its literature as a cultural field trip. The prototype was later translated into a fully immersive environment- Cave Automatic Virtual Environment (CAVE) [34, 36]. Carter and his colleague argued that the learning environment in such a CVE provides students the opportunity to be both creative and critical.

Machado, Prada and Paiva [37] brought another aspect of learning through their project Teatrix CVE. The Teatrix CVE was developed with the aim to bring drama activities into a virtual stage. Drama activities and storytelling play a significant role in children’s development. The aim of Teatrix is to provide young children to develop their notions of narrative through the dramatization of different situations. Children could pick a virtual character and then the story should evolve in reaction to their character’s actions. They also found that children were able to steer their characters successfully and engage in role-playing activity [37, 32] which has been an important element of the current research. The importance of the human-to-human type of interaction between students and tutor for the process of learning has been widely acknowledged as this kind of interaction allows problem-solving, motivation, awareness, assessment and mutual reflection as well as control progress [38, 25]. Moreover, in a collaborative learning environment success of one student also depends on another stu-
dent. Students are responsible for one’s learning as well as others. The weaker students can learn from the better ones such as his or her fellow student as well as from a tutor, in that way both parties can extend their knowledge and understanding of the subject. In CVEs students not only can work together to achieve their goal but also provide them a learning environment which is not possible to make in the real world.

3.5 User embodiment or representation in Collaborative Virtual Environment

User embodiment has become an important issue while designing a collaborative virtual environment [39]. It is concerned with embodying users with appropriate body images so as to make others and themselves aware of their presence in a virtual environment [39]. While in early CVEs, users are represented in a variety of abstract and attributes. However, more recent systems allow more humanoid-looking embodiments or avatars with varying degree of animation and behavioral abilities. Research community in early days has distinguished between avatars and embodied agents [40]. Avatars are usually controlled by a user whereas embodied agents are controlled by artificial engines and computer algorithms. A study conducted by a group of researchers found that avatars are more influential than embodied agents in social interactions [41]. Avatars used in current CVEs such as ActiveWorlds fall into two categories, cartoon and human avatars [42]. The present concern of our study is with human-like or humanoid avatars because they resemble real human body and are easily differentiated from other objects in a virtual environment [43]. Section (5.1) explains how we implemented humanoid avatars in our project. In CVEs, it is an avatar represents almost a user. However, the use of avatars in CVEs potentially entail several useful properties within a virtual environment as well as a set of design issues which should be considered by designers [42, 39].
3.5.1 **Design issues and techniques**

In this thesis paper, we will identify a set of design issues which should be considered while designing a multi-user based educational Enname game, along with a set of possible techniques to support them. These are briefly introduced in Sections 3.5.2 to 3.5.7 under the headings of presence, copresence, identity, gesture and facial expression, location and space, and communication.

3.5.2 **Presence**

Presence has been a topic of research for many years in virtual reality. The term “Presence” is defined as the “sense of being there” where “there” refers to the virtual environment [44]. The concept of being there is not only an important element in a virtual environment but also applies to a range of media and experiences generated by computers. It also forms the core foundation of which immersion is build. There are several types research discussed the way of measuring “Presence” [47] but measuring presence is not a trivial task because the nature of presence depends on many factors including the tasks, sensory, copresence and the kind of technology used. Research on presence has grown drastically, and many researchers agree the sense of being there can impact positively on users’ ability to perform in a virtual environment [63].

Clearly, a user’s avatar may convey a sense of presence in the virtual environment. It also provides a way others to understand better and the intended persona of the underlying user, so that other users can tell “at a glance” who is present [39]. One study conducted by a group of researchers at University College London found self-avatar had a positive and potentially important impact on self-report of presence and embodiment [44]. The study was conducted in an uncontrolled setting ‘in the wild’ where users of Samsung Gear VR and Google Cardboard device were invited to download and run the app. The app presents scenarios where they would sit in a bar watching a singer. Different
scenarios were given to each participant with or without a self-avatar. T.L.Taylor [45] also stated that representation of an individual through an avatar in a virtual world also enhances the feeling of immersion.

3.5.3 **Copresence**

In a multi-user virtual environment, a person’s feeling of presence is represented by an avatar and it is by this property that they allow copresence experience. Copresence is the sense of “being there together” with another person in a computer-generated environment, sometimes also referred to as social presence [46, 42]. The definition of copresence varies in different kinds of literature [47, 48, 49]. But according to the current study, it can be categorized into two camps. In the first camp, copresence is defined as a person’s perception or feeling that others are presented within an interpersonal environment [50] whereas the second camp views copresence as a social, task-related or physiological response to embodied agents [51]. To sense copresence in a virtual environment social interaction, mutual awareness, and collaboration is very crucial to establish a strong relationship in the virtual environment. This can be seeing of other avatar’s behaviors, hearing other persons and noticing other user’s action on the environment or objects in the environment.

3.5.4 **Identity**

A user’s body image might convey identity at different levels of recognition. Firstly, a user’s identity is potentially much more flexible in a virtual world than a real life identity, allowing users to create their identity to whatever they desired [52]. Secondly, it might be possible to distinguish and recognize other users with their embodiments. Thirdly, in a shared virtual environment you might recognize and find other users with their body images. In
a virtual world avatars are not necessary have to be a true representation of a user. In fact, Yee [53] conducted a study where more than 30,000 multi-user game players choose a different identity and changing their identities in their virtual life. In another study, Nowak [54] found that when an anthropomorphic embodiment represents an interaction partner, it was rated more socially attractive than an embodiment that did not appear like a human. Allowing users to personalize their avatar is an important area in virtual environments as it lets them create recognizable body images. However, Cheng, Farnham, and Stone [45] found users may want avatars that are neither too abstract nor too realistic. Hence it is too early to say how much customization is required from a user for their avatars.

3.5.5 Gesture and facial expression

Gesture and facial expression are an important part of human interaction. Gestures mainly expressed by hands have become a popular means of interaction with virtual environments. Human gestures include movement of the fingers, hands, legs and other parts of the body with the aim to express purposeful information or communication with the environment [55]. To support different kinds of gestures in a virtual environment, we have to consider what kind of bones and joints should be mapped onto an avatar. To replicate human gestures onto a 3D virtual avatar as closely as possible to the original human motoring activity, hand trajectories, joint position, bone orientation and arm link orientations must be maintained. This process is often called “puppeting” or “avateering” [56] and can be achieved through the use Microsoft Kinect camera technology and other tracking systems.

Facial expression also plays a significant role in human interaction. Human face plays a complex role in human visual communication and has been considered as a primary site for communication with emotional states. Due to the complexity of our facial expression, capturing and representation of different emotional ex-
pressions are more complicated through technology [39]. There are six universal facial expressions, corresponding to the following emotions: surprise, anger, fear, happiness, disgust/contempt, and sadness [57] which are called involuntary expression. To support involuntary expression in a virtual environment is technically very hard because these emotions are difficult to understand and measure.

3.5.6 Location and Space

Location and space of an embodiment in a virtual environment is an important area to consider especially in a shared virtual environment. These may involve conveying both position and orientation within a given spatial frame of reference, i.e., the coordinate system [39]. In a multi-user virtual environment, conveying orientation plays a significant role in the everyday interaction. It is also crucial to understand how people position themselves with others in a virtual environment. To understand the interaction and communication in a virtual environment, we can draw upon the research that has investigated how people behave within a physical space. Physical space is an area with invisible boundaries surrounding an individual which functions as a comfort zone during an interpersonal communication [58, 59, 60], and the study of people’s personal space is called “proxemic” [60, 61]. Fellipe and Sommer [62] suggested that such a comfort zone may disappear when another person violates an individual’s space or when crowds or groups violate the space. Within a physical space adding a person may affect the current individual’s perception of that physical space. Similarly in a virtual environment when the density of avatar increases and concentrates in the proximity of one’s avatar, it will lead to interaction and navigation problems. In a physical world when people were placed in a very close vicinity they might express discomfort and nervousness. Hence, when designing interaction between humans and humanoid avatar representations through the use of Microsoft’s Kinect such issues should be addressed. It is also interesting to note that due to tech-
nological difficulties, representation of many avatars are very challenging as it creates memory problems and requires lots of bandwidth for storage [63]. Several studies [64] showed that when the number of participant increases, they follow the conventions of the real world such as keeping their distance from each other, turning their face when talking with other people and so on. Philip and Mark [60] also suggested that it is important to keep a distinct physical distance between avatars and real world conventions while constructing spaces in virtual environments.

3.5.7 Communication

Today’s digital world provides various technological options such as telephone, instant messaging, SMS and Skype for communication and interaction over distances. These tools are indispensable for people who can not come physically to learning, collaboration, and work. In most of the shared virtual environment, communication is typically based on the use of either audio or text communication [64]. For example in Second Life [65] an online virtual world that allows users to interact and communicate with each other through instant messaging (IM) and chat (see Figure 3.1).

![Figure 3.1. Screenshot of communication in Second Life using instant messaging (IM) chat](image-url)
However, communication via such tools is limited to the exchange of verbal messages with the emotional well-being often lost. Another significant disadvantage of communication via IM is the likelihood of miscommunication because screens separate people. Ralph Schroeder [64] argued that virtual environments will never provide a full realistic way of communication with others as it lacks the ability to express emotions in the way we used in face-to-face conversation. In many role-playing online games, communication with a non-playing character (NPC) is carried out by an interactive game dialogue or text-based system by selecting the options available from a menu. Game dialogue is used to guide a player throughout the game without tackling the challenges of natural language processing. However, in a multi-user environment, there is a possibility of overlapping of text when communication is overloaded on the screen as game dialogue system is a non-interactive script.
4. Ename 1290

This chapter is divided into two main sections; the first section introduces the virtual representation of the historical site Ename in the era 1290. Then it introduces how a user can interact with it. The second section presents the Microsoft Kinect device and its working principles. Following this, it presents the current state-of-the-art research using the Kinect and its application areas. At last, new features of the Kinect software development kit (SDK) 2.0 and the Kinect device version 2 are presented in detail.

4.1 Ename 1290 virtual representation

Virtual reconstruction of the Ename village and the abbey in the period 1290 was started by a company called “Visual Dimension” [1]. Presently the real-time visualization of the Ename 1290 is used as a virtual walk-through for the Ename visitors and also used as an educational game. Ename 1290 is of particular importance because many important objects were discovered after years of study and excavation. The abbey and the village of Ename were perfectly virtually reconstructed (see Figure 4.1a). Early days, people in the community lives very close to each other as everybody wants to keep an eye on their livestock. Animals such as pigs, cattle, and sheep are virtually constructed in the Ename 1290 to simulate a better sense immersion and presence (see Figure 4.1b). The woodland in the Ename village was the primary source of energy and building materials during that period. The abbey also owns a harbor to ship timbers, fire woods and charcoals to its customers (see Figure 4.2a). Inside the abbey, there is a library, a garden, a scriptorium and a chapter room (see Figure 4.2b). Many precious objects and ancient books through digital restoration are also virtually presented in the abbey.
4.2 **Interactivity in Ename 1290**

Immersion within a virtual environment is truly strong when interactions are easy and exciting because it promotes a sense of place and experience. Users can interact with the Ename 1290 virtual environment through the use of Microsoft Kinect. Through the Kinect, users can navigate inside the Ename village and interact with the virtually reconstructed objects through a virtual character using their hand gestures.
4.3 Exploration in Ename 1290

In a virtual environment exploration is defined as an amount of exploration an environment allows. Ename 1290 has a large area to explore, but in the current application, a predefined navigation path was constructed for navigation. The path was created in Blender and then imported in the Ename 1290 virtual environment. The player characters in the virtual environment will follow the path until he or she finishes the game. The white line in Figure 4.2a shows the predefined navigation path.

4.4 Microsoft Kinect for Windows

Kinect is a motion sensing input device developed by Microsoft for Xbox 360 video game console and Windows PCs. Kinect can be regarded as one of the most advanced devices which enable users to interact with their console or computer through their body movement and spoken language. In 2009 the first Kinect was announced under the codename “Project Natal”, and on June 13, 2010, Microsoft officially announced that the system would be called Kinect [66]. In the same year, the device was launched in the market and became one of the fastest-selling consumers electronic devices certified by Guinness. The impact of Kinect has extended far beyond the gaming industry, and it is also used in the field of robotic, medical science and education. On February 1, 2012, Microsoft published the Kinect Software Development Kit (SDK) for Windows. (source:www.microsoft.com/en-us/kinectforwindows), which unquestionably amplified the software development based on Kinect.

The Kinect device has two versions: the Kinect for Xbox 360 and the Kinect for Windows. The difference between these two is the Kinect for Windows is licensed for commercial purpose, and the Kinect for Xbox is not licensed for commercial use and works only for Xbox360. The Kinect sensor features an RGB camera, a depth sensor, a multi-array microphone and a base
motor to adjust camera angle (in Kinect V1). In addition to the above features, the Kinect for Windows has extra features like facial recognition and voice recognition capabilities. The sensor has an angular field of view of $57^\circ$ horizontally and $43^\circ$ vertically, while the rotation angle provided by the motorized pivot is up to $27^\circ$. The Kinect sensor can track people standing in the ranging limit of 3.9 to 11.5 feet. The latest Kinect sensor can recognize as many as six people in the field view, but only two active users can be tracked in detail (see Figure 4.4). Currently, the Kinect sensor by default can track users who are standing and fully visible to the sensor as well as users in a seated position when the lower body is not visible to the sensor. Figure 4.3(b) shows the arrangement of the RGB camera, the IR projector, the IR camera and the audio subsystem. The RGB camera captures color images with a resolution of 640*480 pixels. The depth sensor is used to discern what is in depth field of view. It consists of an IR projector and an IR camera which is a monochrome complementary metal-oxide-semiconductor (CMOS) sensor. The depth sensor is the most crucial part of the Kinect. The IR projector is an IR laser which emits infrared light beams into the field of view. The IR camera reads the beams reflected back to the sensor which in turn
measures the depth information. The IR camera can capture depth images with a resolution of 320*240 pixels at the frame rate of 30 frames per second. The audio subsystem contains four microphones, an automatic ambient noise filter and an audio processor for capturing sound.

![Image](Image courtesy of Microsoft)

Figure 4.4. Microsoft Kinect can recognize six people but only track two actively

4.4.1 **Kinect working principles**

As shown in the above figures we saw different components of the Kinect device. However, the IR projector and the IR camera are the most crucial part of the Kinect to make capturing of the depth image possible. The depth sensing technology was developed by an Israeli company called PrimeSense. The technology that they used for depth acquisition is called “Light Coding” technology [67, 68]. The light coding technology is based on the principle of laser speckle [67]. Since the IR projector is an IR laser, a spatial scattering phenomenon and random light speckles are generated when the surface is irradiated with a laser. Laser speckles are unique, and different object produces different laser patterns at a different distance. Therefore, we mark spatial codes on each object, and a CMOS image sensor is used to read the corresponding codes. Figure 4.5 shows the laser speckles seen by the IR camera. If the system can match the speckle pattern observed in an
object with a recorded code, we can determine the position of the object in the space. 3D reconstruction of an object in the space is done by using triangulation [69]. Because the light speckles are produced relatively random, the matching of speckle patterns and recorded code from the system can be done in a straightforward way by comparing small neighborhood using normalized cross correlation [69].

![Figure 4.5. Laser speckles seen by IR camera](image)

### 4.4.2 Microsoft Kinect application and research

With recent advancement of the Microsoft Kinect sensors, it has not only revolutionized the gaming experience but also created many opportunities in other fields. With Kinect, people can interact with a gaming console or a computer freely with their natural gestures and speech. With low cost and less development complexity of the Kinect device, many researchers are gradually leveraging the sensing technology to create new ways of interaction with computers.

- **Kinect applications in healthcare:** In hospitals, surgeons need to use computers to watch a patient’s vitals and other medical information like X-ray and scans, etc. Because of the sterile gloves, he or she cannot touch a non-sterile surface of
a mouse or a keyboard. With the help of Kinect sensor, surgeons can literally wave their hands to observe the real-time information of the patient during the operation (see Figure 4.6). Kinect sensors are also used for rehabilitation of stroke patients where they can play monitor game-based rehabilitation exercises. Researchers also demonstrate the potential of using Kinect to help visually impaired people to navigate.

![Figure 4.6. Application of Kinect in surgery](image)

- **Kinect application in Education**: So far the use of Kinect in education is still at a development stage, but many researchers and practitioners see a great potential of Kinect to facilitate teaching and learning. Because of affordance and interactivity of the Kinect, it is used as a tool for education and learning. Regarding education, teachers can now interact the contents of their presentation via their body gestures and voice command which makes learning more interactive and engaging. Also with the help of Kinect’s depth camera teachers can teach various activities such as dance and martial arts [70]. Due to the fact that Kinect can obtain much information from a user such as gestures, voice and face recognition, we can allow students to feed their creativities in the program. For example, students can now learn mathematics and anatomy with the help of Kinect [84, 85] (see Figure 4.7).

- **3D model reconstruction**: Using the Kinect depth camera we can quickly capture a full body scan and then convert these
scans into a 3D model. For example, a group of researchers used Kinect’s depth camera to create a real-time 3D model of an indoor scene [71].

- **Kinect application in Games:** Introduction of Kinect for Xbox 360 not only changed gaming experience but also brought games to another level. It was perhaps one the most selling product in the world. Now you can play Kinect games with your body movements. For example, “Kinect Adventures” gives a good family gaming experience with a variety of mini-games and require the use of full body movements. “Just Dance” is another fun dance game using Kinect and “Fruit Ninja Kinect 2” where you can cut fruits with your hand gestures (see Figure 4.8).

4.4.3 **Microsoft Kinect for Windows Software Development Kit (SDK)**

We have discussed different applications of the Kinect in the above sections; Microsoft called this as the “Kinect Effect”. To expand the Kinect effect and the potential to transform human-computer interaction (HCI) in other areas, Microsoft released Kinect Software Development Kit for Windows (SDK). Kinect for Windows SDK v1.0 was published on February, 2012 and subsequently with a series of new releases. Now, with the latest “Kinect for Win-
Figure 4.8. Application of Kinect in games

dows SDK 2.0”, we can track 25 skeletal joints of the whole body. Kinect for Windows SDK is easy to install, and it is best compatible with Windows 8 operating system & above. Developers can now write Kinect-based apps in C#, C++, or VB.NET. New features included in Kinect for Windows SDK 2.0 are:

- Advanced facial tracking where resolution is increased 20 times.
- Support Unity Pro, and now you can install SDK 2.0 plugins for Kinect-based Unity applications.
- It also supports multiple applications to access the same sensor.
- Improvement in the tooling for Visual Gesture Builder (VGB) and Kinect Studio. Developers can now build their own custom gestures, and also they can record and playback the gestures.
- The performance of the Kinect Fusion is also improved which can now provide better camera tracking and resolution. Kinect Fusion is used for 3D object scanning.

The Kinect for Windows SDK 2.0 is an important part of our project. Firstly, the Kinect API is now available in Unity Pro through Unity Pro Package [86]. Secondly, the Kinect’s skeletal tracking feature makes the sensor to track six people including two active players in full skeleton. Finally, the newly added features
in SDK 2.0 will give us more accurate avateering with Kinect. Microsoft Kinect V2 was released in July 2014 which was build with more sensitive sensors than the Kinect V1 (see Figure 4.9). The major improvement was the resolution of the camera. The resolution of the color camera is upgraded from 640*480p at 30 frames per second to 1920*1080p at 30 frames per second. The resolution of depth camera is also improved from 320*240p to 512*424p. The horizontal field view and vertical field of view are increased from 57° to 70° and from 43° to 60° respectively. The number of defined skeleton joints in SDK is also increased from 20 joints to 25 joints. The comparison between Microsoft Kinect V1 and V2 can be seen in Figure 4.10.

<table>
<thead>
<tr>
<th>Features</th>
<th>Kinect for Windows V1</th>
<th>Kinect for Windows V2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Color Camera</td>
<td>640*480 pixels @ 30fps</td>
<td>1920*1080 pixels @ 30fps</td>
</tr>
<tr>
<td>Depth Camera</td>
<td>320*240 pixels</td>
<td>512*424 pixels</td>
</tr>
<tr>
<td>Skeleton Joints defined</td>
<td>20 joints</td>
<td>25 joints</td>
</tr>
<tr>
<td>Horizontal Field of View</td>
<td>57 degree</td>
<td>70 degree</td>
</tr>
<tr>
<td>Vertical Field of View</td>
<td>43 degree</td>
<td>60 degree</td>
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<td>Full Skeletons Tracked</td>
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<td>6</td>
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<td>Tilt Motor</td>
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<td>No</td>
</tr>
</tbody>
</table>

Figure 4.9. Microsoft Kinect for Windows v2

Figure 4.10. Microsoft Kinect V1 vs Kinect V2
5. Implementation

This chapter first describes detailed steps of creating a personalized humanoid avatar using Adobe fuse and Mixamo. After that, it briefly explains the steps to adding multi-user support in the existing Ename 1290 application. Finally, setting of 3D models on the predefined path and Unity button creation in the Ename 1290 application are described in detail.

5.1 Creation of 3D model avatar

An avatar is the graphical representation of a player’s character in the virtual environment. In virtual heritage applications, avatars are typically represented as 3D models of humans because human avatars or humanoid avatars resemble real human bodies and are easily differentiated from other objects in the virtual environment [43]. As Chen and his colleagues [72] suggested that immersion in a virtual heritage could be enhanced with the use of personalized avatars. In this section, we will discuss our method of creating a personalized humanoid avatar using simple tools like the Adobe Fuse CC and online platform Mixamo for auto rigging and animation.

5.1.1 Personalized Avatar

Adobe Fuse allows you to build unique 3D characters with no cost. You can customize the body shape, hair color, and clothing of each character in minutes. We will explain the overall workflow of the Adobe Fuse and Mixamo in detail.

Step 1: Selecting your model’s body form
After creating a new Fuse project, click “Assemble” at the top of
the screen in order to enter in the Assemble room. On the right-hand side of the window, you will find a collection of the body parts such as head, torso, leg and arm to build your figure part by part nicely (see Figure 5.1).

![Figure 5.1. A) Shows assembling of body parts B) Shows adding of clothing in Adobe Fuse CC](image)

**Step 2: Customize your model**
Once you are satisfied with the body form of your model, you can now switch to the Customize workspace for more fine-tuned control. In the Customize area, there are many features available to you where you can modify the body form to fit whatever images you have in your mind.

**Step 3: Clothing**
In the Clothing workspace, Fuse will allow you to access a library of tops, bottoms, shoes and more to dress your model.

**Step 4: Adding Texture**
If you want to customize individual parts of your model, then you can switch to the texture workspace to change the appearance of your model.
Step 5: Export your finished model
When you are happy with the model, you can export either by saving it to CC libraries like Photoshop or save it to Mixamo. We will upload our model to Mixamo server as an .obj file.

Step 6: Rigging in Mixamo
Once we have our model in Mixamo, it will go into a process called generating the assets. This process will create a custom skeleton or rig the bones together of your model to make it moves like a real person (see Figure 5.2). After the model is rigged then we have to select two final options; first to enable to Facial Blend-shape and secondly, choose the level of the full detail of our skeleton. When the model is finished for rigging, you can download the model as a “.fbx for Unity” file.

Figure 5.2. Screenshot of rigging in Mixamo

5.2 Adding multi-user support

5.2.1 Collection of user data (Bone and Skeleton) from the Microsoft Kinect

KinectManager: The KinectManager script is the main Kinect-related component. It is used to communicate between the Microsoft Kinect camera and the Unity application. KinectManager collects the necessary data from the Kinect camera like color,
depth streams, bodies and joints position in meters in Kinect’s space.

5.2.2 **Mapping of Kinect data to a 3D model**

*AvatarController:* The AvatarController script is used to track user’s motion and transfers the detected joint positions and orientations to a humanoid avatar. To add multiple users to the existing Unity project, user’s index is added; the player’s index starts from 0.

5.2.3 **Importing Fbx 3D models to Ename 1290 using Unity**

Unity supports Fbx (Filmbox) file format which is generated by Adobe Fuse and Mixamo. The following steps describe how a Fbx file is imported to Unity. The steps are:

- Select the Fbx 3D model and the model should be in T-Pose.
- Import the 3D model into the Unity project. Select import-New asset in the Assets-folder.
- After the model is imported into the Asset folder. Select the model and then click the Rig-tab in the inspector window; set the Animation Type to ‘Humanoid’ and Avatar Definition to ‘Create From This Model’. The avatar will be created to best match the bone hierarchy (see Figure 5.3).
- Drag the model into the scene hierarchy window.
- Once the model is in the scene window, you can now transform the position, rotation, and scale of the model by adjusting each value of the transform component in the inspector window.
- Animation can be added to a 3D model by using the animator component. Right click on the asset folder in the project hierarchy and then create a new animator controller. From the inspector window, different parameters can be set for motion.
Figure 5.3. Screenshot for importing a Fbx 3D model and its rig options and speed. The state of each animation can also be changed from the animator workspace (see Figure 5.4).

Figure 5.4. Screenshot of the base layer for animation in Unity
5.2.4 Adding Kinect Scripts in the Project

In Unity, the behavior of each game object is controlled by the components that are attached to it. Unity permits you to create your own components to trigger different events using scripts. The following points describe different scripts set up in the project:

- Create an empty game object called ‘KinectController’ in the scene view and then add the KinectManager script as a component to it.
- Add AvatarController script to each model as a new component and then set player’s index value to each model, player’s index value ‘0’ indicate for user 1 and so on (see Figure 5.5).

Figure 5.5. Screenshot of adding AvatarController script in Ename 1290

5.3 Setting of 3D models on the predefined path of the Ename 1290

In this project, the player’s object is the parent object and objects grouped underneath are called “child objects” or “children”. Add
the 3D models as a child object of the main camera (the main camera is a child object of the player object).

5.4 **Unity UI button creation**

The canvas component in Unity represents an area or space which is used to render all UI elements. All UI elements must be children of a canvas [73]. It is possible to create more than one UI element. In order to create a pre-made button select create from the hierarchy window, choose UI and select button. Like all UI elements the button must be a child of the canvas. A text element is attached as a child to the button which is used give additional text information in a button. In the inspector window, the button has its own components for color, text, size and image. Create an empty gameobject named it “Action” and attach the script ‘Enable and Disable’ as a component of the “Action” game object. This script is used to enable and disable of the 3D models. In the Ename 1290 game, one of the 3D models will act as an educator, and the other one will be a player. Select the button in the Inspector window and add Actionscript to the OnClick function and name the two buttons as “Help” and “Thanks” (see Figure 5.6). If you want the educator to stand in the scene click on the help button and if you click on the thanks button the educator will disappear.
Figure 5.6. Screenshot of buttons in Ename 1290
6. Embodiment in Ename 1290

As discussed in Chapter 3, there are several issues to be addressed while designing user embodiments in a collaborative virtual environment. In section 3.3.1 we discussed Edu-LARP improves many social skills and had a significant impact on students learning experience. This intuitively suggests that it might be beneficial to extend the concept of educational live action role-play with virtual reality mainly virtual heritage, user embodiment, and Microsoft’s Kinect camera technology. Given that, the new design can potentially connect students to the virtual heritage as well as improving their social skills and feeling of immersion through their avatars. This chapter, therefore, describes a prototype developed in such an environment and discuss how the design issues and techniques of user embodiment in a multi-user based CVE have been addressed and how we relate other disciplines in our proposed prototype.

6.1 Prototype development

Ename 1290 is a virtually reconstructed heritage site application. Currently, it is used as a virtual tour as well as an educational game. The game is controlled by a first person point of view. The newly proposed system supports multiple users technically two and users can interact with each other in real-time.

A variety of embodiments can be implemented in the Ename 1290 virtual environment. However, in the proposed system (see Figure 6.1) users are represented as humanoid avatars because they are socially attractive [54] and sufficient to convey presence, copresence, identity, location and orientation of a user. In Ename 1290, body gestures can be detected through the use of Microsoft
Kinect camera. To provide a natural and an immersive experience, Kinect gives users the ability to interact with the Ename 1290 system by tracking different users’ gestures. In such a way, users can interact with the system without the need to touch a controller. Different users can participate in the virtual environment through their humanoid avatars. When a user is represented as a humanoid avatar, two things will occur first the mental model of the user’s body when a physical body is mapped onto a virtual body, second, the virtual body may have different social role than the user’s body. In our proposed system, we used Microsoft Kinect and Unity game engine to configure our avatars; this process is often called as avateering [56]. This process requires few steps to build your humanoid avatar. First, you have to create your humanoid mesh in a 3D modeling software-Blender, Fuse, and Maya. After that, the 3D model should be rigged. Rigging is a process of creating a skeleton of joints to control the movements.
Lastly, the Kinect will acquire body data such as bone and joint orientations, and the rigged humanoid avatar mesh is parented to the bones and joints. This process will give more stable avateering, more accurate body position evaluation and more sense of presence in the virtual environment.

Gestures in the proposed system are supported by the tracked body of a user. It is also possible to track a user’s facial expression by the Microsoft Kinect, but at this moment it is not developed in the proposed system. However, in the proposed system a user can notice other people in real-time as both of them have to be positioned in the Kinect’s field of view which is determined by the setting of IR camera. As we discussed in section (4.4.3), the Kinect can track 25 joints, but there are some issues with the Kinect camera when tracking movements like the somersault, super fast movements, and a 360 degree turn.

Since a virtual body may represent a different social role than a user’s actual body, the meaning of an avatar is often situationally or environmentally dependent. Anyone entering in a virtual world is by default playing a role imposed on them by the virtual environment. For example, in the Ename 1290, a user can be represented by as a monk or a farmer avatar because it provides a different social meaning. Another important point in the proposed system is the use of real-world physical space. The position of an avatar in the virtual environment depends on the user’s actual position in the physical space or where the user is standing or sitting in the Kinect’s field of view (see Figure 6.2).

In a multi-user environment, users have to keep their physical space and to be recognized by the Kinect; a user simply needs to be in the Kinect camera’s field of view and making sure the camera can see their head and upper body. As we discussed in section 3.4, CVE is a virtual space where people can meet and interact. CVE is particularly suited for collaborative work with people physically in the same place or in a different location. The current Ename 1290 offers such a place for collaboration. Collaborative interaction occurs when two users interact with the same screen space and inputs. There are two models where users can
interact with the system; the single-driver model assigns one of the user as the driver to interact with the system and the second model allows both users to interact with the system. However, the later is a more complex model for navigation and interaction. In the proposed system, educational role play is mainly played between a student and an educator who have a vast knowledge and expertise in the area of the skills to be taught. Students and educators can communicate in real-time having real dialogues, and that is transposed into the virtual world through the use of Microsoft Kinect as a motion capture device. In such a way the conversation or dialogue becomes a powerful tool for education as well as for collaboration. Additionally, it will also create a sense of presence in the virtual world since the characters are not artificially created but are real people with real movement and voice.
Figure 6.2. Proposed system with Kinect vertical field of view in default range (in meters)
The newly proposed system that we discussed in Chapter 6 represents an early prototype that we developed with the Ename 1290 virtual heritage. The new system involves many other disciplines, and to this point, we have not conducted a formal user evaluation of the system to show how users can explore and interact with the Ename 1290 game and how educational role play and collaboration improves the learning experience and social skills. However, in this thesis, we proposed an evaluation framework with the aim to evaluate both technical and pedagogical nature of the proposed system.

In the past few years, interest in collaborative virtual environments (CVEs) to facilitate learning and collaboration has been increased drastically [75]. CVEs have been used in multiple application fields such as training, entertainment, and education, etc. [76, 77]. CVEs in particular for learning has gained a lot of interest because it supports several important learning objectives such as collaborative learning, simulation-based learning, and community-based learning [78]. As a result of the increasing use of CVEs in different areas, providing a thorough evaluation is very crucial. However, the design of CVEs includes many factors like immersion, presence, copresence, social interaction, communication, coordination, pedagogical practices and task involvements make the evaluation process a difficult task. There are several evaluation approaches for CVEs, but many of them either focus on technical aspects or human aspects of a CVE [79, 80]. A particular category of CVE aims for education especially for learning requires a new type of evaluation framework because of pedagogical values added in the environment. In this thesis, we proposed an evaluation framework that is designed to evaluate the technical, human and pedagogical aspects of the system.
7.1 Proposed evaluation framework

It is important to determine the goal of evaluation when proposing an evaluation framework. The goal of evaluation is to collect data and feedbacks about the issues of a system by a specific group of users for a particular activity within a specified environment [81]. A number of studies and researchers have been working on various evaluation goals including usability, effectiveness, interaction, sense of copresence and confidence [82]. However, considering evaluating all these criteria in one session is almost impossible. Moreover, there is no mutually accepted array of evaluation framework which is applicable to all educational softwares [82]. Taking into account of the multidimensionality nature of the CVEs, we proposed an evaluation framework which allows multiple criteria to be evaluated. The proposed framework is used specifically for the general evaluation of the current developed prototype but can also be used for other educational CVEs. The proposed evaluation framework is structured into four stages. A flowchart describing the proposed framework can be seen in Figure 7.1.

First stage: It is important to select right target group of evaluators to cooperate during the evaluation process. Therefore, in the first stage of our proposed evaluation framework, candidates should participate in a pre-test questionnaire. The participants are divided into two groups namely students and educators. Each group will get a different set of pre-test questionnaire. For students, the pre-test will inquire learner’s prior knowledge of the Ename, experience with interactive 3D collaborative virtual environments, experience with educational role play and certain demographics information such as their age and education. For educators, the pre-test comprised of open-ended questions in order to gain insight into their regular teaching practices and difficulties they faced.

Second stage: Going a step further in the evaluation, the second stage allows users to familiarize themselves with the software application that hosts the CVE and experiment with the user interface and the available tools for interaction and navigation. At this stage, it is important to observe and understand the behavior of
users in order to determine issues like usability, interactivity and functionality. As discussed in the proposed system users are represented by avatars; therefore it is important to evaluate user’s interaction through the use of Kinect, the spatial orientation of a user in the physical space, virtual objects manipulation and virtual metaphors [82]. Data collection tools such as interview, survey, think aloud protocol and video recording can be used in this stage.

**Third stage:** After the familiarization session, we evaluate different human issues involved in a CVE. In this session, we will evaluate three parts of human issues which include engagement,
psychology, and cooperation. In the first part, involvement or engagement is evaluated. Observations and video recording of participants were conducted in order to study the extent to which engagement and interaction were demonstrated. The second part would evaluate the psychology of a user. User embodiment especially humanoid avatar plays a significant role in the design of virtual environments, especially in CVEs [83]. The embodiment in a CVE is to give a sense of presence and copresence. For the evaluation studies, evaluation criteria such as survey and questionnaires are used to measure presence and copresence. The final part is to evaluate user’s cooperation with others. In a collaborative virtual environment, it is important to communicate and understand others in order to learn and achieve certain tasks. In this part, evaluation questionnaires were completed by educators and learners immediately after the experiment to ascertain the effectiveness of information exchange and communication awareness.

**Fourth stage:** The final stage of this evaluation framework is to evaluate the learning outcomes in a collaborative virtual environment. Learners and educators comprise the evaluation group for this stage. At this stage of evaluation, it is important to examine relevant criteria such as performance, satisfaction, knowledge gained and improvement of the subject’s internal concepts through this learning experience. Evaluation criteria such as psychometric surveys, questionnaires with open/closed questions, semi-structured interviews, and audiovisual recordings can be used for data collection.

As described in the above sections, the proposed evaluation framework consists of four different stages. In the first stage, participants are separated into two groups namely students and educators. The goal of evaluation is set at this stage, and a set of pre-test questionnaire are presented to the group in order to study their previous experiences with CVEs, educational role play, teaching experiences, etc. The next stage allows the participants to familiarize themselves with the available tools in the CVE and overall user interface. This stage is used to evaluate the participants’ interaction with the interface and usability problems of the
user interface. In the third stage of evaluation, human issues of the participants such as engagement, psychology and cooperation are evaluated. To support participants in a collaborative activity, these issues along with the usability of the application tools are thoroughly evaluated at this stage. To have a successful CVE assessing the collaborative outcomes are very crucial [82]. The final stage of this evaluation framework is used to evaluate learning outcomes of a CVE. For an educational CVE, it is important to evaluate what kind of knowledge was gained by students through learning in the CVE, how the CVE enhance the learning experience and how it can be improved. To evaluate the proposed evaluation framework, suitable data collection methods are required to measure and analyze each stage thoroughly.
8. Conclusion and development limitation

This chapter summarizes the work presented in this thesis and discusses limitations faced during the development stage of the project.

8.1 Conclusion

In recent years, modern education has taken advantage of virtual reality (VR) for teaching and learning. In particular, virtual heritage (VH) application utilize VR tools to recreate historical sites and cultural artifacts of the past. Many VH applications are for educational use where students can enter and understand ancient cultures that are different from their own. These applications which make the use of tracking technologies like Microsoft Kinect allows a user to explore and interact with reconstructed ancient cultures in a better and immersive manner. Ename 1290 is a virtual heritage site and utilized as an educational game. It was described at the beginning of this thesis that the current Ename 1290 application lacks multi-user support. With the absence of multi-user support, the application offers less scope for learning and teaching of the Ename historical site. In this thesis, we described a prototype in which we developed a multi-user approach of the current Ename application using Unity game engine and Microsoft’s Kinect. As discussed in Chapter 4, Microsoft’s Kinect camera technology can recognize six people including two active players. With this feature, real-time gesture detection of a user can be done with a represented humanoid avatar in the virtual environment. We have developed humanoid avatars using Adobe fuse and Mixamo which are readily available to download and easy to build. In order to inform the design of multi-user through humanoid avatars, theories of user embodiments within a collaborative virtual environment was explored and different design issues
of user representation in a collaborative virtual environment were discussed in detail. Those theories and issues could be helpful in the understanding and design of user embodiments in a multi-user based virtual environment. We outlined six design issues of user embodiment in a multi-user based CVEs using Microsoft Kinect as a motion capturing device. These issues were addressed in the developed prototype.

The older version of the Ename 1290 application is used to teach students the ancient monuments, buildings, and cultures of Ename. It was designed with a single user mode of interaction and offers a limited opportunity for social interaction and learning. After the exposure to the Kinect, virtual reality, and user embodiment we began to think that the existing Ename 1290 application can be used as a tool for collaborative learning because Ename in the era 1290 is entirely virtually reconstructed and provides a space for collaboration. With these reasons, it would add a valuable contribution to make students learn the history of Ename in a more exciting way. This leads us to explore combining educational live action role-play with the Ename 1290 application. This combination seems to have the potential to improve engagement, communication, interest and at the same time it can acquire many social skills within it. To combine educational live-action role play, Ename 1290 application, user embodiment and Microsoft Kinect, we explored the general concepts of live-action role play, educational live-action role play and collaborative virtual environment for learning in detail. We also came to a conclusion that when combining or relating multiple disciplines one have to learn the theories and investigate the benefits and challenges of each discipline. From our research and experience, we can conclude that using these techniques together can help us to facilitate an educational role play lesson and collaboration. The current prototype was not evaluated formally. However, we proposed an evaluation framework with the aim to assess both technical and pedagogical nature of the proposed system. We also believe that it would serve as a novel approach to support constructive learning and allowing social interaction and communication through user’s avatar in a virtual environment.
8.2 Development Limitations

During the development stage of this project we faced many problems and limitations. First of all Ename 1290 requires systems with high graphics and processors in order to run it fast and smooth. Secondly, because of time limitation, technical difficulties and lack of proper documentation, it’s difficult to get full knowledge and concepts in the implementation part of the Ename 1290 game. Another problem we faced during the development stage was to add new gestures using “Gesture Editor” function in the current Ename 1290 application.
9. Future work

During the study of this project, a number of issues have arisen which are beyond the scope of this thesis to address but are believed to be of interest to researchers in the field. One of the paramount future work is to develop the current Ename 1290 complete functional with multi-user support. Since no formal user evaluation is conducted due to time and technical limitations. In future, we would like to do a formal user evaluation to study how users interact with the system and experiment and investigate how educational role play benefits social interaction and collaboration. For interactivity in the current application, we used mouse input to enable and disable a user. We would also like to implement a total mouse and keyboard less system in the future. Beside gestures, voice, and facial expression contains a wealth information which can help computers to understand human visual communication and ideas. In this project, extra features of Kinect for Windows like facial recognition and voice recognition are not used, but it would be interesting to work on these features in the future.

As we discussed in chapter 3, CVE is believed to be a promising area in education where participants experience collaborative learning. In the current system, collaboration is mainly between two participants in a single virtual environment. However, in the future we would like to extend the system to many participants at a different location by installing a multi-user server. Participants can access the central server via internet and interact with the system through their own Kinect setup. In this way, we can study social interaction and collaboration and benefits of this model.

One particular application area of educational live action role-play is believed to be very suited for Special Needs students
concerning self-efficacy [27]. There is social impairment: a person with special need finds it is hard to perform well in a traditional classroom setting. Secondly, there is physical impairment: a person with disabilities (especially when he or she is in a wheelchair) finds it hard to physically involved in a natural Edu-LARP setting. The technology based on Kinect and virtual reality discussed in this thesis could potentially assist students with special needs an easy way to thrive in the complex learning environment and enhance engagement. Thus circumvent their social and physical impairments and sense of isolation. The findings on different benefits of educational live-action role play, Microsoft Kinect’s ability to track two active users and user embodiment in particular, may offer high-quality education, but this needed to be investigated in practice.

We see much potential for students, tourist and researchers to connect to virtual heritages using virtual reality and 3D interactive tools like the Microsoft Kinect and Unity game engine in future. Finally, we see the collaboration of pedagogical expert and game design researchers can provide a wealth of information to develop educational games using virtual reality.
10. References


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