O_HAI 4 Games - D3.1. HoloGame Platform Implementation

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O_HAI(4)Games

Orchestration of Hybrid Artificial Intelligence Methods for Computer Games

HoloGame Platform Implementation

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Some of the results presented in this deliverable have been published in [25].

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1. Project Description

1.1 Abstract

Hybrid artificial intelligence (HAI) methods, which can be defined as the orchestration of complementary heterogeneous both symbolic and statistical AI methods to acquire more precise results, are omnipresent in contemporary scientific literature. Still, the methodology of developing such systems is in the most cases ad-hoc and depends from project to project. Computer games have always been connected to the development of AI. From the earliest chess minmax algorithm by Claude Shannon in 1949 to the more recent AlphaGo in 2015, computer games provide an ideal testing environment for AI methods. Similarly, AI has always been an important part of computer games, which have often been judged by the quality of their AI and praised if they used an innovative approach. Computer games allow us to test AI methods, not only for fun and leisure, but also for numerous other fields of human activity through the fields of serious games and gamification. The project proposes to establish a new framework for the orchestration of hybrid artificial intelligence methods with a special application to computer games. Therefore an ontology of hybrid AI methods as well as a meta-model shall be developed that would allow for creating models (ensembles) of hybrid AI methods. This meta-model would be implemented into a modular distributed orchestration platform which would be further enriched with a number of modules to be tested in four gaming related environments: (1) MMORPG games, (2) gamified learning platform, (3) serious game related to autonomous vehicles and (4) a game for a holographic/volumetric gaming console which would also be developed during the project.

1.2 Introduction

The application of HAI which can be defined as the orchestration of heterogeneous artificial intelligence (AI) methods including both statistical and symbolic approaches in various domains is omnipresent in current scientific literature. It is largely overlapping with the term hybrid intelligence (HI) that has been defined as *"the combination of complementary heterogeneous intelligences (...) to create a socio-technological ensemble that is able to overcome the current limitations of (artificial) intelligence."* [9]. HI lies at the intersection of human, collective and artificial intelligence, with the intent of taking the best of each.

There have been numerous studies recently addressing issues related to HAI and HI methods in a multitude of application domains including but not limited to land-slide prediction [17], drug testing [7], forecasting crude oil prices [33], prediction of wildfire [15], evaluation of slope stability [16], modeling of hydro-power dam [5], wind energy resource analysis [11], industry 4.0 and production automation [3], airblast prediction [2], heart disease diagnosis [19] and these are just a few references from 2018 until the time of writing this proposal. Most of these and such studies report building HAI systems by combining various AI methods to acquire better and more precise results. However, when it comes to methodology of the actual orchestration of HAI methods the usual approach is ad-hoc and depends from project to project. The lack of methodology in orchestrating HAI shall be addressed in the proposed project.

In a previous project sponsored by the Croatian Science Foundation (Installation Project No. HRZZ-UIP-2013-11-8537 entitled Large-Scale Multi-Agent Modelling of Massively Multi-Player On-Line Playing Games - ModelMMORPG - see [31] for details) a comprehensive methodology for modelling large-scale intelligent distributed systems has been developed that includes a graphical modelling tool and code generator (described in [30] and in more detail in [20]). The implemented toolset allows for modelling complex multi-agent organizations and could be applied to numerous applications domains [26, 27]. Herein, we would like to apply and incorporate this methodology to the development of the HAI orchestration platform.

Computer games have always been connected to the development of AI. From the earliest chess minmax algorithm by Claude Shannon in 1949 to the more recent AlphaGo™ in 2015, computer games provide an ideal testing environment for AI methods. Similarly, AI has always been an important part of computer games. Computer games have often been judged by the quality of their AI and praised if they used an innovative approach like the ghosts in Pacman™ which had individual personality traits (1980), Creatures™ which used neural networks for character development (1996), Black & White™ which used the belief-desire-intention (BDI) model (2000), F.E.A.R.™ which used automated planning algorithms (2005) and many others (see [35, pp. 8–15] for a very detailed overview). Artificial intelligence in games is not only used for non-playing character (NPC) or opponent implementation, but also for various other parts of games [35, pp. 151–203] including but not limited to **generation of content** (graphics including levels and maps, sound, narratives, rules and mechanics or even whole games like the Angelina game-generating system [8]), **player behaviour and experience modeling** [35, pp. 203–259], as well as **bot development and automated game testing** [35, pp. 91–151]. Due to their complex nature and endless possibilities of creative design, computer games present us with an excellent opportunity to study the orchestration of HAI in various scenarios – not only for fun and leisure but also for other domains in form of serious games and/or gamification.

In the previously mentioned ModelMMORPG project, we have already used an open source massively multi-player on-line role-playing game (MMORPG) called The Mana World (TMW) for which we have implemented a high-level interface to test intelligent agents playing the game. Additionally a number of connected game quests have been developed for various scenarios which allowed us to build an automated game testing system [29]. Herein we would like to use this interface to test orchestrated HAI methods, but also develop other testbeds for the planned platform.

Therefore, the main contribution of the proposed project shall be: (1) a comprehensive framework for the orchestration of hybrid artificial intelligence methods for computer games allowing to define models of HAI for various purposes, (2) an open source distributed cloud platform that will allow to implement such models based on existing HAI methods and connect them directly from game development platforms, (3) a set of best practices in developing HAI ensemble models tested in at least four specific testbeds described bellow.

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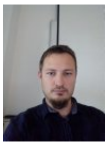

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2. Streamed Holographic 3D Game Engine

2.1 Introduction

A game engine is a computer program that enables the development and management of all aspects and computing resources required to run a game (e.g., graphics, sound, user interface, scripts, events, data storage, networking, artificial intelligence, physics, etc.). The user of a computer game engine is a computer game programmer. In this work-in-progress we are on our journey to develop a game engine that would allow games to be (1) streamed over a network and (2) displayed on a holographic display device.

Game engines are complex systems consisting of numerous subsystems (see figure 2.1). Our objective herein is not to *reinvent the wheel* and reimplement all parts of a game engine from scratch, but to focus on two particular aspects of game engines which will allow us to achieve the above stated objectives: game streaming and holographic display of games.

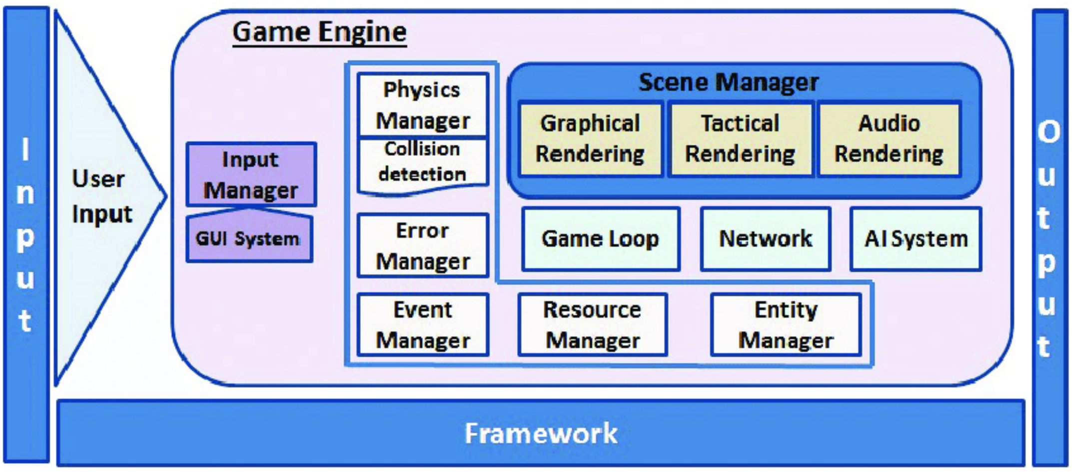

Figure 2.1: A game engine's architecture [36]

Thus, we have chosen to use an existing game engine (namely UPBGE - a community based continuation of the Blender Game Engine[1] and extend it with: (1) a game streaming architecture, (2) a display transformation to allow display on a holographic display.

2.2 Game Streaming

The advancement of technology allows most households to own at least one personal computer (PC). Such PCs can usually suffice when playing video games is considered, most modern games included. The key and the most observable element of enjoying a game is observing rich and smooth graphics provided by the game designers, especially when combined with smooth and fluid storytelling and game mechanics, provided by the games' developers and other artists. The most important building block of a PC, in the context of providing enjoyable graphics, is graphics hardware, i.e. external graphics cards (as opposed to on-chip integrated graphics hardware). The main problem in the domain of graphics cards is their price, which soared during the last decade, and made high-tier PCs almost unavailable to average targeted consumers in e.g. the EU, North America, or Far East. This obstacle, in turn, makes it harder for gamers, i.e. variously skilled players of games, to enjoy the full potential of games and their developed graphics.

With the advent of access to the Internet, and the increasing speeds available in increasingly large areas and portions of the world, e.g. access to high-speed optical fibre across the EU, an average user can rely more on the constant availability of information, and the speed of recovering it whenever needed. Constant availability of the Internet rendered music and video storage, such as a CD-ROM, a DVD-ROM, a BluRay disks, or a USB memory drive, or even a portion of a disk with stored music files, almost obsolete. Reliable access to the sources that provide multimedia files as streams of data shifted the focus of an average user, shifted the behaviour towards legal use of various types of multimedia, and created new habits when multimedia consumption is considered. Even though they are dispersed amongst many streaming services, a rich collection of music, movies, TV shows, cartoon series, etc. is available in a matter of seconds to a great number of users throughout the world.

The trouble with streaming video games is that video games are an interactive type of multimedia entertainment. Videos and music can be streamed safely, but they are being streamed one way only: from the service provider to the user, and not much interaction is expected except for maybe starting a stream, pausing, moving the time line and other simple instructions. In streaming video games, the game is expected to behave according to the input of its player in real time. For example, if the player moves by pressing a key on the keyboard, the in-game character is expected to move almost instantly; if the player clicks on a menu item, the interface is expected to change accordingly; if the player's avatar is being attacked, or is found in a situation where speed is of the essence, the game is expected to react to the player's input almost instantly, etc. The described scenarios are only a few, a needle in a haystack of playing video games, that require almost instant reaction of the game – moreover, they require that the player receives an almost instant feedback that the game instantly reacted to the received player's input. Usually, establishing such a quick feedback loop is not a problem in PCs, but it does present a challenge in video game streaming services.

There is a caveat that should be addressed though. Not all games require feedback loops that are (as much as possible) instantaneous. Some games (usually single-player games) can be played with an occasional slight delay, because such a game, for example, does not rely on the speed of its player's reaction, or that particular feature is of low significance.

The benefit of combining the ideas of video games and multimedia streaming services is manifested in the opportunity to play video games without having necessarily to own the hardware that can run those video games. Usually, the time spent on gaming, i.e. playing video games, is only a fraction of the time spent on using the PC for other purposes. Therefore, owning hardware

[1] For further information, see `https://upbge.org/`

that will provide the resources for playing a video game can be expensive, especially when time, utility, and use are considered. On the other hand, a video game streaming service can be used whenever needed, and (in some cases) on virtually any device available, if the appropriate Internet speed and game-controlling hardware (e.g. a game controller, a keyboard, a mouse, a wheel, etc.) are at the player's disposal.

There are technologies and approaches that are used for further reducing the expected feedback loop duration, and providing smoother playing experience, such as predicting a player's move and rendering possible actions before they actually happen, or rendering only specific sets of pixels that change in consequent frames, etc. [28]

Game streaming systems are usually complex and consist on numerous components that deal with various aspects of networking, game interaction as well as graphics rendering (see figure 2.2 for an example architecture based on virtual machines proposed by [14]).

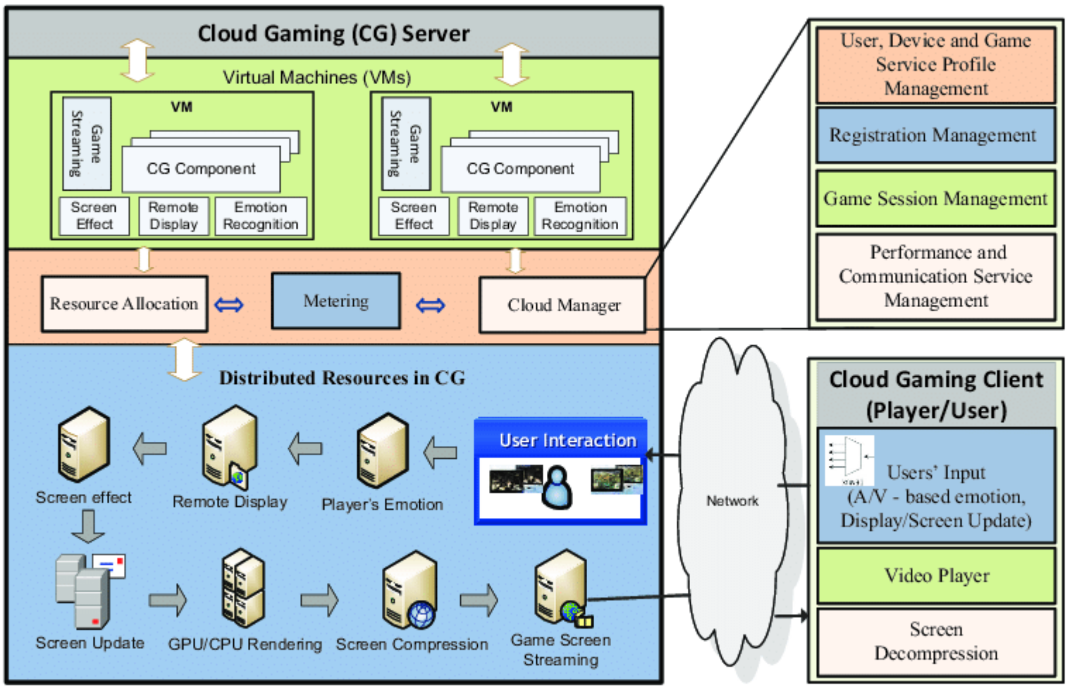

Figure 2.2: A game streaming architecture [14]

Many video game streaming platforms exist today [12], each of which uses a different method of providing games to be streamed, some of which are: NVIDIA GeForce NOW[2], Amazon Luna[3], Sony PlayStation Now[4].

The initial test case scenario for the holographic platform described in this chapter will consist of a game that does not rely on the speed of its player, rather it will be used to showcase the possibilities of playing a game developed for, and played on, such a platform.

2.3 Holographic Technology

A hologram is 3D visual display that is visible from all angles. At the time of writing there are a number of promising holographic technologies available [1, 4, 6, 10, 13, 18, 22, 32]. From a

[2]For further information, see `https://play.geforcenow.com`

[3]For further information, see `https://www.amazon.com/Luna/`

[4]For further intofmation, see `https://www.playstation.com/en-us/ps-now/`

commercial perspective, there are various technologies that will produce a similar effect, albeit they aren't real holographic technologies but merely use various tricks that make our eyes and brain believe that there is a 3D visual object floating in the air.

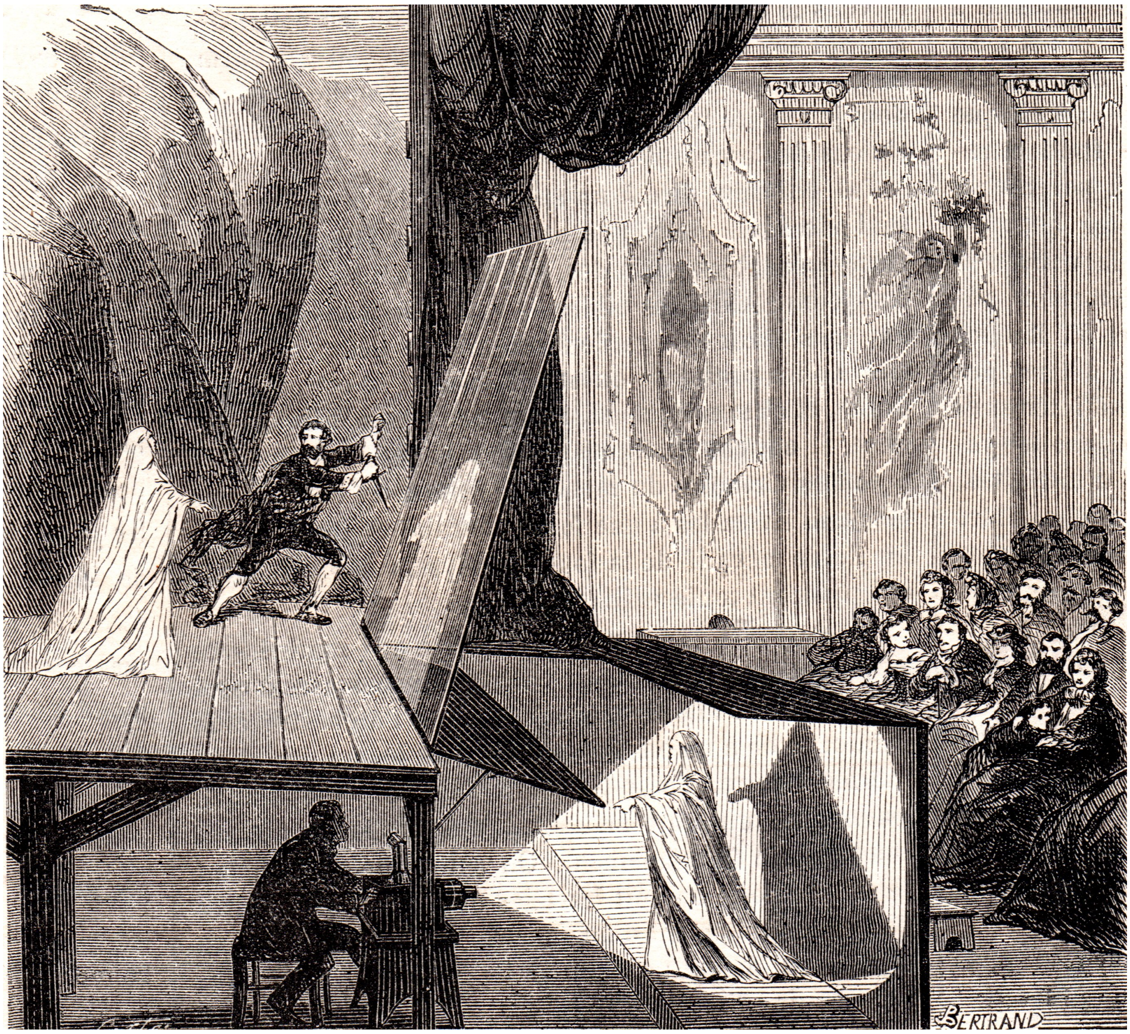

Figure 2.3: By Le Monde Illustré, Public Domain

One such technology are so called Pepper's Ghost images, after the English scientist John Henry Pepper (1821–1900) shown on figure 2.3. The basic idea behind this technology is to use a light display that emits an image on a reflective (usually transparent) surface which reflects the image and provides a holographic experience.

A common enhancement of the original system is to use a glass or acrylic four sided pyramid instead of just one surface, and place a display above the pyramid so that the holographic image is visible from all four sides of the pyramid (see figure 2.4.

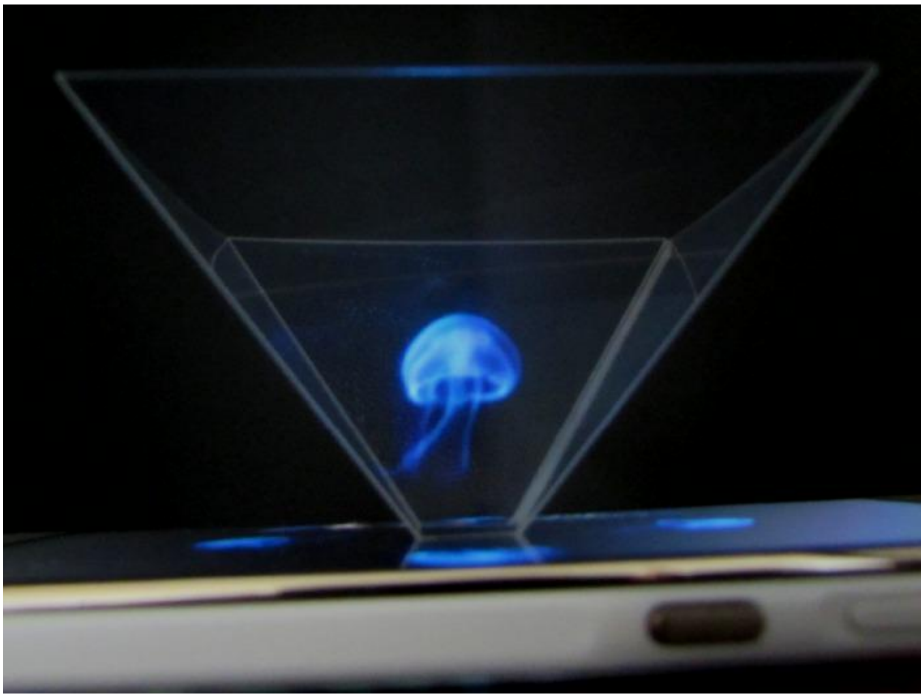

Figure 2.4: By Karthikch98, CC BY-SA 4.0 via Wikimedia Commons

On the other hand, voxel technology is based on producing an information that consists of volume and pixel. Pixels are physically created in space as floating objects. Displays that support such technology are called volumetric displays and stand for actual true holograms [34].

Figure 2.5: By Abhishek Agarwal, Available at: https://www.pinterest.com/pin/pos--452611831299988802/

Holography based on fans are also drawing attention. The idea behind the technology is to transmit a light towards a running fan. Unless on a close proximity, one will not notice visually that a fan is spinning, however, transmitting a light on it will produce an effect of having floating objects from any distance [23]. Figure 2.5 shows a commercial example installation.

Herein we have chosen to test (1) a volumetric 3D display and (2) a Pepper's ghost based pyramid display with the final objective to develop a holographic / volumetric (Ho/Vo) gaming platform.

3. Prototype Implementation

In this work-in-progress we present our initial attempt in building a streamed 3D holographic game engine. Game streaming technology provides the opportunity to use cloud-based resources like advanced graphic processors to play computer games on low-cost end-user devices. Holographic games are a relatively new technology which provides a new way of experiencing multimedia and games but are currently a high-cost. Herein we present a prototype game streaming engine we have built that allows us to stream holographic games to consoles based on Volumetric (fan) displays and Peppers's Ghost pyramids which emulates a holographic display.

3.1 Prototype 1 - Volumetric 3D display

The first prototype for a streamed Ho/Vo gaming platform was built by using a volumetric fan display which was connected to a Raspberry Pi 4 microcontroller together with speakers to allow for sound effects. The hardware setup is shown on figure 3.1. The the fan display, together with the microcontroller were mounted on a custom-made stand that we have put together from various spare parts.

As of the time of writing we have partially implemented the following three use-cases:

1. Non-interactive presentation
2. Interactive (on-chip) gaming
3. Cognitive agent interaction

The first use-case is the most simple one: we have implemented a script that allows us to start any video presentation (see example of rotating logo in the second row of figure 3.1). In order to achieve a visually appealing result the presentation has to be a 3D model or animation on a black background as in the example.

Figure 3.1: Developed volumetric 3D display

The second use-case is more complicated mainly due to the fact that in order to allow for gaming a way of interaction with the console has to be established. While it is possible to connect a controller, mouse and/or keyboard to the microcontroller, we opted for a cable-less solution due to player and device security concerns (at least in the first iteration of the prototype, as explained below). Two options for a cable-less solution were to use (1) bluetooth or similar controllers or (2) to allow interaction through mobile devices. Mainly because we were planning to use the console in public spaces (especially for the students of the Faculty of Organization and Informatics), the first solution has the downside that any controller has to be available and accounted for and, in line with recent events regarding the COVID-19 pandemic, has to be disinfected after use. The second solution has the downside that a player has to have a mobile device in order to be able to play.

We have chosen the second solution and have implemented an initial controller interface in form of a web application which is served by the microcontroller and accessible over a wireless access point (AP) that is started by the microcontroller. The player has to connect to the AP and point her browser to the server which serves a webpage that includes a controller image (see figure 3.2) as well as adequate scripts which allow control of the game at hand.

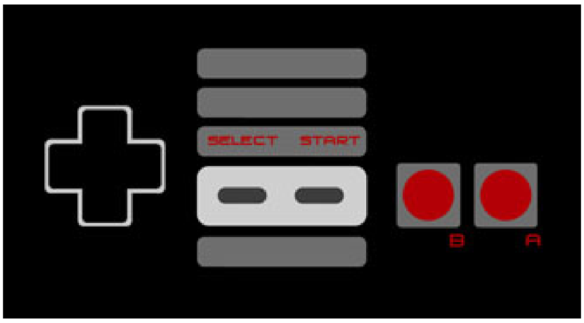

Figure 3.2: Controller image reminiscent of the legendary Nintendo Entertainment System Controller

The third use-case is the most complicated of the three since the interaction has to be sound/voice based and due to the fact that the fan produces a certain amount of noise as does the actual surroundings (background noise due to other people passing by). We have implemented our cognitive agent called Beautiful ARtificial Intelligence Cognitive Agent (B.A.R.I.C.A.)[24] on the console in order to allow for direct interaction. After testing with various microphones in various conditions it has become obvious that due to background noise the speech recognition doesn't work in a satisfactory way. In order to minimize the influence of fan noise it would be possible to build a transparent thermoplastic casing around the fan. This would have the additional benefit of securing the device since the unprotected fan could injure a person. Thus we plan to create a custom casing in a future version of the prototype. On the other hand to minimize surroundings' noise a possibility would be to use a similar approach to the second use-case, i.e. to use mobile devices to interact with the cognitive agent. For example any Voice over IP (VoIP) enabled technology could be used to transfer voice data from the user to the cognitive agent, and since mobile phones often have adequate noise cancellation technology, we predict that results of speech recognition could be better than with using an on-console microphone. We plan to implement such a setting in a future version of the console.

Additionally to these three use-cases we are planning to implement a fourth one which would allow for playing streamed games. Since the use of the game streaming platform (described in the second prototype below) requires additional adjustments to the consoles software and hardware (for example, the current implementation does not feature an Internet connection which is key to streaming games), we will try to implement this use-case in a future version.

3.2 Prototype 2 - Pepper's ghost based pyramid display

In order to provide a working proof-of-concept holographic game engine we have designed and partially implemented a game engine for streaming holographic content. During design and implementation we have used multiagent systems (MASs) as a natural way of developing intelligent distributed systems. The architecture of the system is shown on figure 3.3. Additionally, we have used a gaming console as a metaphor for the implementation. The system consists of a pool of existing game agents which comprise containers called cartridges that represent the games that are supported by the engine (implemented by actual game developers). Each cartridge is a microservice container (in our case Docker[1] container) which consists of a minimalized Linux operating system that includes a graphical user interface and a game engine (in our case UPBGE), the actual game implementation as well as a camera transformation that allows us to display the game on a holographic display based on Pepper's Ghost technology.

[1]For further information, see `https://www.docker.com/`

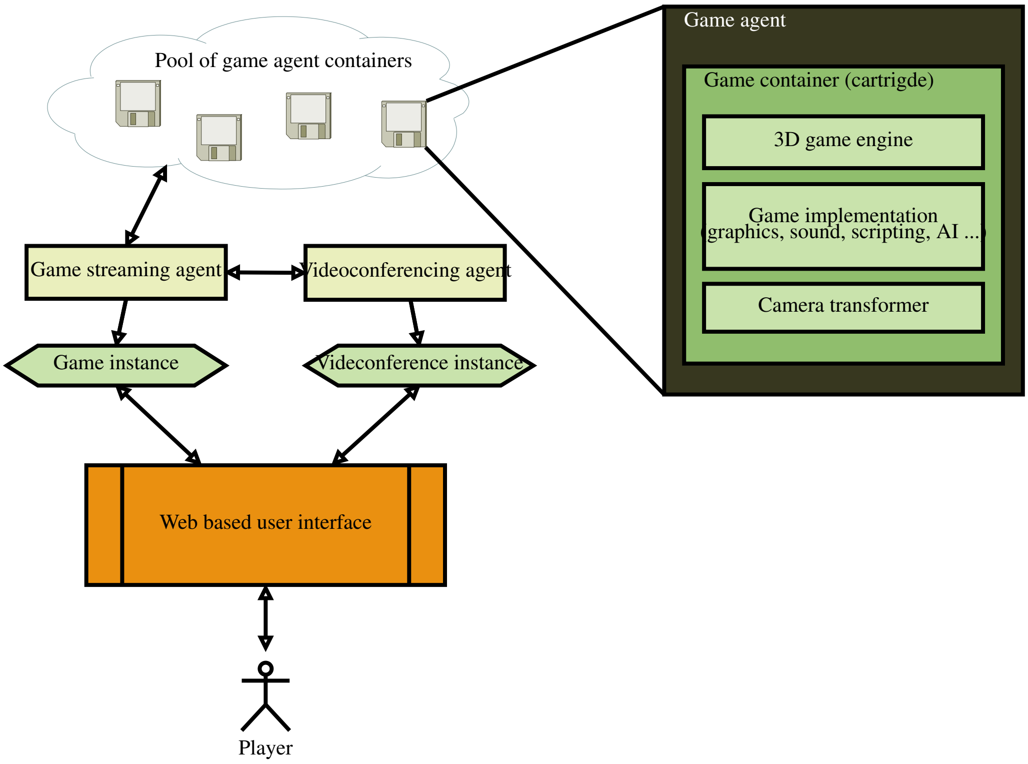

Figure 3.3: Prototype Architecture

We have implemented this transformation in UPBGE by using a simple technique. In order to get the state of the 3D world for each of the four sides of the pyramid we have used four cameras which display the world in real time from four perspectives. Additionally, we have created a custom viewport that shows all four camera outputs on the same display at once, which allows us to use one display above the pyramid to show all four perspectives. The implementation of this script is shown in the following listing:

```
from bge import logic, render
camList = logic.getCurrentScene().cameras

cont = logic.getCurrentController()
own = cont.owner
camn = camList[ own[ 'camn' ] ]
cams = camList[ own[ 'cams' ] ]
camw = camList[ own[ 'camw' ] ]
came = camList[ own[ 'came' ] ]

a = render.getWindowWidth()
b = render.getWindowHeight()

x = int( ( a - b ) / 2 )
y = int( b / 4 )
z = int( b / 2 )
```

```
# setViewport( left, bottom, right, top )
camn.setViewport( x+y, y+z, x+y+z, b )
cams.setViewport( x+y, 0, x+y+z, y )
camw.setViewport( x+y+z, y, x+2*y+z, y+z)
came.setViewport( x, y, x+y, y+z )

camn.useViewport = True
cams.useViewport = True
camw.useViewport = True
came.useViewport = True
```

For example figure 3.4 shows the UPBGE interface for a simple world in which we have put an interactive 3D model of a dragon[2] on a simple plane. The dragon can be manipulated using the usual keyboard and mouse inputs in real time.

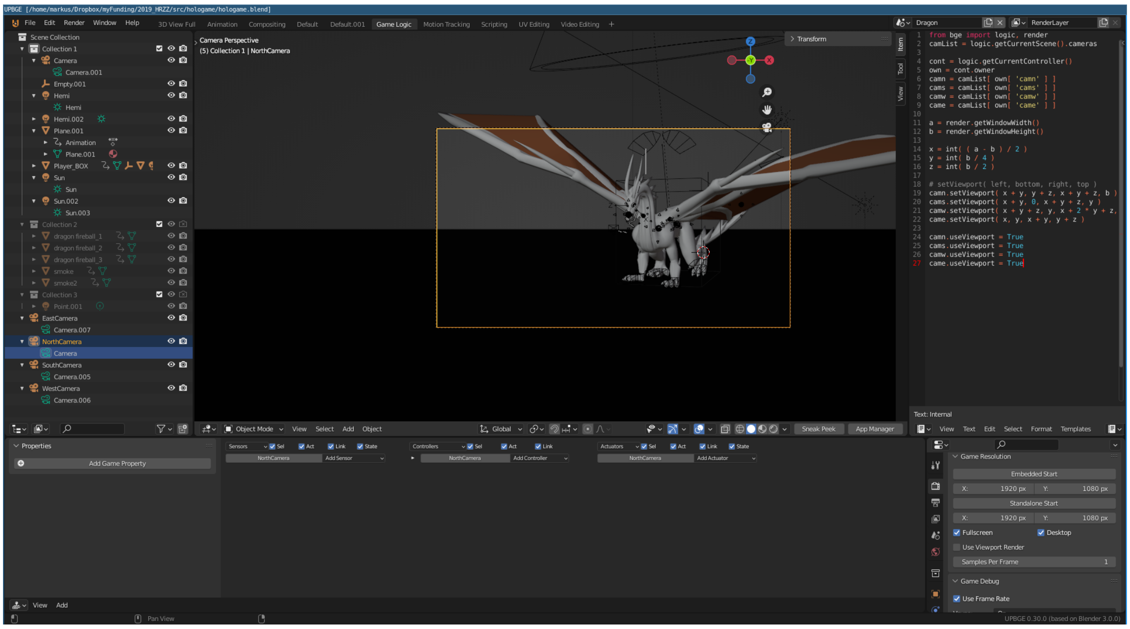

Figure 3.4: UPBGE interface

By using the script shown above, the world is rendered as shown on figure 3.5. As one can see, four cameras show the dragon from four sides (north, east, south, west) at the same time.

By using a transparent pyramid and placing the center of it in the center of the display by aligning the sides with the sides of the display, one can get a hologram-like appearance as shown on figure 3.6. In this way, any game implemented in UPBGE with the given transformation can be transformed in a holographic game. Of course, this transformation is not suitable for all existing games, but only for those for which a holographic display can or should be used. We envision that various new types of games, which make use of the holographic nature of the display in their core game mechanics can be implemented that go beyond games based on traditional non-holographic displays.

In addition to game agents, there are two other important types of agents: (1) game streaming agents as well as (2) videoconferencing agents. The gane streaming agents are envisioned as orchestrators. They get requests from clients that would like to play a game from the pool of available games, allocate resources in the could (which could be any orchestration platform like

[2]Available at `https://3dmdb.com/en/3d-model/bge-dragon-20/1005315/?free=True&q=bge+dragon`

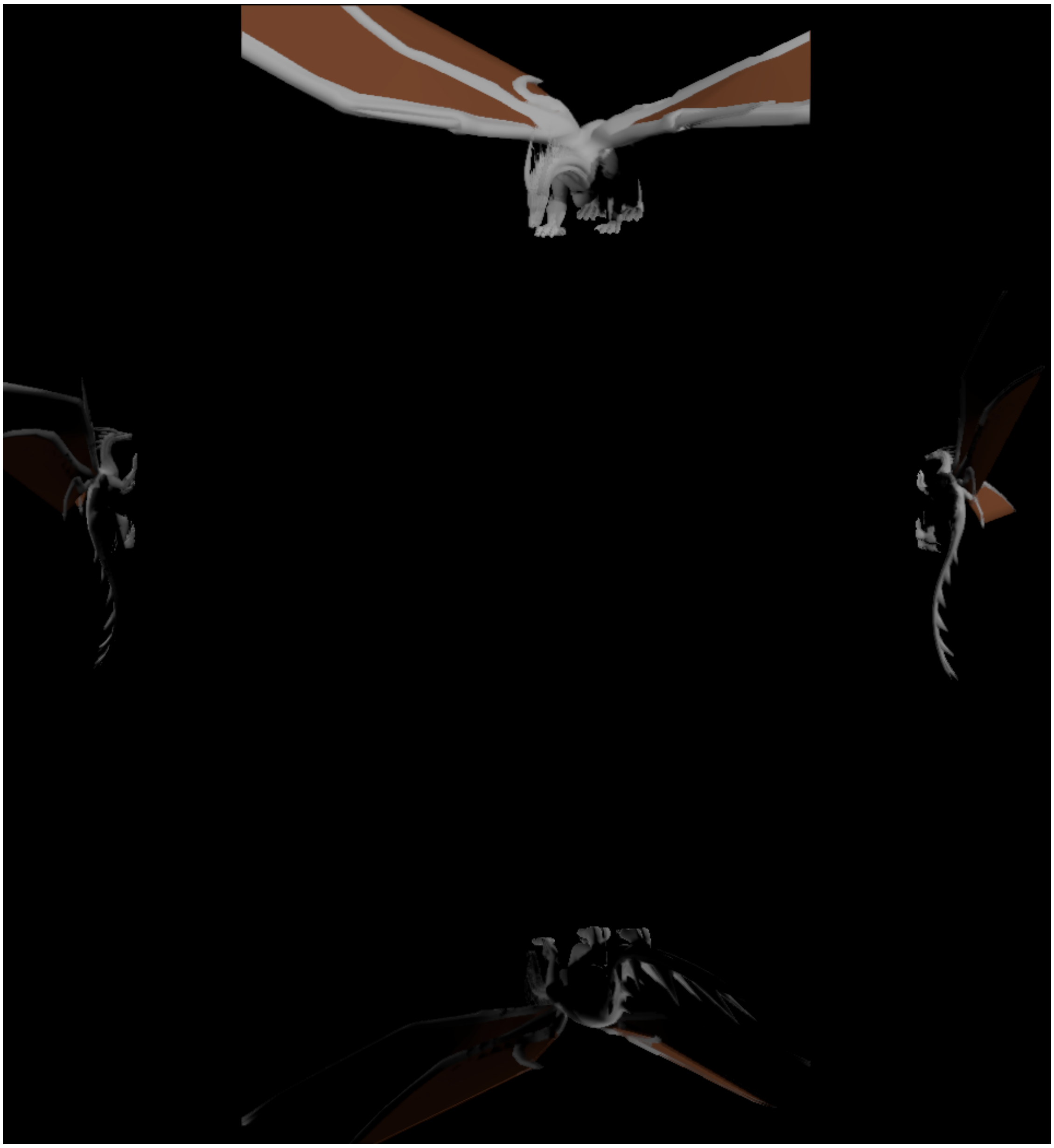

Figure 3.5: Display with four parallel cameras

Kubernetes of Docker Swarm) and instruct a game agent to start it's cartridge as a container instance on the allocated end system. This allocation is considered a game instance in which an instance of a game agent directly communicates with an end-user's web based interface to which a game is streamed. The streaming is implemented by using XPRA[3] and a X11VNC[4] server which are contained in each game cartridge.

In addition to game streaming agents, videoconferencing agents are implemented as well that allow audiovisual and text communication between players (in multiplayer games for example) or live streaming of a players video and audio feeds (for live events for example). The game sgtraming agents instructs a videoconferencing agent to open an new room for each game that is being streamed and this new videoconference instance then directly communicates with the player's

[3]For further information, see `https://xpra.org/`

[4]For further information, see `https://launchpad.net/ubuntu/+source/x11vnc`

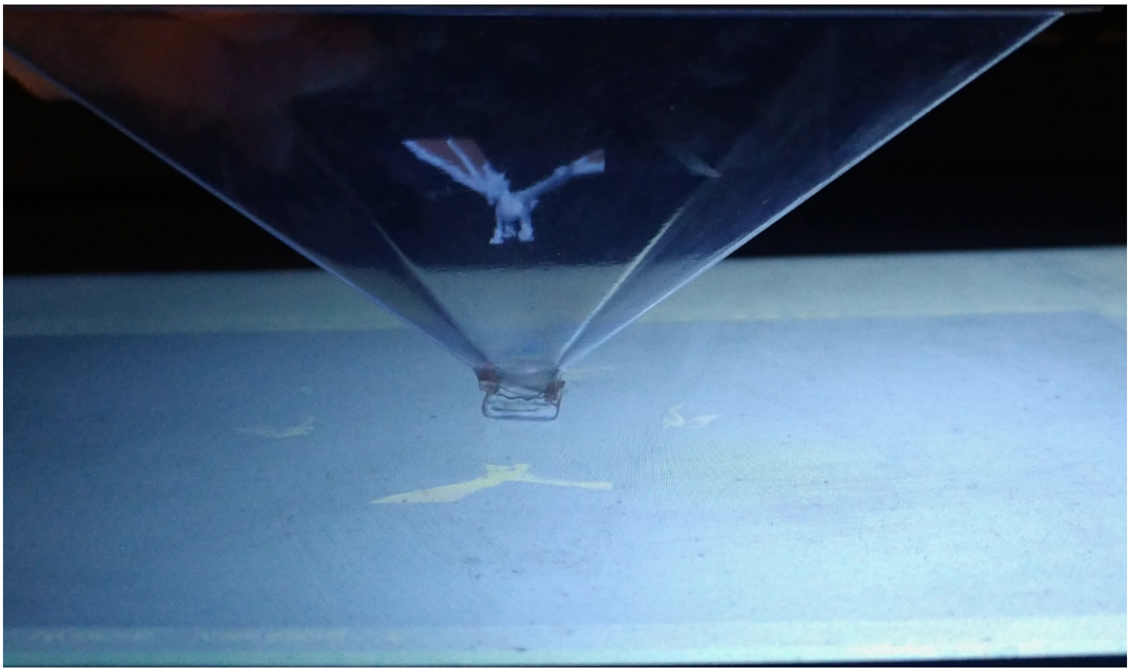

Figure 3.6: Hologram-like appearance

web based user interface. Videoconferencing is implemented using Janus WebRTC server[5].

In the end, the web based user interface features a VNC client that displays the streamed game and allows user interaction as well as a WebRTC client to allow for video and audio streaming.

All agents are implemented using Python, especially the SPADE platform [21]. The web based user interface is an adaptation of noVNC[6] with additional WebRTC client implementation in JavaScript.

Our future research is aimed towards enhancing this technology with possibly other 3D game engines that allow for multiple camera views that could be embedded into game cartridges as described above. Additionally, we are working on the design and assembly of a 3D holographic game console based on the technology described herein.

[5]For further information, see `https://janus.conf.meetecho.com/`

[6]For further information, see `https://novnc.com/`

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