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Design and Development of a Virtual Agent for Interactive Learning Scenarios

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Abstract

From the first chatbot ELIZA to today's virtual assistants like Siri and Google Assistant, technology is improved drastically. With the improved technology, new trends in chatbots such as pedagogical agents came into existence. Chatbots have been replacing human beings for the last decades in every industry, including educational organizations. To give lifelike illusion to the user, virtual agents were introduced. These virtual characters are gaining popularity in education they've been considered as aids to improve the educational process, given a physical representation, depicted as having a human appearance, and used in real world educational settings and these are known as Pedagogical agents.

This thesis research introduces the concept of pedagogical agents to support students with academic activities and enhance communication between users and computers. Beginning with the introduction of avatars and virtual agents, this report provides the state of the art of different pedagogical agents such as Cyberpoty, STEVE, NEVA, AVARI, etc. The earlier studies provided a strong foundation from which the design criteria are collected for developing a pedagogical agent. The proposed pedagogical agents are chosen to be of Caucasian ethnicity with an age group of 20 to 30 years old with gestures and facial expressions. These criteria's were chosen based on the highest numbers of interactions made by users around the globe. Furthermore, this report describes the series of steps from the concept phase to the animation phase, to implement and design a pedagogical agent. A post-implementation survey was conducted to know the users' response and any recommendations for future implementation.

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List of Abbreviations

LSTM Long Short-Term Memory

CETAM-EAD Centro de Educação Tecnológica do Amazonas

AVARI Animated Virtual Agent Retrieving Information

API Application Programming Interface

SAMIR Scenographic Agents Mimic Intelligent Reasoning

STEVE Soar Training Expert for Virtual Environments

ADELE Agent for Distance Learning: Light Edition

AIML Artificial Intelligence & Machine Learning

WebGL Web Graphics Library

HTML5 Hypertext Markup Language

ECA Embodied Conversational Agents

CHARLIE CHAtteR Learning Interface Entity

HIK Human Inverse kinematics

PALD Pedagogical Agents Levels of Design

NLP Natural Language Processing

1 Introduction

Many things have evolved since the earliest chatbots in the 1960s (such as Eliza) to today's virtual assistants (such as Siri). Despite amazing progress in Natural Language Processing (NLP), we are still a long way from constructing a machine that can understand natural language, which has long been a goal of Artificial Intelligence (AI) and is likely the ultimate aim of NLP[23]. Due to rapid development in the technology, Avatars and Virtual agents are to come into existence. The term ”avatar” (from the Sanskrit avatāra) comes from Hinduism, where it refers to a bodily manifestation of Immortal Beings or ”the Supreme Being” [24]. When related to computers, this concept suggests that an avatar is a representation in the virtual world, and for some, it can be considered their ”Incarnation” into the Internet[25]. Avatars are virtual representations that are perceived to be controlled by humans, whereas virtual agents are virtual representations that are perceived to be controlled by computer algorithms. Avatars include facial expressions, gestures, head and hand movements, eye gaze and speech[25].

The paper [26] defines avatars as virtual representations seen to be controlled by humans, while virtual agents are those perceived to be controlled by computer algorithms. Avatars and agents are virtual representations of individuals used in computer-mediated interactions. Avatars and agents differ in the aspect of control: avatars are controlled by humans, whereas agents are controlled by computer algorithms. As a result, interaction with an avatar falls under the category of computer-mediated communication (CMC), whereas interaction with an agent falls under the category of human-computer interaction [26].

So, what makes Avatars and Virtual Agents (A & VA's) so unique? Humans naturally engage in sophisticated cognitive activity involving speech and hand gesture, which they manage through social conversational norms comprising voice, eye gazing, facial emotions, head movement, and hand gesture. Where social collaborative behavior is important, Casswell [27] suggests that portraying a system as a human is the best interface. Embodied Conversational Agents is her concept for A & VA's. She claims that an Embodied Conversational Agents (ECA) is an interface in which the system is represented as a person and information is sent to human users through numerous modalities such as speech and hand gestures, among other things. Casswell [27] was able to add the rules of engagement into a table of conversational functions and associated behavior realization, which could then be employed inECA-based systems to make the user interface as close to human-to-human contact as feasible.

The first digital avatars and agents came in the 1950s and 1960s, when computers were still in their infancy. Stuart Weizenbaum's persona ELIZA was one of them.

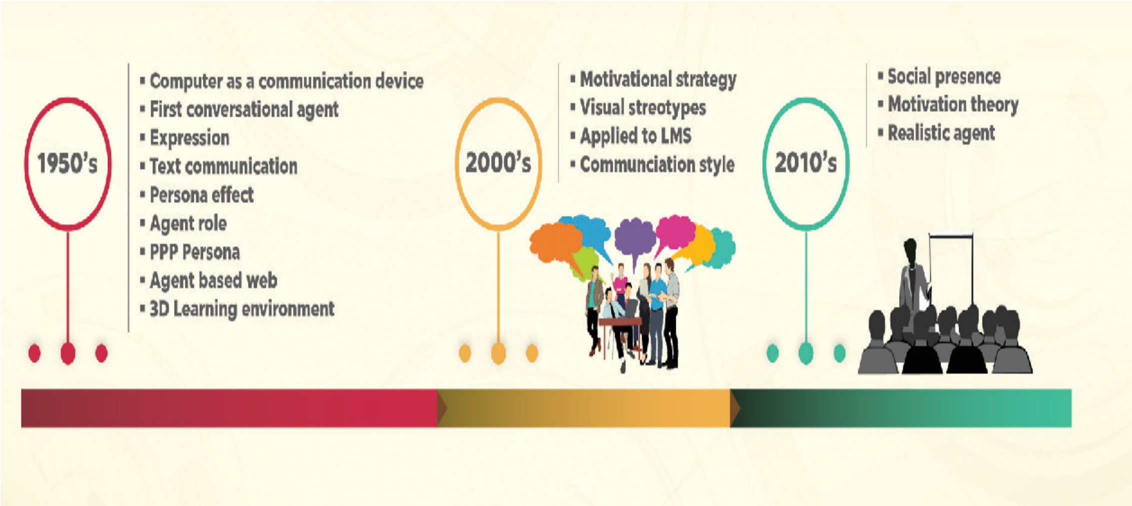


Figure 1.1: Metamorphosis of Pedagogical Agent Research [1]

In the early 1960s, this computer software resembled a Rogerian psychotherapist. ELIZA gave the impression of intelligence and was capable of answering basic questions.

The best example for the avatars is depicted in the figure .1, in the starting stages these avatars are portrayed using simple images. Later, avatar technology included cartoon-like animation. These animations were made out of short video segments and could not be interacted with at the time. Their task was straightforward. Characters have been spotted reading commonly asked questions or website information. With the passage of time, a few changes were made to these cartoon avatars, such as the addition of an interaction feature. Shona is an example of a flexible presenting avatar in Figure .1. She represents the Swedish Executive's younger department and is in charge of reading news and disseminating information, particularly to youngsters and young students. Her talents have grown beyond reading to include instructing.

The figure .2 is an agent which is one of the most innovative efforts in the field of Artificial Intelligence is A.L.I.C.E. (Artificial Linguistic Internet Computer Entity). A.L.I.C.E. is the initiative that created the Artificial Intelligence & Machine Learning (AIML) language, which allows software chatterbots to be developed [21]. A.L.I.C.E. has won the "Loebner Prize in Artificial Intelligence Contest," which is based on the Turing test (a method to determine whether a machine can display human intelligence).

The goal of these implementations is to turn personal interactions into face-to-face conversations. Information is exchanged this way through an agent. When we consider the function of our own body in everyday discussion, the way we employ our hand motions, non-verbal utterances, and eye expressions, we can see why embodiment is so important.

This program reminds us of what would eventually become customer care chatboxes, which exploded in popularity in the 1990s when the Internet became widely available. Chatterbots, which can supply information to clients, are still frequently integrated into the dialog systems of automated online assistants. Voice-based Virtual Agents were also used in call center IVRs for self-service in the 1980s and 1990s, with the retail, banking, and government sectors being the most popular. Julie from Amtrak was another well-known virtual agent. Julie was the pleasant voice you hear when calling Amtrak's 1-800 number for over ten years. It began with a personality which was mostly related with voice-activated services, and is now also used by Amtrak for Internet chatting and is associated with a woman's image that helps you through the corporate website [25].

Virtual agents also known as 'Pedagogical agents' are frequently integrated in online learning environments since 2005 [19]. In an E-learning environment, pedagogical agents are static or animated anthropomorphic interfaces that fulfil a range of instructional aims [28]. These agents are frequently given human or non-human features such as emotion, gestures, and speech [29]. These agents have two main benefits: they extend the bandwidth of interaction among students and computers [28] and they improve the computer's ability to interact and encourage students [19].

Making educational agents alive and credible is vital for two reasons. Firstly, realistic agents are more likely to be engaging, making learning more fun. Second, unusual actions draw attention to themselves and divert users' focus away from the task at hand [1].

Virtual characters have become the norm rather than the exception in recent years, with educational institutions trying to create learning spaces in virtual worlds where users are required to present themselves as digital characters. These improvements create a variety of concerns about the usage of virtual characters in E-learning settings, including the following: What should virtual characters' look be like?? What impact does their external appearance have?, if any? What function does aesthetics play in the creation of virtual characters? Does the appearance of virtual characters affect learning, engagement, and learner perceptions? [30]. These questions are well discussed in chapter 2.

The first thing learners notice about a pedagogical agent is its obvious visible characteristics: gender, nonverbal cues, ethnicity, hairstyles, hair color, and attire. As a result, preconceptions and expectations of agent usefulness, credibility, and intellect may be activated as a result of these traits [30]. For example, designing a pedagogical agent with playful animals or cartoons can motivate school children and a human like characters can motivate a professional adult.

As shown in 1.1, these 3D agents date backs to 1950s with computers as communication devices, the first conversational agent, 3D learning environments. Many research papers are presented till 2000, and after that new strategies are formed and those researches are applied to Learning Management System (LMS) with visual stereotypes and different communication styles. From 2010, new theories such social presence came into limelight and also developed of the realistic agents came to existence.

Social agency theory [31], according to this theory E-learning environments can be structured to encourage learners to function under the presumption that their interaction with the computer is a social one, in which human-to-human communication standards apply. The idea basically states that using verbal and visual social cues in computer-based environments can help learners form connections by encouraging them to think of their interactions with the computer as equivalent to what they would anticipate from a human-to-human discussion.

The lifelike features and actions of an animated agent, according to social agency theory, inspire the learner's social engagement, allowing the learner to build a simulated human connection with the agent. Learners may rely on certain basic human-to-human social principles to guide their engagement with the E-learning environment after this social partnership has been created [32].

The paper [32] support the using of speech, especially a male voice with a standard accent, to facilitate social agency in an E-learning environment, supports numerous findings. First, their findings back up the social agency theory prediction that participants in the standard accent group will outperform their peers in the foreign accented voice condition on transfer measures and rank the speaker's voice higher. Second, the study supports the idea that a human voice, rather than a machine generated voice, might improve the learning process and outcome by giving significant social cues through the use of a familiar, socially acceptable voice.

The researchers from the paper [31] attempted to establish a sense of social presence in learners so that the computer-based presenter may be viewed as a social companion in order to test the social agency hypothesis of [32]. Overall, they found that a voice effect in which students showed greater transfer performance when the on-screen agent interacted in a human voice rather than a machine generated voice in two independent tests with different types of participants. Learners also rated the on-screen agent who spoke with a human voice rather than a machine voice on an instrument meant to capture the social aspects of speakers higher scores. Both trials had people who were not experts in the topic but could learn it.

These hypotheses and their findings demonstrate how the appearance, age, gender, and voice may influence a learner's capacity to learn. In the following paper, chapter 2 provides the state of the art of developed agents and the required design criteria of the agent, chapter 3 describes the series of steps to model the 3D agent and finally in chapter 4 shows the modelled 3D models followed by the survey results and conclusion.

2 State of the Art

This section describes the development of avatars in different fields over the years. In the 1990s, the first online avatars were discovered. Early versions were merely animated characters designed to draw attention, but later versions provided information to the video gamer. Furthermore, the evolution of virtual and augmented reality technologies, particularly in gaming involved the user selecting an avatar to operate and, in most scenarios, play as an extension of himself. The use of virtual pictures depicting the player is becoming more common as 3D graphics, gesture recognition, and real-time image processing improve. World of War-craft is one of the most popular avatar-based games. In this MMORPG (Massive Multiplayer Online Role Playing Game), players select an Avatar that is explicitly centered on warfare [25]. Later, when these avatars started catching eyes of more people, some other fields also started implementing and adapting to the avatars to get more attention. 2.1 shows some fields including education system developing the avatars for using them on websites, portals, support systems, libraries, etc.

Table 2.1: Developed 3D agents in different fields

Name	**Task description**	**Tool**
Midoriko Chatbot[2]	provide better experience to the user with emotions and body movements	Unity game engine
CyberPoty[3]	Online query system	Haptek's PeoplePutty
3D Talking Head[4]	20 questions game with users	Haptek's PeoplePutty
AVARI[5]	virtual receptionist	Haptek's PeoplePutty
3D Talking Face[6]	Conversational agent	FaceGen software
NEVA[7]	Query management system in library	Haptek's PeoplePutty
SAMIR[8]	virtual assistant	Fanky animation tool and FaceGen software
3D chatbot[33]	assists students in overcoming some common university issue	Unity game engine
MMD Agent[34]	online voice communication robot	Web Graphics Library (WebGL)

Currently, studies are being conducted under the professorship of computer science for the development of virtual agents in an E-learning environment at the Technical University of Chemnitz. This thesis is a part of designing and developing virtual agents. Parallel to the development of virtual agents, studies for the frontend user interface and backend are currently going on. Also, several publications are released by the professorship of Computer science on virtual pedagogical agents, Adaptive Agent supported mobile Learning [35], Agent support in the mobile learning context [36], and Effect of system-induced delays on human memory performance in a virtual agent-based training [37] are some proceeding publications.

MIDORIKO CHATBOT

Midoriko chatbot [2], a Long Short-Term Memory (LSTM)-based emotional 3D avatar, was developed by the members of communication engineering at national central university, Taiwan. They used unity game engine for designing the 3D anime model and neural network for scripting. This chatbot uses facial expression and body movements during the conversation and provide better experience to the user. It can also run on VR devices, and this model was developed for educational settings.

Figure 2.1: Midoriko Chatbot [2]

Figure 2.1 shows the design of midoriko chatbot. It is designed like a female cartoon with full body. It can perform facial expressions such happy, sad, angry, surprise along with the eye and body movements. The only negative factor is that midoriko can just respond to the user's sentence input; but, in most chatty settings, the discussion will be focused on a specific topic, and the system should be able to recall what the user has said previously to make the conversation process more manageable.

CYBERPOTY

In 2010, a 3D chatbot is developed by the students of Federal University of Amazonas called **CyberPoty** [3] using the software PeoplePutty, which according to [38], includes multiple characteristics, including the creation of an avatar with motion and the ability to speak, as well as various accessories such as goggles, hats, and earring.

Figure 2.2: CyberPoty: Virtual assistant at CETAM-EAD [3]

The avatar may be observed with 3D movement and speech using the software installation Haptek Player, which uses JavaScript to accomplish these actions, according to [4]. Only the Windows operating system and Internet Explorer web browser are supported by the Haptek Player program. The speech synthesizer Windows TTS is used by CyberPoty to communicate (Text-to-Speech). The goal of this CyberPoty is lowering the number of questions posed to staff and help students to clarify their doubts fast.

2.2 shows the design of CyberPoty. CyberPoty is a female avatar, which can move hands and perform other gestures during the conversation. This avatar was built with different characteristics such has hair color, eyes, skin color, clothes, lips etc.

The public can utilize CyberPoty on the CETAM-EAD website. They also evaluated the data using a PHP-based system that reads data from the AIML interpreter and a Joomla-based data recording website; both programs use the MySQL database. The information gathered covers the months of January to December 2010. During this time, the CETAM-EAD site received 31307 hits, 2038 of which were to the page chatbot, and 939 of these users actually spoke with CyberPoty, accounting for 3 percent of the total, as shown in 2.3.

This Chatbot design, primarily to various expressions and emotions, is used as a new form of information access, assisting teaching-learning activities on the Web, reducing feelings of isolation, and making user interaction more personal. Because

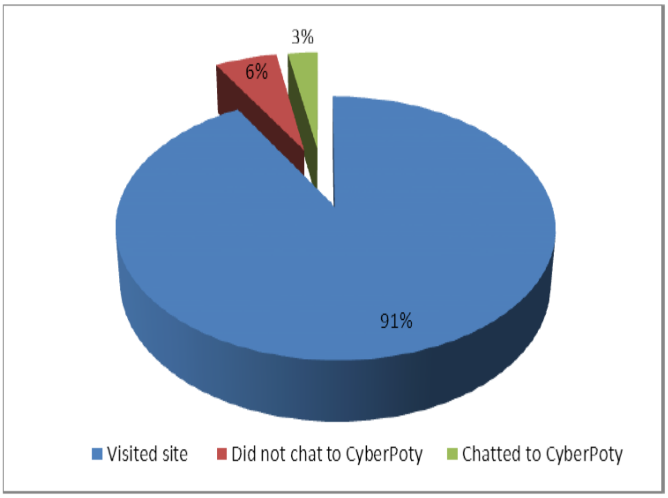


Figure 2.3: Statistics of interaction with CyberPoty [3]

CyberPoty incorporates elements that capture the user's attention, such as visuals, images, music, movement, and emotion, the environment becomes more dynamic and exciting.

3D TALKING HEAD

A **3D Talking Head** by representatives of school of computer science, Nanyang Technological University, Singapore [4], which is used to play a 20 questions game with users. Haptek's PeoplePutty tools (commercial, but inexpensive) were used to make a talking head (full-body figures capable of movements could also be made). Unique modeling, morphing faces, adding accessories (such hats or spectacles), constructing custom gestures, integrating textures or exterior 3D rendering environment backgrounds, and leveraging 3rd party animation systems are all included in this package. Haptek movements, gestures, face expressions, and animation sequences can be programmed and synchronized with speech using JavaScript, Visual Basic, Active-X Controls, C++, or ToolBook [4].

2.4 is the talking head created using PeoplePutty with semantic memory, it looks like a male face with beard and hair. This avatar can perform facial expressions such as smile as shown in 2.4. The only negative factor is, it can not perform any gestures as it does not have hands or a body.

AVARI

AVARI, a virtual receptionist, is developed at "The University of North Carolina" at Charlotte [5], using Haptek's PeoplePutty. AVARI has the ability to get visitors to interact with her, detecting a person's movements in front of her, interacting with

Figure 2.4: Haptek-based talking head was used as an interface to play the 20-questions game [4]

people via verbal and visual aids, and guiding conversations toward a certain goal. AVARI communicates with real speech, and her voice carries through in her tone, facial gestures, and comments. AVARI's appearance, movement, gestures, and voice are rendered via JavaScript calls to the Haptek plug-in for Internet Explorer.

Figure 2.5: AVARI's desk [5]

As shown in 2.5, AVARI appears as a female receptionist. The hardware components are housed in a hollow wooden box that serves as the desk. AVARI's body is made up of a wooden structure that stretches from the desk's top. On the wooden frame is hanging a stuffed blouse that represents a female's upper body. AVARI is a young woman in her early twenties with a youthful aesthetic. Her virtual face appears on a monitor placed at eye level on top of her actual body. On AVARI's workstation, there are speakers for audio output, a microphone for voice input, and a second display for visual signals and prompts. A camera is discreetly positioned somewhat below knee level on the exterior of an average-sized user's cabinet. The entire desk is set on lockable wheels, allowing AVARI to move around.

AVARI had a total of 536 interactions. Around 57% of contacts lasted fewer than 15 seconds, as shown in 2.6. The initial greeting from AVARI's takes 17 seconds, showing that these people contacted her and then left without responding to her first question. This could indicate that about a quarter of the users were too afraid to talk to AVARI. The majority of the remaining 43 percent of discussions consisted of a single dialogue unit.

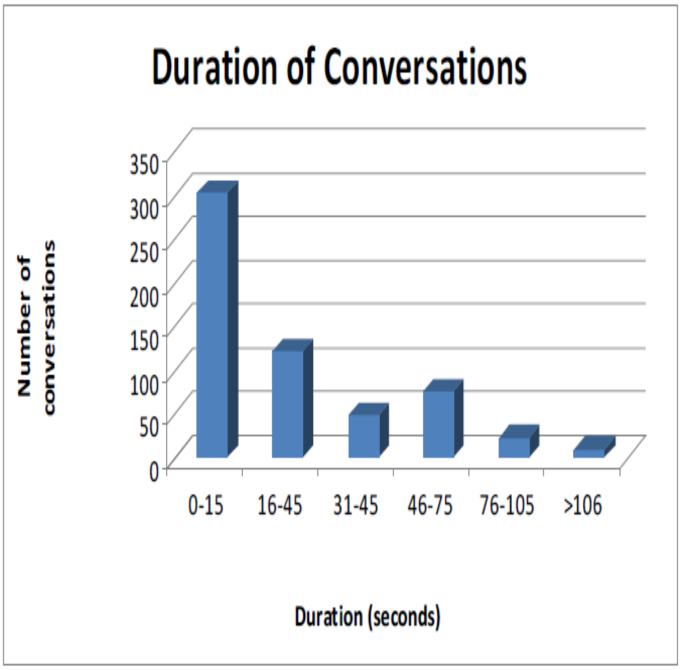


Figure 2.6: Duration of Conversations AVARI [5]

3D TALKING FACE

A **3D Talking Face** is proposed by the representatives of computer science department at University of Palermo, Italy [6], this 3D head model was imported from the FaceGen software, which provides the visemes that correspond to English phonemes. They modified each viseme in order to be compatible with Annosoft's, which is considered state-of-the-art. There were, 1004 triangular polygons in the skull, but 712 were needed for the face and lips. They only animated the face as shown in the 2.7, eliminating the rest of the head, in order to achieve a faster pace. The animation is done with the Java3D Morph class, which is similar to key frame interpolation. The vertices of the face are translated from their beginning location to their final position in the last frame using a linear law similar to. It is feasible to obtain a sequence of frames in this manner. This talking head enables for the translation of the conversational agent's responses throughout the user's dialogue into a suitable 3D facial animation.

Figure 2.7: 3D Talking Face [6]

2.7 shows the 3D model of the created talking face, which is a female face with only eyes, nose and lips. The talking face doesn't have any emotional reactions on his face; it's sole purpose is to pronounce words.

NEVA

NEVA [7], a 3D model system for library, that supports personalization and user-independent services such as library information, technology overview, book search and user ratings, alerts for new arrivals. The characters in Neva are build using Haptek's PeoplePutty, it not only allows for the creation of realistic characters, but it also allows for lip synchronization. Haptek provides Application Programming Interface (API) support for integrating these characters in other languages platforms at the development level. The content creation capabilities are contained in a rich set of "Haptek Hypertext" commands in the API. It's a set of instructions that may be used to create web-based and non-web-based controls.

Neva's system consist of six avatars (see 2.8), and users can choose one of the six avatars available to play the job of librarian. Every avatar has a unique voice, appearance, and expression, which makes the communication more realistic. Every time a new avatar is selected, the interface is given new energy and excitement for the user.

The Neva system is being developed as part of an HCI research field aimed at creating more realistic and individualized, life-like characters in the library. The

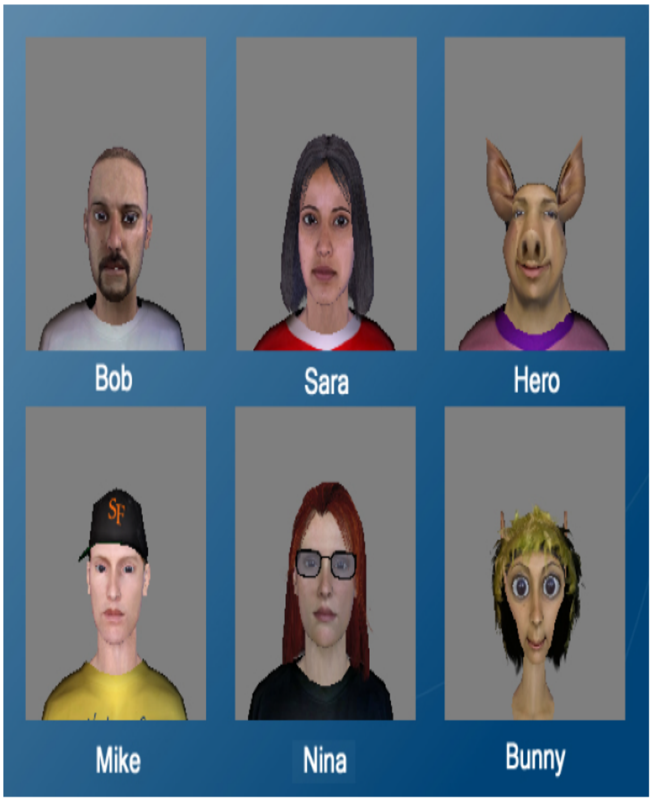


Figure 2.8: A screenshot of Neva when the user is asked to select his or her avatar [7]

prototype was developed and demonstrated by the McLuhan Documentation Center at the ISNM-International School of New Media at the University of Lübeck in Germany. For the users, several dummy profiles were created, and the students were given login chips to evaluate their performance and express their emotions.

Although it wasn't a comprehensive evaluation, the preliminary review of user reactions and input was sufficient to demonstrate Neva's potential as a useful, friendly, and engaging information system. Neva's design encouraged pupils to interact with the system in a natural and intuitive way. The children liked the notion of employing many characters with varied moods and expressions. Nina (2.9), was the most popular and attractive character among the characters, and it gives more formal look with black outfit and spectacles which gives the familiar impression as of a librarian, so she was chosen as the default character for the Neva.

SAMIR

SAMIR [8], a virtual assistant that combines an AI-based Web agent with a 3D realistic, cartoon-like layout, or robotic. This 3D agent can assist customers in

Figure 2.9: Nina: Library assistant [7]

looking for books on a website. SAMIR system is developed using Fanky animation tool, and 3D faces using FaceGen software.

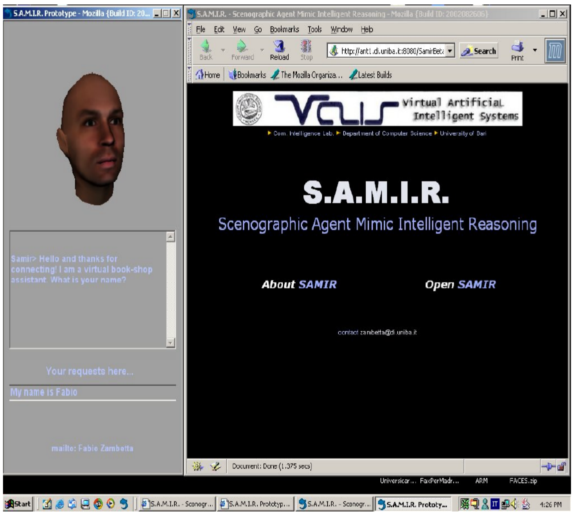


Figure 2.10: SAMIR, a virtual assistant [8]

After developing, users were instructed to interact with SAMIR for a week as part of the study. They were free to speak with the agent about broad issues such as sports, politics, and so on for the first half of the week. Users have been obliged to ask SAMIR for books on Amazon.com in the last three days. At the end of the week, users were asked to fill out a survey and offer comments and ideas regarding their experience.

The outcomes of this survey questionnaire suggest that users, on average, enjoy conversing with an animated 3D agent, and that the majority of our users found SAMIR to be amusing, interesting, and so on. They, on the other hand, do not believe SAMIR is beneficial for searching books, preferring instead to use Amazon.com's traditional search engine. This is hardly surprising, given that our people use Web search engines on a daily basis and are skilled at crafting effective queries.

2.10 shows the SAMIR Web Agent's initial appearance as it starts up; SAMIR introduces itself and asks the user for his or her name for user verification and recognition. As shown in the 2.10, SAMIR is a male faced avatar with only a head and no hair or beard, but it can be able to perform expressions such as happy and disappointment. The system's sole purpose is to create a realistic form of interaction by keeping the 3D face's emotional emotions in sync with the dialogue flow.

Candidates who proposed SAMIR at the department of Informatics at the university of Bari [8], conducted a survey to test the user's acceptance towards the SAMIR, in the experiment users were instructed to interact with SAMIR for a week as part of the study. During the first half of the week, they were free to speak with the agent about anything they wanted, including sports, politics, and so on. Users have been obliged to beg SAMIR for books on Amazon.com in the last three days. Users were asked to fill out a survey at the end of the week to share feedback and ideas on their overall experience.

Users preferred to converse with an animated 3D agent, according to the results of this survey questionnaire (most of our users thought of SAMIR as funny, interesting, etc.).

STEVE and ADELE

The Center for Advanced Research in Technology for Education (CARTE) at the USC Information Sciences Institute has created two animated pedagogical agents: **STEVE** (Soar Training Expert for Virtual Environments) and **ADELE** (Agent for Distance Learning: Light Edition).

STEVE 2.11, is a virtual reality system that allows students to engage with each other in a networked immersive virtual world. It has been used in military training activities, such as controlling the engines on US Navy surface ships. Interactive digital settings allow for dynamic interactions between humans and agents; students may see and hear the agents in stereoscopic 3D, and the agents depends on the virtual environment's monitoring technology to keep track of the student's position and orientation[1][9].

STEVE is integrated with Lockheed Martin's 3D display and interaction software, USC Behavioral Technologies Laboratory's simulation authoring software, and Entropic Research's speech recognition and generation software to create a rich virtual environment in which students and agents can interact in instructional settings.

ADELE 2.12, on the other hand, was developed to run on desktop systems with traditional interfaces, extending the reach of pedagogical agent technology [39]. ADELE is a program that runs in a student's Web browser and is intended to be used in conjunction with Web-based digital learning materials. ADELE-based postgraduate medical courses in medicine and graduate level geriatric dentistry are

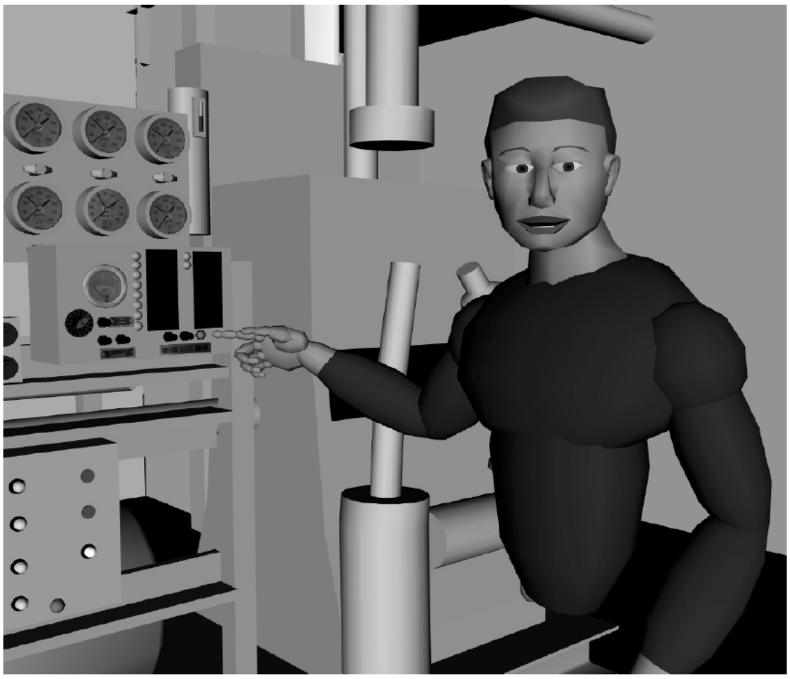


Figure 2.11: STEVE [9][1]

produced, with more courses scheduled for creation at the University of Southern California and the University of Oregon[1].

Representatives of CARTE, at the USC Information Sciences Institute [39], conducted a survey with the sample size of 24-25 students. The survey questions are based on a scale from 0-4 (0-strongly disagree, 4-strongly agree). According to the majority of students, it would be a good distance education tool (0-4%; 1- 8%; 2-16%; 3-44%, 4-28%) and valuable in class as a preparatory tool(0-4%; 1- 17%; 2-8%; 3-38%, 4-33%), but it would not be enough to replace a class lecture. ADELE's suggestions were useful, and the students loved her explanations(0-0%; 1- 4%; 2-33%; 3-21%, 4-42%).

In general, students believed that the system was simple to use(0-0%; 1- 8%; 2-8%; 3-42%; 4-42%), with a user-friendly design (0-0%; 1- 4%; 2-24%; 3-52%; 4-20%) and easy navigation between different views - chart, patient, and progress - but they struggled to figure out what to do (0-12%; 1- 16%; 2-24%; 3-40%; 4-8%) and didn't think two of the system's components were really useful. The latter remarks imply that more guidance is required than what the system currently offers.

Presenter Jack

A virtual human presenter was developed by Tsukasa Noma and Norman I. Badler [10]. Figure 2.13 displays a wide range of distinct deictic motions. Presenter Jack can use his index finger to point at specific components of his visual aid, just like

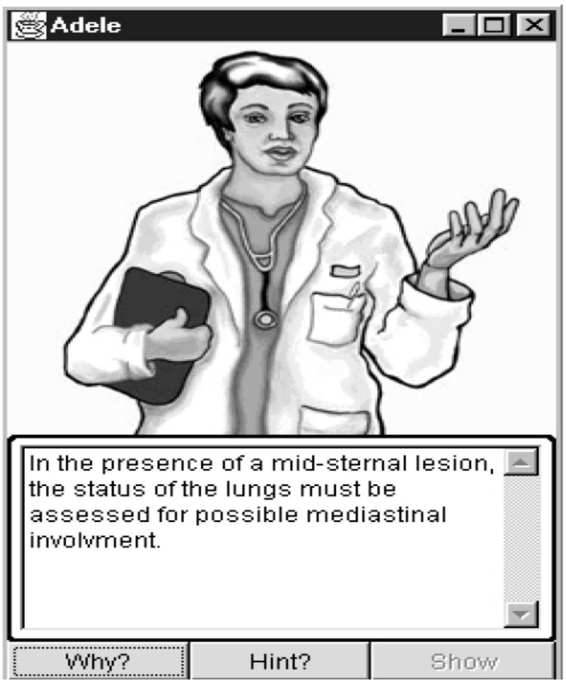


Figure 2.12: ADELE [9][1]

STEVE and ADELA can. Additionally, he can gesture to show a flow on a map or chart by moving his hand while pointing with his palm facing the visual aid to suggest a wider region.

Furthermore, he seamlessly incorporates these gestures into his presentation by moving to the particular object before his speech calls for the deictic gesture and adaptively selecting the best hand for the gesture based on a heuristic which significantly reduces the distance between the current body position and the following one in the presentation as well as visual aid occlusion.

Jack was implement using SGI's Onyx Reality Engine. Presentation animations were created in real-time at a frame rate of 30 frames per second using speech input and commands. The TrueTalk Text-To-Speech system from Entropic Research Laboratory was utilized for voice.

PaT-Nets (Parallel Transition Networks) were used to control the presenter Jack. These networks are finite-state automata with simultaneous executions. With each tick of the clock, they demand action and conditionally change states. Noma and Badler [10] re-implemented the Pat-Nets using C++, since during that time of existing implementation were inappropriate. These Pat-Nets consist of different networks to control the different parts of the body. The networks such as 'SpeakNet' is to control the lip sync and speech, 'SeeNet' is to move the head position to point the specific components on the graph, and 'GestureNet' is to control the overall gestures such as walk, hand and arm movements.

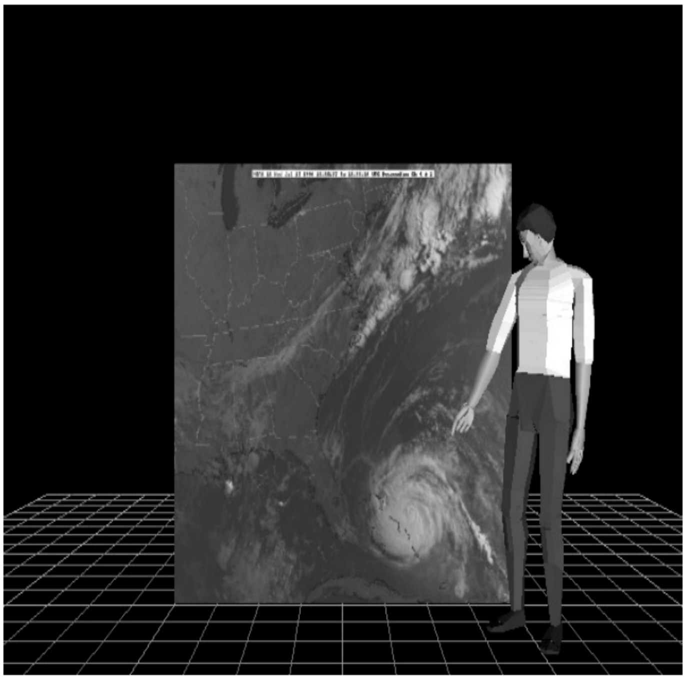


Figure 2.13: Jack, Virtual Human Presenter [10]

Agents by North Carolina State University

Three animated pedagogical agents have been created by the IntelliMedia Initiative at North Carolina State University: Herman the Bug [11], Cosmo [12], and WhizLow [13].

Figure 2.14: Herman the Bug [11]

In Design-A-Plant, a learning environment for the subject of botanical anatomy and physiology, Herman the Bug resides (Figure 2.14). Children engage with Design-A-Plant by graphically putting together unique plants that can survive in a given range of environmental circumstances.

Herman is a chatty, eccentric bug who burrows into plant structures and gives kids advice on how to solve problems. Herman observes the kids as they construct plants and offers clarifications and pointers. He demonstrates a wide variety of skills while explaining ideas, such as walking, flying, shrinking, enlarging, swimming, fishing, bungee jumping, teleporting, and acrobatics.

Cosmo offers assistance in solving issues with the Internet Protocol Advisor (Figure 2.15). Students navigate through a number of subnets while learning about network routing processes while interacting with Cosmo. They guide a packet via networks of linked routers when given one to escort through the Internet. At each subnet, they may examine nearby routers and transmit their packet to a certain router. They get an understanding of the foundations of network architecture and routing processes by making judgments regarding issues like address resolution and traffic congestion. Cosmo explains how computers are linked together, how routing works, and how traffic concerns come into play. He is helpful, encouraging, and occasionally a bit sarcastic.

Figure 2.15: Cosmo [12]

Cosmo was created to research spatial deixis in educational agents, or the capacity of agents to flexibly blend gesture, movement, and voice to refer to things in the environment while providing problem-solving guidance.

The 3D learning environment CPU City is home to the WhizLow agent (Figure

2.16). The motherboard that houses the RAM, CPU, and hard drive is displayed in the 3D environment of CPU City. It concentrates on system procedures including the fetch cycle, page faults, and virtual memory, as well as the fundamentals of compilation and assembly. It also includes information on architecture, which includes the control unit (which would be decreased to a simple decoder), and an ALU.

Figure 2.16: WhizLow [13]

WhizLow can do activities for students by gathering data and command packets, delivering them to predetermined destinations like registers, and connecting with hardware that performs arithmetic and comparison operations. He works with address and data packets, which can include variables with integer values. In less than a second, after the work specification is finished, he starts carrying out the student's assignment.

PPP Persona and WebPersona

The PPP (Personalized Plan-Based Presenter) Persona [14] is an animated persona that André, Rist, and Müller created for the DFKI (German Research Center for Artificial Intelligence) to provide online assistance instructions. The agent directs the student through web-based materials, utilizing pointing motions to highlight certain webpage items and synthetic voice to provide comments (Figure 2.17). The core PPP system creates interactive multimedia plans for the agent to deliver; the agent then adaptively carries out the plans, changing them in real time in response to user actions like moving the agent across the screen or asking follow-up questions.

Figure 2.17: PPP [14]

The usage of animated characters for information presentation over the Web is now possible, especially with the development of Web browsers that can run programs embedded in Web pages. A Web presentation may include dynamic media like audio, animation, and video, all of which must be shown in a coordinated way both geographically and temporally. Additionally, coordination is required for dynamic presentations that include text, images, video clips, or other media elements that a lifelike figure points to and audibly remarks on.

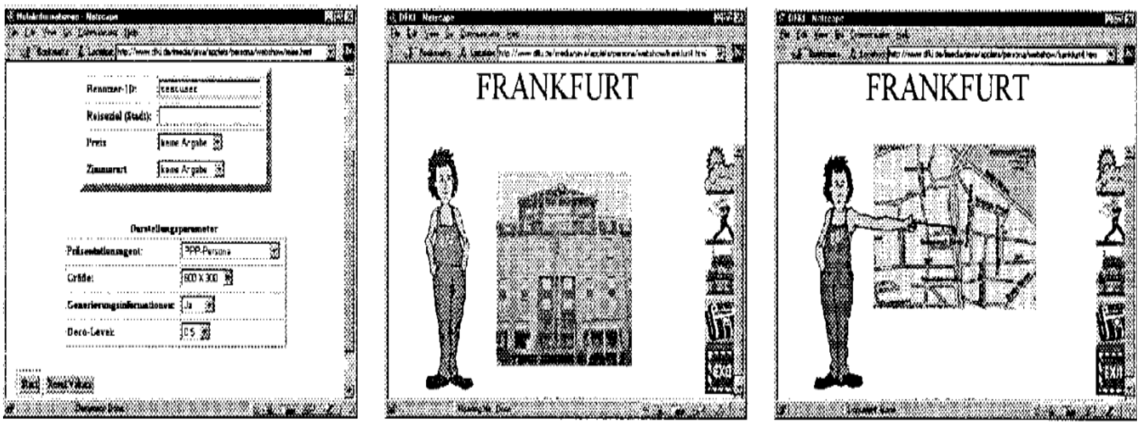


Figure 2.18: WebPersona in the role of a personal travel agent [14]

The idea was to provide the client a Web page that contains the chosen media objects, together with instructions for how they should be organized and time-scheduled, and a presentation runtime engine (such as a Java applet) that displays the media objects in accordance with a layout specification.

The first hotel options are displayed by WebPersona (Figure 2.18, middle image). Depending on what it discovers on the Web, these displays will change in shape and content. AiA (Adaptive Communication Assistant for Effective Infobahn Access) may occasionally even integrate information units that have been gathered from many sources into a single presentation item. For instance, a hotel's address is entered into a different Web search to get a map showing where the hotel is situated (right-side of Figure 2.18).

With WebPersona, presentation scripts and navigation structures are built automatically from pre-written document snippets and things kept in a knowledge base, which is innovative.

As opposed to the majority of traditional Web displays, following a navigation link does not result in paging. Instead, a new presentation script for the agent is delivered to the client-side presentation runtime engine together with the necessary text and visual content.

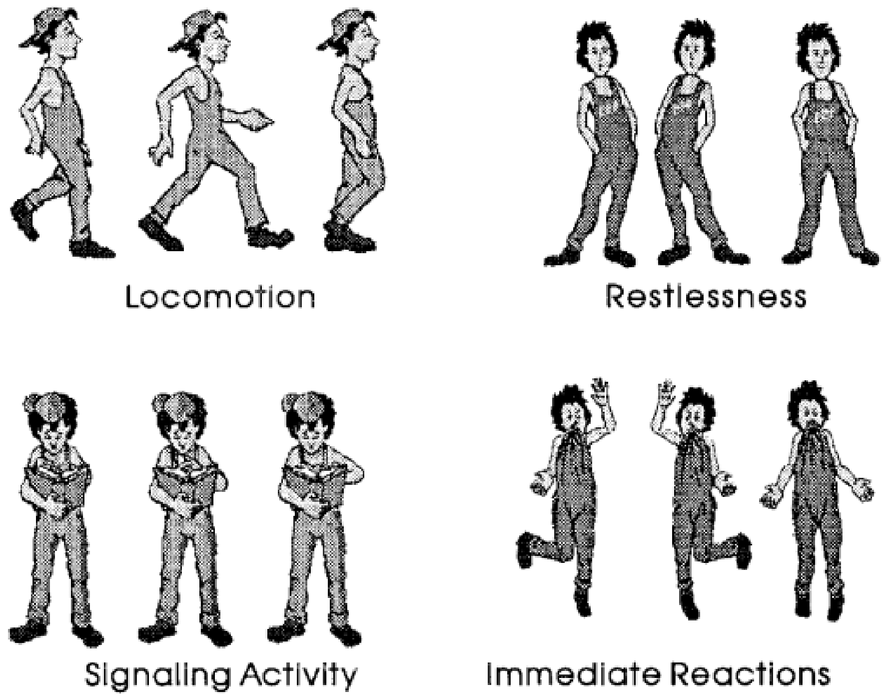


Figure 2.19: Classification of Persona self-behaviors [14]

Figure 2.19, shows the activities performed by the WebPersona depending on the user request.

VCATs

Virtual Cultural Awareness Trainers (VCATs) from Alelo are a wonderful illustration of how educational agents may play several roles and use various skills for each position [40] [41]. In VCATs, students learn about many cultures and put that information to use in simulated interactions with members of those cultures. Throughout the course, a Virtual Coach (Figure 2.20, left) offers direction and comments in addition to narrating the lesson materials.

Figure 2.20: Classification of Persona self-behaviors [14]

The learner's avatar engages in cross-cultural conversations with virtual role-players during the role-play simulations (see, for instance, Figure 2.20, right), with the Virtual Coach's guidance and feedback.

Over 50,000 trainees have taken VCAT courses, and VCATs have been created for more than 80 different nations. As a result, they offer helpful information on agent design best practices. There is no one right answer to whether agents should be animated, static visuals, or disembodied voices because it plainly depends on the purpose of the agent. It makes sense for virtual role-players to be disembodied voices in relatively few situations. On the other hand, there are several realizations for virtual coaches and instructors.

There are several realizations present in the VCAT Virtual Coach situation. The Virtual Coach first appears in the course as an animated figure. The Virtual Coach eventually disappears and becomes less intrusive as the student grows accustomed to working with her. She speaks in the third person when she serves as the narrator. She mostly plays an off-screen role when teaching virtual role-plays, appearing on the screen only when the student asks a question. When she does emerge, she is shown as a still image. She completely disappears at the completion of the instruction, and students are then required to present that they can do the work without assistance.

3D Animated agent

A 3D agent was developed by Vicomtech-IK4 Research Center, Spain [15]. WebGL technology was chosen to render the 3D virtual agent into any browser that supports it without the need for extra plug-ins. The components that make up the Animated Agent Engine were created using the JavaScript programming language while adhering to all HTML5 and Web3D standards. On the contrary to the development, this system was not validated with real students.

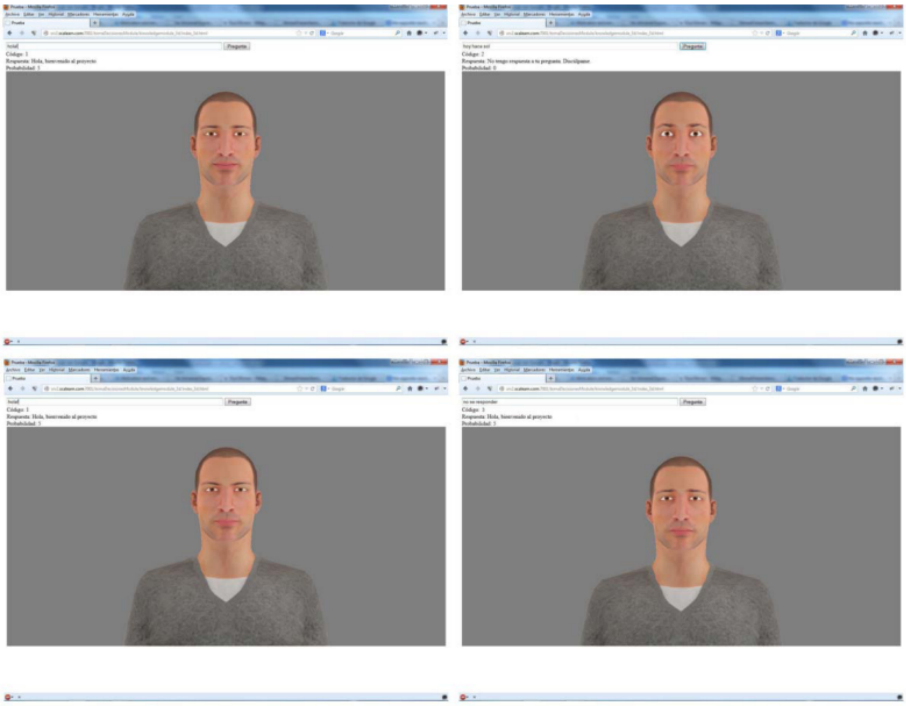


Figure 2.21: Emotions from the Animated Agent [15]

The animated agent can perform four facial expressions as shown in figure 2.21: happy, sad, angry, surprise. The role of the agent was divided into three states [15]:

Explanation state: the animated figure will welcome the class and go through any essential details. The agent will make many motions that are representative of natural behavior, such as iconic or deictic gestures, to make this explanation more acceptable to the learner.

Evaluation state:based on the replies from the students, the virtual agent responds.

Waiting state: this state is active while the virtual agent is not analyzing or elaborating.

Other virtual avatars

A 3D chatbot is developed by the student of Howest University of Applied Sciences (BELGIUM) using the Unity game engine for modelling 3D avatar and AIML, Rivescript for chatbot, Google Cloud Speech for speech recognition. This chatbot assists students in overcoming common issues that the university students face, such as procrastination, lack of study preparation, and communication issues [33].

MMD (MikuMikuDance) Agent [34], a web-based online voice communication robot that includes a 3D avatar and supports artificial intelligence, speech synthesis, speech recognition, and motion reaction. This 3D avatar is developed using WebGL, chatbot using AIML, speech recognition in Hypertext Markup Language (HTML5).

GeriJoy, an avatar looks like a cat or dog, is a caregiving companion for elder people, designed to meet many of the unique issues that elders and their families experience. The GeriJoy Companion avatar is meant to be a caring and supporting buddy. It can hear and remember, what the user is saying, such as grandchildren's names, favorite destinations, and TV series. It keeps track of the elderly's emotional states, such as loneliness or confusion, and can give entertaining and sympathetic discourse [25].

Medical Avatar [42] is a website that offers online health monitoring and maintenance services. It can recognize health symptoms on the patient avatar as the user interacts with a 3D image to map out his ailment or complaints. Both GeriJoy and Medical avatar are supported from the backend, but enabling self-service for at least some tasks can save time by processing simple requests, which is especially beneficial for frequent users.

There are other 3D agents in different fields, such as Shona [7], a flexible presentation avatar. A 3D virtual real estate agent created by Bickmore and Cassell employs gestures to accompany the material [43]. A 3D teaching assist that teaches tasks within a shared virtual setting, Rickel and Johnson use deictic, eye gazing, and gestures [29].

2.1 Appearances of the pedagogical agents

The E-learning environment is significantly influenced by the design and appearance of the avatar or pedagogical agent, and the function of the agent can greatly increase student's learning outcomes. With appropriate design features in pedagogical agents, students can be more involved in learning, but the design must be integrated with innovative features in animation, characters design, movement, natural voice, and nonverbal communication [28]. The agents that are designed based on different forms such as 2D & 3D characters, Human like agents and the communication with these agents can be using text and voice. Some questions regarding the design of the agent to be addressed:

1. How should be the physical appearance (age, gender and ethnicity) designed ?

2. How the gesture and emotions of agent's effect the learners ?

To address these questions, [16] designed 4 pedagogical agents having the same voice, animation, and texts, the only difference being the race (African-American, Caucasian) and gender of the characters (male, female) 2.22. These are agents are developed using Microsoft agent character builder, Poser 5, and a 3D character design tool.

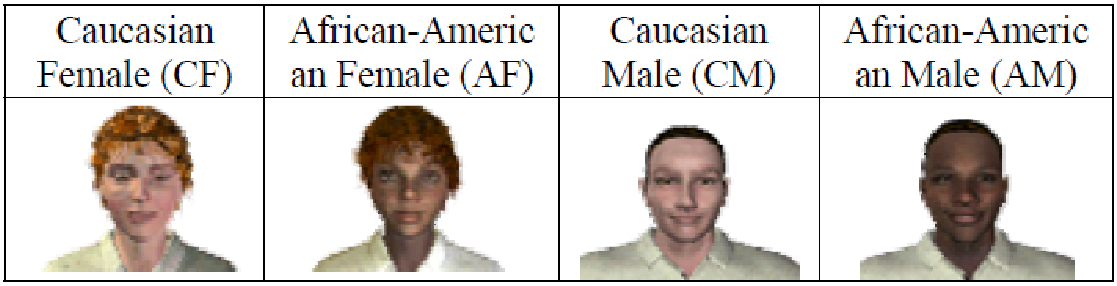


Figure 2.22: Four agents [16]

A survey was conducted with 139 pre-service teachers enrolled in an introductory educational technology program at two big southeast universities in the United States were among the participants. Males made up 27.3% of the participants, while females made up 72.7%; Caucasians made up 59.7% of the participants, while African-Americans made up 40.3%. Students who worked with agents of the same ethnicity thought the agents were more engaged and friendly. These findings imply that male agents are more likely to provide positive learning outcomes. Male students thought Caucasian agents were more receptive to new ideas than African-American agents, but female students thought the reverse.

The interaction of student ethnicity and agent gender revealed that African-American students perceived male agents to be more neurotic than female agents, but Caucasian students perceived male agents to be more neurotic than female agents. Overall, the results indicated that learner perceptions of agent personality, motivating traits, and perceived effect on the learning process are influenced by the gender and ethnicity of educational agents [16].

Further, [17] also conducted a survey on eight 3D pedagogical agents created with Poser which had three characteristics: gender, realism (human, cartoon), and ethnicity (African-American and Caucasian)2.23. 183 undergraduate students (39.8% male, 61.2% female; 54.1% Caucasian, 37.2% African-American) enrolled in computer literacy classes at two public southeast universities participated in this study. One of the two universities is a typical African-American undergraduate university. The participants' average age was 20.45 years old.

The choice of the agents preferred by the students according to the [17] as follows:

- African-American females (AAF) preferred African-American female realistic (AAFR) agent with 50%, followed by 15.9% African-American male realistic (AAMR) agent and 13.6% of Caucasian man realistic (CMR) agent.
- African-American males (AAM) preferred an African-American female realistic (AAFR) agent (50%) and African-American male realistic (AAMR) agent (40%)
- Caucasian females (CF) were more likely to choose a Caucasian female realistic (CFR) agent (24.2%) or a Caucasian male realistic (CMR) agent (29%).

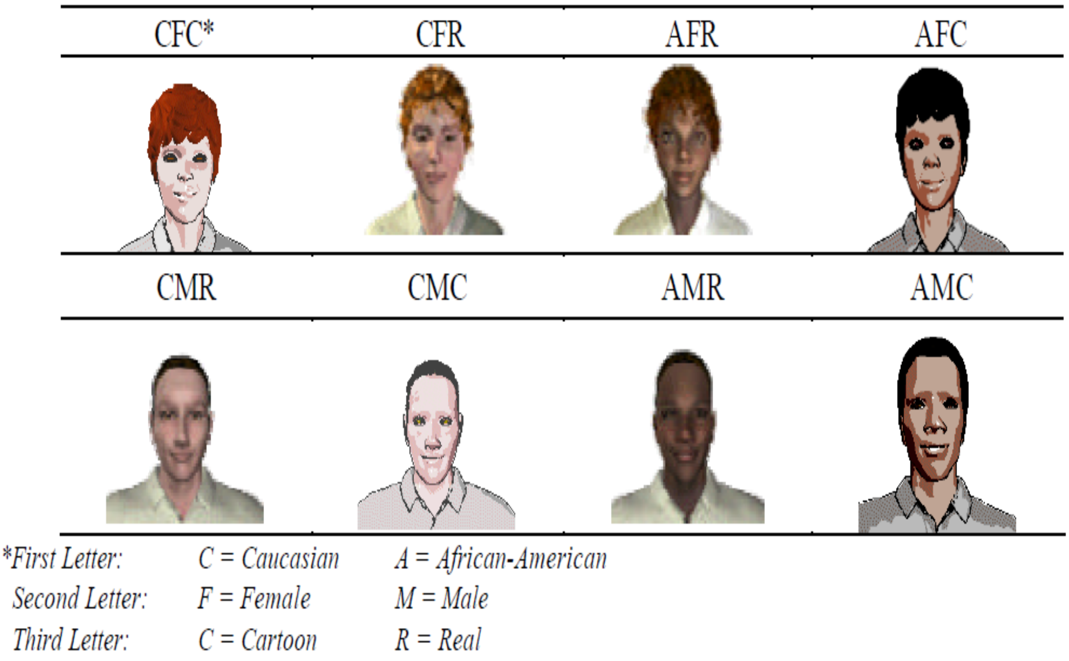


Figure 2.23: Cartoon and Human agents [17]

- Caucasian males (CM) opted African-American female realistic (AARF) agent (24.3%), African-American male realistic (AAMR) agent (24.3%), and Caucasian female realistic (CFR) agent (21.6%).

A further survey summarized that agent's gender, age, characteristics, personality plays a key role in the choice of agent by the students. For example, African-American opted the agent with which they can relate their gender and ethnicity, and female learners choose the agent with which they can relate their human instructor.

Roxana and Terri [18] conducted a survey to test their hypothesis on the gender and ethnicity by considering 10 different APAs (Animated Pedagogical Agent) as shown in figure 2.24. Their survey includes 56 undergraduate students who were chosen from a southwestern university's Educational Psychology Subject Pool made up the participants. With a mean age of 25.91, there were 16 males and 40 women. 26 White Americans (W), 21 Hispanics (H), 3 Native Americans (NA), 2 African Americans (AFA), 1 Asian American (ASA), and 3 were from other different ethnicities (O).

In each session, participants were assessed in groups of 1-4. Each member was given a unique computer station at random. The participant questionnaire was first filled out by participants at their own paces. Second, the researcher gave participants oral instructions that the computer will display a selection of personal agents and prompt them to group the agents into one of many categories. The presentation would begin by pressing the "Return" key, it was explained to participants when they signed in by inputting their full names. Third, the computer displayed the above-mentioned multimedia software. Following the conclusion of the multimedia

Table 2.2: Survey results for realistic vs cartoon agent [7]

		Realistic				Cartoon			
		CF	CM	AAM	AAF	CF	CM	AAM	AAF
Male(M)	Caucasian(C)	21.6%	13.5%	24.3%	24.3%	2.7%	5.4%	5.4%	2.7%
	African-American(AA)	4.2%	12.5%	33.3%	50%	0%	0%	0%	0%
Female(F)	Caucasian(C)	24.2%	29%	9.7%	16.1%	3.2%	3.2%	12.9%	1.6%
	African-American(AA)	2.3%	13.6%	15.9%	50%	2.3%	2.3%	9.1%	4.5%

presentation, attendees were thanked and given a debriefing.

Table 2.3: Percentage of perceived ethnicity and gender for 10 APAs [18]

Agent number	Perceived ethnicity						Perceived gender		
	AFA	ASA	H	NA	W	O	F	M	O
1	5.4	0	94.6	0	0	0	0	100	0
2	0	92.6	1.8	0	3.6	1.8	100	0	0
3	0	0	0	0	100	0	0	100	0
4	100	0	0	0	0	0	100	0	0
5	0	1.8	1.8	94.6	1.8	0	0	100	0
6	0	0	100	0	0	0	100	0	0
7	0	94.6	0	0	0	5.4	0	100	0
8	0	0	0	0	94.6	5.4	100	0	0
9	100	0	0	0	0	0	0	100	0
10	0	3.6	0	91.1	0	5.4	100	0	0

The percentage of participants in each of the gender and ethnic groups that correctly identified each of the 10 agents is summarized in Table 2.3. The table shows that all participants had the same perception of the ethnicity of 4 among the ten characters and the perceived gender of the ten characters. For eight characters, there was less than a perfect agreement on their perceived ethnicity, although a significant number of students (more than 90 %) believed that each of them belonged to a certain ethnic group.

The majority of people's perceptions of agents 1 and 6 were that they were Hispanic, while those of agents 2 and 7 were Asian Americans, those of agents 3 and 8

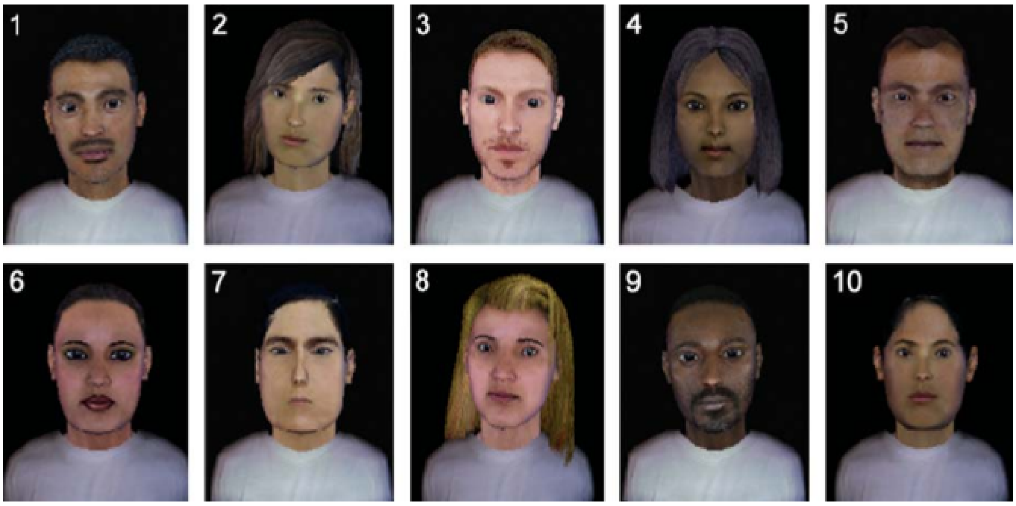


Figure 2.24: Ten APAs used in the preliminary study and main experiment [18]

were White, those of agents 4 and 9 were African Americans, and those of agents 5 and 10 were primarily viewed as Native Americans.

In the table 2.4, it is shown that the 14 participants out of 40 are chosen the agent of same ethnicity as their own, 17 participants out of 40 chosen the agent that resembles their own gender, and only 7 out of 40 opted the agent with same ethnicity and gender as theirs. Also, no participant opted to the system without image. This study concluded that some students tend to interact with the APAs which resembles their own ethnicity and gender.

In a study conducted by [19] with four agents differing by age and gender 2.25. These agents can be found on MathGirls website, which is a web-based environment developed by Kim for high school girls to solve the algebra problems in classroom as well as at home.

In a survey with nearly 100 students (male and female) showed that students tend to opt female agents: students who picked female peer agent are 45%, 32.5% opted female teacher agent, 20% students preferred male peer agent and only 2.5% students selected male teacher agent. This indicates that high school pupils prefer to deal with a female agent, maybe since the majority of high school professors are female.

Also, a survey conducted by [44] with sample size of 75 students concluded that the avatar must include the characteristics such as engaging with learners, person-like outlook, credibility, and instructor-like agent.

2.2 Impact of Appearances on Learners

In the previous section, it is cleared that the appearance, gender, and ethnicity plays a key role in opting an agent by the students. Now, the question need to be addressed is why the design of the agent or avatar this way? and how it impacts

Table 2.4: Type of APAs chosen by participants [18]

Number of participants	Participant ethnicity	Participant gender	Same ethnicity	Same gender	Same ethinicity and gender	No image
1	ASA	F	0	0	0	0
2	AFA	F	1	1	1	0
9	H	F	6	3	2	0
3	H	M	1	2	0	0
4	NA	F	3	3	3	0
1	NA	M	0	1	0	0
13	W	F	3	5	1	0
5	W	M	0	1	0	0
2	O	F	-	0	-	0
1	O	M	-	1	-	0
Total:40			14	17	7	0

Table 2.5: Survey results for Peer vs Teacher agent [8]

	Female peer	Male peer	Female teacher	Male teacher
Students opted	45%	20%	32.5%	2.5%

the learners?

Generally, when humans communicate with one another, they utilize a variety of nonverbal clues to draw inferences about one another. Any observable trait or object, such as haircut, hair color, existence of spectacles, jewelry, clothes, ethnicity, gender, or voice intonation, might provide nonverbal clues [45]. Individuals can create impressions about others based on the sum of nonverbal clues [30].In the same way, when the students interact with an educational agent, the first thing they notice are its evident visual features, such as gender, facial gestures, ethnicity, hairstyle and color, and the outfit of the agent. As a result, preconceptions and expectations of agent effectiveness, trustworthiness, and intellect may be activated as a result of these qualities [45].

Animated pedagogical agents, in general, are lifelike avatars that perform actions such as emotive reactions, interaction, and effective pedagogy [46]. Initially, agents who appear to be concerned about students' development may persuade them to

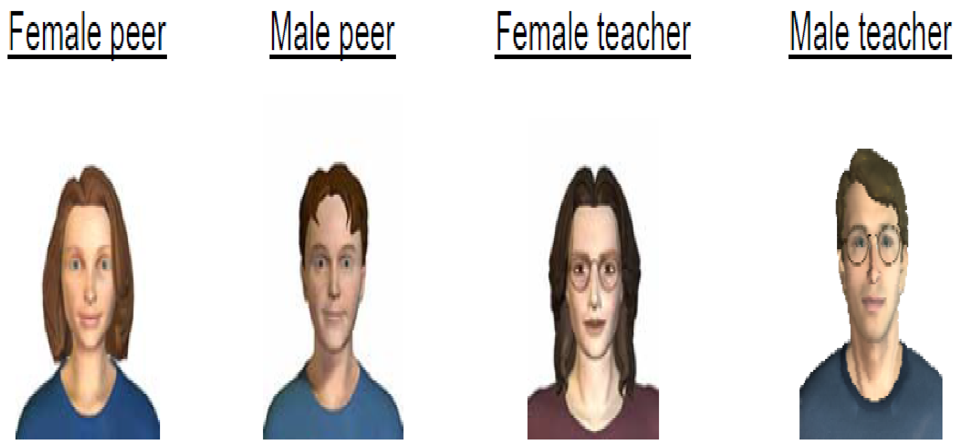


Figure 2.25: Agents differing by age and gender [19]

be concerned about their own. Furthermore, agents that are sensitive to students' emotions can give information to keep learners engaged, and the agents who are enthusiastic about the subject are often more likely to elicit the same passion in their students. Finally, agents with complex and engaging characters make learning more interesting for students.

The agent should be designed in a way such that the agent interact and encourage students to participate actively in the learning process so that the agents and learners can work together to complete tasks, solve issues, and build explanations. These interactions with the agents will help students to trust and use the agent [46].When a pedagogical agent is dynamic and adaptive, then the teaching and learning will become more effective.

To address the question of why the agent or avatar should be modelled in a particular way, the proposed candidates from the National Taipei University [47] conducted a survey with 284 students as participants. Out of this, 121 were male and 163 were female with average age of 22.

The study by [47] presented some hypotheses such as the impact of sensual appearances on effective learning and learners' views of the agents' appearance, credibility, and competency is moderated by the gender of the students and the educational agents, Students' views of trustworthiness and expertise are negatively influenced by pedagogical agents with sensual appeal.

For this study, six agents were used with different levels of outlook such as demure, seductive, and overtly sensual. The same avatar with the same features was used to create pedagogical agents of the same gender. The only thing that differentiated them was their clothing and accessories. In fact, two voice performers suited to each agent's gender prerecorded the agents' voices. The pace, speech, and linguistic style of both male and female voices were comparable. Lip synchronization was achieved by combining the pictures and sounds. These agents have to explain the different harmful effects of smoking, and the teaching material used was a computerized video. Different measures were taken into consideration, such as trustworthiness (credibility), attractiveness, expertise, intention and attitude.

The results from the survey showed that the male students perceived overtly sensual female agent has more attractive, trustworthy and expertise, which is completely opposite for female students. When the results of all students with female agent is considered, then it indicated that an overtly sensual agent is less trustworthy than a demure agent with an equal amount of expertise, but still students felt demure agent is less attractive than an overtly sensual agent.

For male agents, it indicated that both male and female students considered the demure agent to be more trustworthy and attractive but seductive agent as more expert than the demure and overtly sensual agent, for example, an agent which gives a formal impression with formal attire as a tutor has more probability of gaining learners than the agent with informal attire. This indicates that the appearance of an agent will play a key role in the learning process.

A study conducted by [15], which is mainly focused on the appearance of the pedagogical agent.The initial objective of the experiment was to determine if the presence of a pedagogical agent increases learner motivation and learning outcomes by contrasting various groups that studied using a pedagogical agent with those who learned the same knowledge by reading on-screen text (control group, no agent).

From the previous studies, it can also be concluded that **attractiveness**: how attractive should an avatar be designed, **credibility**: how the design of an agent can gain the trustworthiness of learners, and **expertise**: how the design impacts the learners, all these criteria play a major role in designing an avatar.

2.3 Empirical Analysis on the design criteria of the Avatar

An online survey has been conducted with the international university students consist of 54 males and 35 females. The survey consists of 10 questions (refer to 7) that are related to 3D agents. These questions were based on the state of the art of previously developed agents. The questionnaire also asks about the users' age, ethnicity, and educational background. Furthermore, the questionnaire asks the student's age, gender, and agent type preference. The literature review forms the basis for the questions regarding the agents. The survey form was made using free web tools for this study. The data is automatically analyzed by the software, which then produces the graphs.

According to the survey, 68.18% of students have used standard chatbots and only 20% of the students used the 3D chatbots.

For the question about the students whether they want to use 3D agents or standard chatbots, 63.64% of students are interested to use the 3D agent 2.26.

For the question, if they prefer their own ethnicity to interact, 68.89% of the

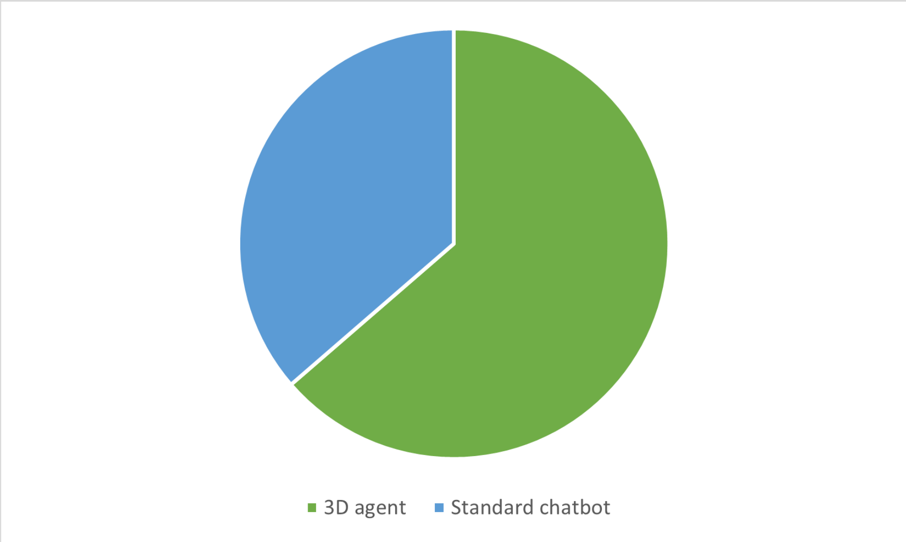


Figure 2.26: Students preference

students preferred to communicate with the agent of their own ethnicity related 3D agent.

One of the most important questions was about the gender preference of the agent. Interestingly, 62% of students opted that the gender is not important, and the 20% of the students opted for male agent and 18% opted for female agent as shown in 2.6.

Table 2.6: Gender preference

	Male agent	**Female agent**	**It does not matter**
Gender	20 %	18 %	62 %

A question regarding the outlook of the agent was also including in the survey. 53% of students opted that the outlook also does not matter, 20% opted for human agent, and 27% of students opted for animated agent as shown in 2.7.

Table 2.7: Agent preference

	Human agent	**Animated agent**	**It does not matter**
Agent	53 %	27 %	20 %

In the end, a question regarding the age of the agent was presented and 38% of students opted for does not matter option, 36% opted for the age between 19-24 years, 24% opted for age between 25-30 years, and only 2% opted for above 30 years as shown in 2.8.

Table 2.8: Age preference

	19-24	**25-30**	**Above 30**	**It does not matter**
Age	38 %	24 %	2 %	36 %

2.4 Derivation of Design Criteria

The previous sections provide an overview of how and why the avatar or agent should be designed in a particular way to impact the learners. For instance, an agent or avatar should be designed in a way that it should attract and engage the students, include person-like features such as facial features and expressions, must be trustworthy, and it should resemble an instructor.

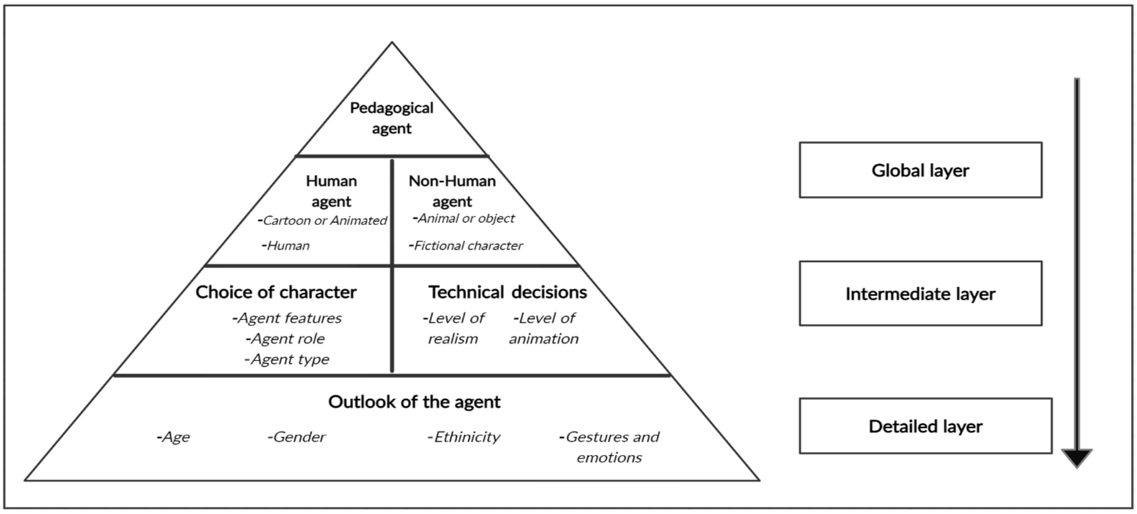


Figure 2.27: 3-Layered Pedagogical Agents Levels of Design (PALD) model

In a Virtual Learning Environment (VLE), a well-designed pedagogical agent can lead to effective learning experiences [48]. In 2011 Heidig and Clarebout [49] developed the Pedagogical Agents-Levels of Design (PALD) paradigm as a framework for designing pedagogical agents. Following PALD model, Kaliyamah Raman et al., [48] designed a conceptual framework called Kawaii-Style Pedagogical Agents. Both Kawaii-Style Pedagogical Agents and PALD model are used as basis for the construction of 3-Layered PALD model, as shown in 2.27.

The PALD model consists of three layers: a global layer, an intermediate layer, and a detail layer. The global layer represents the whether the agent should be human or non-human in the required learning scenario. In the intermediate layer, it's all about the choice of character, such as agent feature, role (tutor, student), type (real or fictional character) and technical choices including animation quality, life-likeness, partial display, and level of realism are considered. In the final layer, detailed characteristics (outlook) of the agent such as age, gender, ethnicity, gestures and emotions are determined.

As per study described in the section 2.1 and section 2.2, appearance of an agent plays a vital role in motivating and influencing the learners. As per survey in 2.1 students preferred a human looking alike agent over the animated agents. So, this will be the first criteria for designing the agent for this project.

- The first criteria for the proposed agent will be Human agent [17].

Students' motivation enhanced when the teaching agent resembled them in appearance[50]. Students are more likely to choose a pedagogical agent who is in their age group[51]. Furthermore, learning and motivation are linked, and utilizing a pedagogical agent of the same age can help to improve both[52]. So, age of an agent will be the second criteria.

- The second criteria will be the age of agent, which is between 20-30 years [19].

As per the survey in section 2.1, gender and ethnicity[53] also plays a crucial role in the virtual learning environment. According to the survey, students preferred the opposite gender and the ethnicity resembles the students. So, these are the other criteria.

- The proposing system will have two agents, both male and female agent [17][19].
- The ethnicity and the race of the agent will be Caucasian male and Caucasian female [16][17].
- Other criteria such as the agent's role, features, and level of realism of the agent[17] also need to be considered. The proposed agent is a mentor or assisting agent with the features such as emotions and gestures.

According to the literature review, all these criteria improves the social interaction between educational agents and students is a powerful motivator for students to take an active role in the learning process.

According to the survey from section 2.3, student preferred to use 3D agent over standard chatbot. The students did not concern about the age or gender of the 3D agent, but they preferred human agents over animated agents.

3 Concept and Implementation Steps

This chapter provides a series of implementation steps for designing a 3D avatar. The process flow is follows as shown in 3.1.

For this project, AutoDesk Maya is used as the 3D modeling, animation, and rendering software. There are other modelling tools available like 3Ds Max and Blender. Table 3.1 describes the difference between the three tools.

Table 3.1: Maya vs 3ds Max vs Blender [22]

Comparison	**Maya**	**3Ds Max**	**Blender**
Compatibility	Windows and Mac	Windows and Mac	Windows, Mac and Linux
Interface	The GUI is difficult.	Less difficult than Maya.	Same level of difficulty as Maya
User Experience	Maya is difficult to learn	Learning Max is simple as, unlike Maya, it starts displaying automated outcomes after only a few steps	Blender is also difficult to learn
Features	3D animation and texturing tools	3D architectural designs, models, and engineering models	Blender has more animation and visual effect features, which are aimed specifically towards the film and entertainment industries
Availability	Licensed	Licensed	Free to use
Usage	For 3D modelling and large professional projects	For game development and architecture design	Designed primarily for small businesses interested in 3D animation and visual effects.

Maya, Max, and Blender are three different types of 3D modeling software. Maya and 3Ds Max are from AutoDesk software foundation, whereas Blender is from

Blender software foundation. However, each one has its unique function and specialty. Maya, on the other hand, is mostly an all-rounder when compared to the other two. It can perform both Max and Blender tasks [22]. Also, Maya provides one year free subscription for the students. Maya enables an end-to-end creative workflow for artists. It is a very advanced professional tool with numerous functions.

For the texturing, Substance painter is used, which is a licensed software but provides one year free subscription for university student. This tool is easy to use as it provides some free texturing skin colors, and also it is very compatible with Maya.

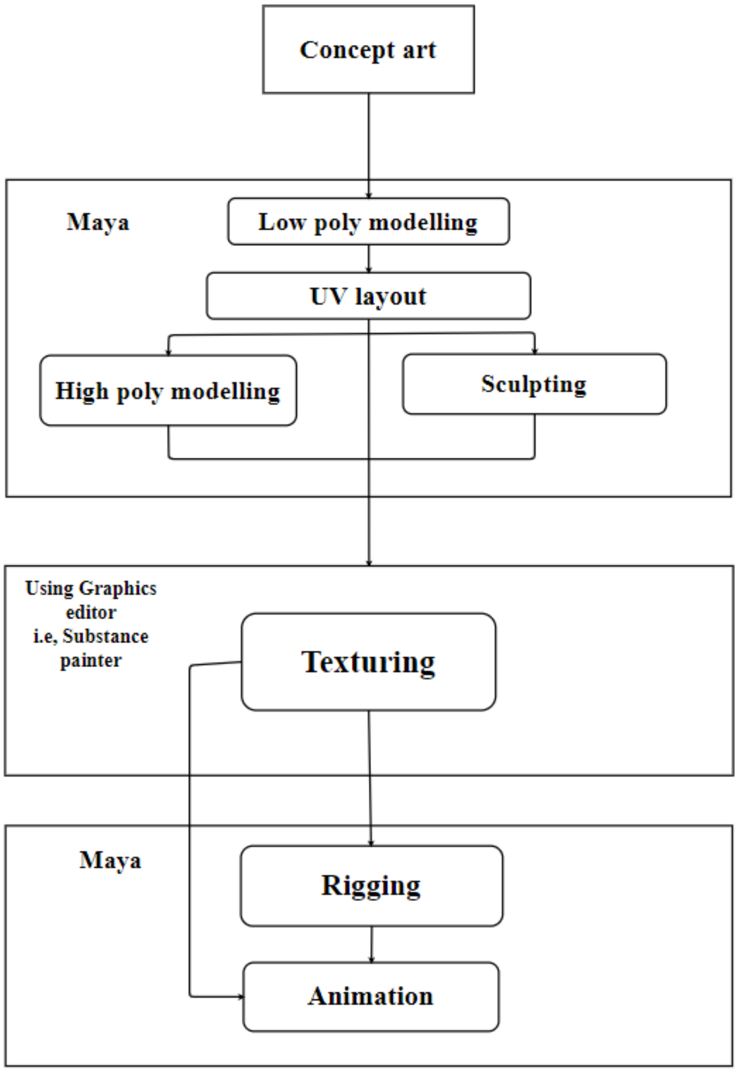


Figure 3.1: Implementation steps [20]

Figure 3.1 describes the steps for modelling the pedagogical agents starting with the concept art, agent modelling, texturing and animation. Following sections provide detailed overview on the implementation steps.

3.1 Concept art

Concept art mainly focuses on the main assets of the avatar, which are gathered from the feedback of the supervisors. In this stage all the required assets such as gender, ethnicity, age, facial expressions, gestures, etc., are finalized and final sketch of an avatar is decided. As the final step, an avatar with both front and side views is created or downloaded from the available online sources, using those views, modelling and texturing are done using Maya and Substance painter.

3.2 Base mesh

A base mesh or the base object is the original polygon that is used to create a model by deforming the faces, edges and vertices: A face (polygon) is a group of four or more edges joined together. A set of polygons enables a 3D model to be translated into 2D space and then textured. An edge can be formed by extruding a single vertex, while a face can be formed by combining four vertices. Many faces can be utilized to create a model since they act as a solid surface [54].

3.2.1 Mirroring

Because the face characteristics are fairly symmetrical, the concept benefits from mirroring. Extruding one vertex to make an edge necessitates an equal amount of extrusion on the opposite side. The mirror modifier in Maya provides for workload reduction through mirroring [54].

3.2.2 Views, Loops and Edge flow

Multiple perspectives are possible in Maya. There are four different perspectives: front, side, top, and camera. The XYZ planes are formed by front, side, and top views, and the camera is a mixture of the three, i.e., perspective view. It's helpful to configure the camera view during base mesh production to match the view of the original concept picture; this ensures that we're on track. The importance of switching between viewpoints stems from the fact that a mesh may appear to be perfectly aligned from one view but not from another. The resolution of a mesh is referred to as geometry. A single face is the same size as a single pixel and has little information. Many faces can be used to create a more distinct image/model. Numerous faces can result in sluggish performance and delayed interface interaction. It is recommended that quads be used instead of triangular faces with only three sides. Normally, triangles generate artifacts and pose an issue during texturing. Faces at odd angles generate artifacts, which appear as a dark or projecting edge. In comparison to higher order polygons, quads and pentagons limit aliasing effects.

Rectangular squares are favored over four-sided squares. This prevents the pinched appearance, which can degrade textures.

A set of faces with linked edges is referred to as a loop, and it can be separated to add geometry. Unnecessary polygon geometry should be avoided. The geometry can be easily and quickly added by keeping these loops separate [54].

3.3 Design of Mesh

3.3.1 Low Polygon Modeling

From concept to 3D model, the initial stage is to develop a low polygon model. Quads are preferred by most modeling artists over triangles. Smoothing or hardening normals is also a part of low polygon modeling. To avoid models with drastically different levels of detail, it's a good idea to set a maximum polygon count in advance, based on the size and relevance of the model. During this phase, however, several adjustments are necessary to accomplish a consistent look for all the low polygon models [20].

3.3.2 UV Layout

Maya needs to convert 3D space to 2D space using face-polygons so that texturing and painting can be done. UV layout or mapping is the process of unwrapping the faces so that the user can paint on a flat 2D surface. In Maya, a UV set is made up of a single UV layout. Numerous UV layouts are possible for an object with multiple texture types. A maximum of three UV settings per object were defined for this project:

1. Color map UV set: This is used to create color textures. Faces can share texture space, which means that a single texture space can be shared by several faces

2. UV set for normal map (optional): Only used if a separate normal map is needed

3. Light map UV set: Texture space cannot include overlapping faces. Each face will have its own amount of space in the UV layout, since each face can have distinct lighting information.

3.3.3 High poly modelling

After the UV layouts were completed, certain low polygon models were enhanced to high-resolution models using either Maya's smooth-operation (providing additional subdivision polygons) or AutoDesk Mud box's artistic sculpting. A normal map is the output of this high polygon modeling step [20].

3.3.4 Sculpting

Maya allows the user to build virtual 3D surfaces in the same way that real 3D things are sculpted from clay or other modeling materials. Polygons are used to create the virtual 3D surfaces instead of clay.

When a user moves a sculpting tool over a part of the model, the vertices in that area are re-positioned, changing the model's 3D form. The polygonal faces linked with vertices are also relocated when they are re-positioned. The shape of the 3D object varies because the polygonal faces reflect light, color, and shading information back to the user.

On a polygonal model, the density of the vertices/faces determines how much fine detail can be sculpted. There are fewer points to change the 3D shape of a polygonal object if it has fewer vertices. Increase the amount of polygons by subdividing to create finer detail [20] [55].

3.4 Texturing

Texturing in Maya is accomplished by first creating a material and then associating it with various textures. A UV Map, which maps a 2D picture/texture to a 3D model, is used to add textures. Each texture has a unique influence on the model. Diffuse, Shading, Specular, and Geometry are examples of these effects. The way light and shadow interact with the model is changed through shading. The model's peculiarity affects how light bounces off it. Substance painter is one of free source tool for texturing the avatar.

3.5 Rigging and Animation

A process known as 'rigging,' which builds a virtual bone structure for each figure, is utilized to enable artists to easily produce organically looking animations of characters. This structure can then be utilized to naturally control the movements of the characters during animation. The character's mesh is connected to the skeleton and weighted between influencing bones after the bone structure is complete. In most cases, inverse kinematics is utilized to indicate the position of bones when shifting skeleton handles.

4 Modelling Pedagogical Agents

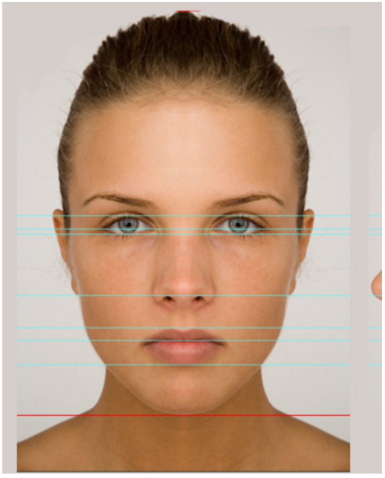
4.1 Modelling the Agents

The basic modelling of the agents, from head to toe, is covered in this section, along with UV mapping for texturing and next sections describe the skin painting, rigging and animation of the agents.

4.1.1 Head Modelling

These chapter describes the modelling of an agent using AutoDesk Maya, a framework for 3D modelling. Firstly, the reference images are imported to the Maya and aligned both front and side view (female images 4.1 and male images .3) plane. Create a polygonal cylinder over the eye and give it 12 subdivisions on its axis and 2 subdivisions on its cap before deleting all except the top cap's faces. So, in both front and side perspectives, it's positioned over the eye, and then it's duplicated and moved over the mouth. The head is built around these two-cylinder caps. Take the inner ring of vertices, which will represent the outer margins of the lips, and the outer ring, which will represent the grin or laugh line, as well as many of the animation points surrounding the mouth. The animations are taken into account when creating this topology. Removing the two sets of triangular edges from the lips, leaving only the central edge, and then use the multi-cut option to join straight up and down. So, from top to bottom, this forms straight lines with three rows of vertices: the top lip, the center of the lips, and the bottom lip.

Starting with positioning the second row, which is extremely near to the center and sits higher than the center point on the top lip. The divot for the philtrum will be created as a result of this, and the center row will be tweaked to match the center line of the lips. To match the reference image, adjusting all the vertices. A normal posture is to tilt the corner of the lips down a little. Then take a look at the side view and make any necessary adjustments. Pulling the vertices forward, right under the nose, in the same way. When this vertices moves forward, it will be on the right corner of the nose, which will aid in the alignment of the remainder of the mouth. When receiving the lower mouth area, the outside ring is the laugh line, and it sticks quite close to the mouth. Adjusting the outside borders of the lips to match the reference, then place the vertices in the perspective view for the center of the lips, then picking the edges and link components to create another row. Pushing the rows out using the Transform Components tool to inflate them, which provides the lip area a lot of roundness. To make a few mouth tweaks, going



(a) Front view

(b) Side view

Figure 4.1: Female reference images

to smooth proxy mode (press the 3 key). Beginning with the eyes once the lips are modelled. Starting with the inner ring of the eyes, which should correspond to the margins of the eyeballs. This will be similar to the mouth, connecting straight up and down. When inserting the vertices in the side view, the center will come all the way forward to the center of the eyeball. And then simply locate the outside corner by dividing the difference between the two rows. Because the inside of the eye cannot be viewed from the side, alter the corners using perspective view. The top part of the eye is the simplest to define; it simply follows the brow above the eye. Placing the bottom half next to the eye, then line it up depending on those brows in the side view. The vertices on the inside of the eye rest on the side of the nose, while the vertices on the outside sit extremely near to the eyeball. Smoothing the eye using 3 key, just as the lips. Grabbing the borders surrounding the eye and crease the vertices using the crease tool to give it a sharper form.

Making a new cylinder and tilting it up vertically using 8 subdivision axes for the nose. In front view, wrap the cylinder around the nose, aligning it with the outside border of the nostril and the bottom of the nose. Draw all the center rows forward to create the nose's depth, erase the inside borders, and connect so that only four faces remain. Subdivide the faces and pull them forward until the nose takes shape. Then smoothing the nose and beginning to develop the nostrils, which can be seen from the side. Because the bottom of the nose is not quite flat, extrude the faces somewhat at the corner. In front and side views, place the nose opening, then beginning positioning the septum, which is quite small and visible in side view. It is simpler to join the edges of the nose before smoothing. To make the negative space, select all the nostril faces and extrude upwards and inwards.

Adjusting all the vertices according to the front and side views of reference pictures after modeling the eye, mouth, and nose independently. Adding a new set of edges between the nose and the lips to construct a philtrum, then merge all the vertices

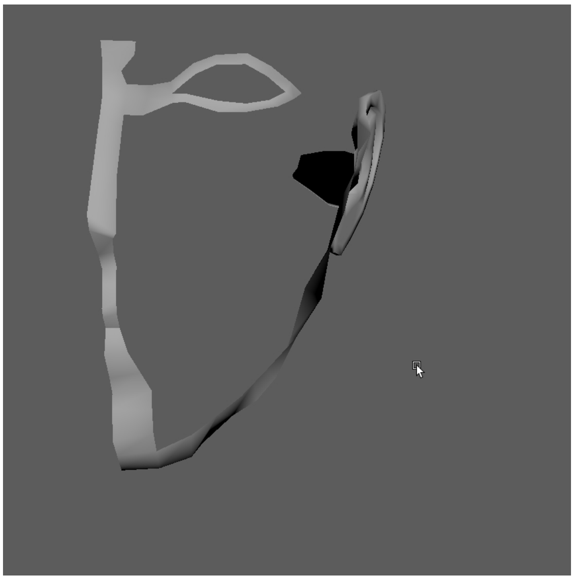


Figure 4.2: Modelling Face

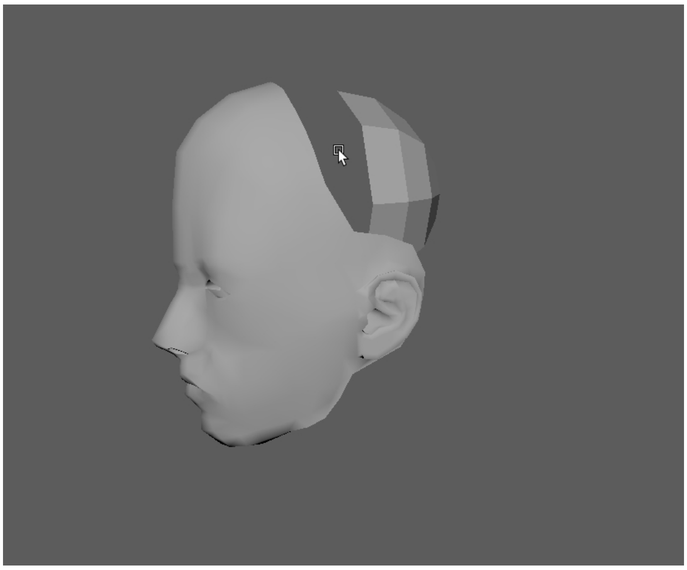


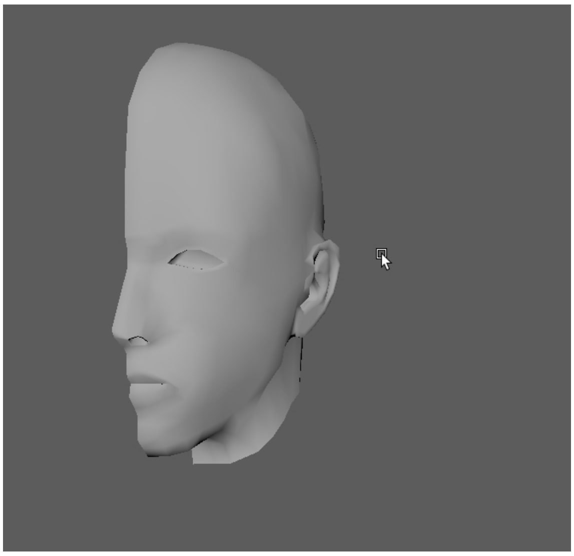
Figure 4.3: Modelling skull

together using the multi-cut option. This creates the appearance of a single item, complete with an eye, mouth, and nose. Extruding side faces till the back to the corner under the ear, where the ear and jaw meet, to define the jaw line. Selecting all the faces from the sides of the laugh line and the mouth area under the lips and extrude down to form a chin and extrude side faces till the back to the corner under the ear, where the ear and jaw meet, to form a chin and extruding side faces till the back to the corner under the ear, where the ear and jaw. Then, extruding the entire edge forward and cut a subdivision into the jaw to match the topology, then adding a few more subdivisions to improve the shape from the front perspective.

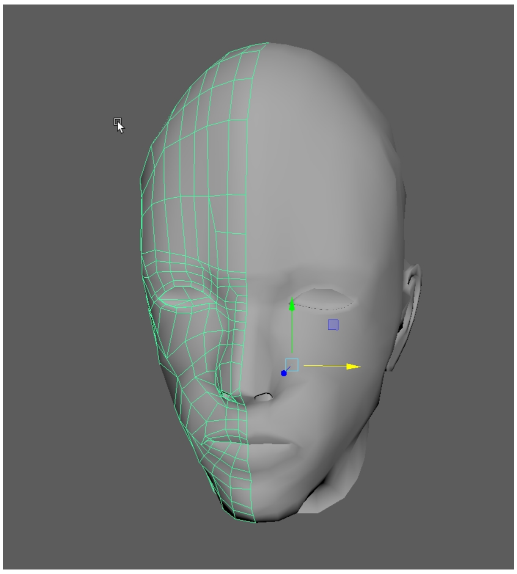
Grabbing the edges under the eye and extrude out in a radial fashion, weld that vert at the top of the eye and nose area, and moving the set of faces in such a way that it can now merge that vert to the nose and then using Fill Hole, then start to merge to the outside cheek area by flattening the row of vertices, so it will be easier to integrate into the rest of the cheek. Then simply extruding again by connecting the bottom-most extrusion and bridge over to the appropriate face. Before filling in any gaps, spreading the vertices out to make it easier to govern both the anatomy and the topology. Beginning at the chin and working way down, extruding the laugh line all the way around, from the side of the nose to the bottom of the lips. To build the ideal chin, filling all the gaps by combining the vertices using the Merge-tool and matching the reference photos. To increase the curvature of the structure, the forehead is now generated via radial extrusion from the eyebrow area.

Next, creating a sphere for the skull by selecting one with the same number of subdivisions as the head, then snapping points up to the forehead to align it. The back of the skull is larger than the front of the skull. As a result, it narrows a little in the front. To round things out, extrude the faces straight down and add a few subdivisions.

The ear is shaped like a cylinder cap that sits flush on the face. Extruding out from the matching faces on the ear in the side view, then snapping them to the skull, combine all the points to make the full shape by asymmetric adjusting. This forms a half face 4.4a and upon the completion, the other half face is duplicated on the negative side and then using combine and merge, the vertices are joined to form a full face 4.4b.



(a) Half female face



(b) Full female face

Figure 4.4: Female agent's head

4.1.2 Body Modelling

Importing front and side views of a human body onto the 3D plane in order to begin modeling the agent's body. The torso will be made out of a cylinder, which will be the first step in the modeling process. Create 8 subdivisions around the axis and 4 or 5 subdivisions on the height, then using the Move and Scale tools to align the cylinder with the reference in front and side views by changing entire rows at a time. The top and bottom rows are particularly important; the bottom row depicts the waist, while the top row represents the clavicle and neck area. Rotating the rows to duplicate the flow of the spine. Extruding out all the faces in the top region, then extruding it out again by making it much narrower; this will be the neck form, and the torso shape will follow. Before beginning to make the arm, the Edge Loop tool is used to create an edge ring on the upper torso.

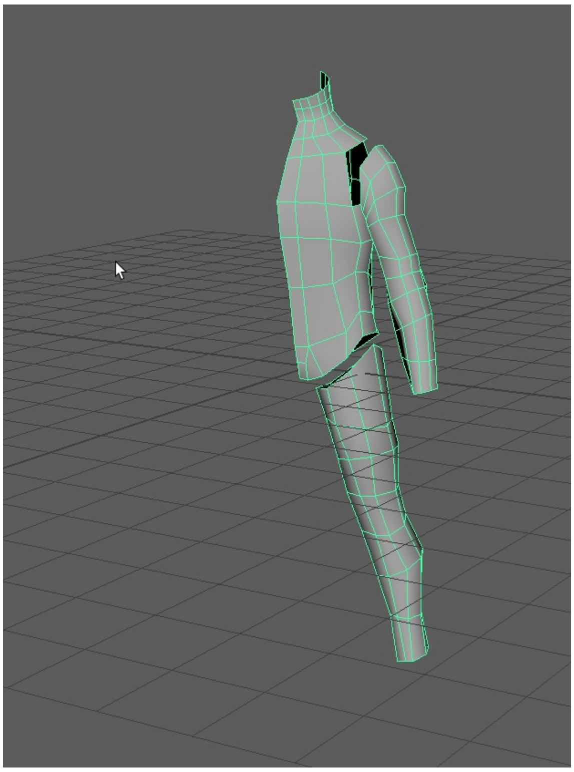


Figure 4.5: Separately modelled body parts

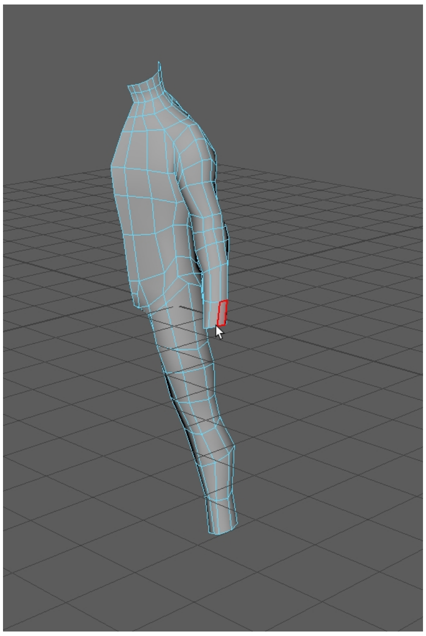
On both the axis and the height, the arm is a cylinder with six subdivisions. Editing the cylinder row by row to match the reference. Starting with the forearm tilted in the side view, then use the 'd' key to temporarily move the pivot and rotate the forearm into the proper position. Now, starting with the side view and working way to the front view, shift all the vertices to match the reference, row by row. There are eight axis subdivisions and six height subdivisions on the leg's cylinder. Therefore, it is distinct from the arm. As with the arm, scale and move individual rows individually. Inserting a new row between the upper leg and the ankle using the Insert Edge Loop tool. Adjusting the waist by angling the leg outwards. If there is any tilt near the leg, use the Rotate tool to create uneven rows that replicate the body's organic structure. After all the shapes have been outlined, connect everything by removing the caps from the lower body, upper leg, and upper arm. Then, simply combining the selected elements using the Combine tool. Next, using Duplicate Special with an instance with a minus one (-1) X axis scale to make a mirror image of the object, and switching to the Legacy Default Viewport Renderer to eliminate the problem with the dark normals. In the final reference image, there is a row under the pectorals that runs down the side of the arm, and then the next row up on the chest goes all the way around the arm, all the way to the back, and the row above it also runs around in a ring. Therefore, the arm should extend from the upper chest. Firstly, moving the upper-torso downward, extruding the top two faces of the upper torso out, and then snap to the arm's outermost vertices. Moving it around and arrange it, since this will be the new shoulder. Connecting the vertices under the arm after that. Because the pectoral goes into the side of the arm, use the bridge tool to connect them.

Selecting the edge row that runs along the side of the body and bevel it to split it into two if the number of subdivisions does not match. If there are any extra subdivisions, use the Bridge tool to connect them to the back row of the arm, as well as the body to the arm.

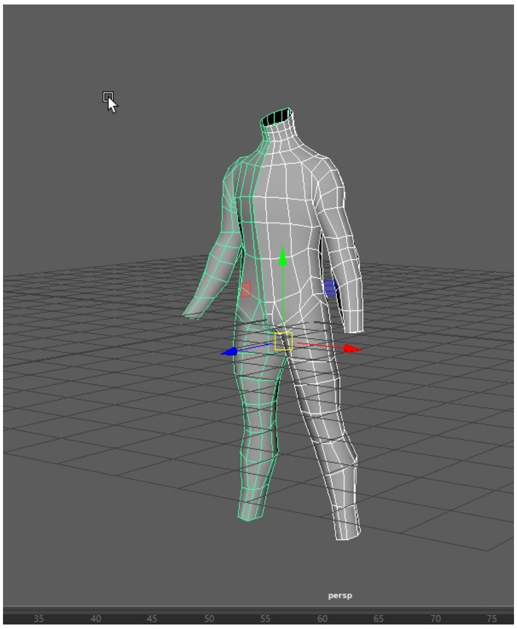
Extra rows can aid in better defining the human body. Taking some volume from the front and put it in the back. This corresponds to the position of the lats on the body. The back of the body, not the front, is where the lats are located. Using the Insert Edge tool, add another row to the vertices on the front and back of the arm, and merge the vertices. Then link across the chest with the Multi-Cut tool, and try to better define the pec area. Simply use the Fill Hole tool to close the hole and eliminate any triangle edges that may appear.

Then, to cut across the next row, using Multi-Cut once again. As a result, there's a whole new row in there. Now that everything is connected, going through the anatomy and polish it to make it look better, as well as fill in some holes. Using the Insert Edge Loop tool, adding an edge ring across the chest and back, and then connect it to the appropriate points on the arm. Some extra triangles in the arm locations or quads running up the arm and into the upper chest, which can be eliminated by making a set of quads and use the Multi Cut tool to link those points on the outside of the shoulder, then deleting the two edges to shift some quads around. Now, creating another 'V' in the reverse direction using the Multi Cut, and cut through the middle of that 'V' to get a bunch of good quads. Removing a couple of edges to form the body topology.

For anatomy, adjusting the vertices in the upper chest and shoulder region; while adjusting the vertices, consider the front and side reference photos. Utilizing the Insert Edge Loop tool to carve rows into the front and back of the object. And on the back, using a new row to indicate the region of the shoulder blades and the region of the spine, the next row should be pulled out to generate volume for the shoulder blade.



(a) Male agent Half body



(b) Male agent full body

Figure 4.6: Male agent's body

Adjusting the number of vertices near the chest and torso to provide greater definition for the abdomen and pectoral region. Moving the vertices to make room for these vertices so that things do not become overcrowded. In general, good topology is uniformly distributed. Therefore, when modifying the anatomy, one must keep this in mind. After that, neck modifications are done. Regarding the neck, it should be noted that the front of the neck is lower than the back.

To smooth the model, press 3 key to activate Proxy Smooth. That will drastically alter the mesh volume. After smoothing the model, adjusting everything so that it matches the reference images. Every time, after smoothing, the volume of the mesh will be drastically reduced. This will become increasingly significant during sculpting.

The leg connection is the next step. Similar to the rows on the arm, these rows extend from the waist to the lower thigh. In this instance, there may be two more faces for the genital on the front and back. Because of how the cylinders are constructed, the body and the leg should be a somewhat close fit. Adjusting the bottom row on the body by shifting the faces to approximately the leg area. Bridging from the back of the body to the front, and then building three subdivisions on the new face using Connect Faces or Insert Edge Loop to complete the assembly.

Now, there could be three rows at the base of the body that correlate extremely well to the interior of the leg. On the side of the leg, there will be some vertices that are fairly close together. Merging the vertices using the Merge Vertex Tool to begin linking them. Using Multi-Cut device, cutting a second row, above, into the body. Next, adding a divide to the torso's border and combine it down, then filling it with a Fill Hole option and link the two edges in the center, pulling out, and the anatomy will be seen. Modifying the points beneath the body based on the front view reference, and in general, just adjust to match the anatomy. Meanwhile, paying attention to the back of the body and make the connection between the two outside vertices and their matching front vertices.

In the next process, adding a split to the face so that it has five sides, but by pushing it down and out, the corners will begin to appear. Fill the region with a bridge to eliminate the five-sided face. Make a few alterations, and then join diagonally on that lower face corner. Then, linking across the bottom row on the butt, make a few additional adjustments to better accommodate the anatomy in that region, and then joining across the bottom row on the butt. Collapsing the edges and eliminating the corner edge at the bottom, which provides each quad the correct angle.

Adding some extra subdivisions where more definition would be needed, such as the hip, and then change orientations globally to capture a bit more of the anatomy.

4.1.3 Palm and Foot Modelling

For creating a Palm and Foot, starting with a cube, add four subdivisions (along the depth in this case) to align with the knuckles and two subdivisions along the height, and then tweaking the hand to fit the reference image, exactly as previously done with the other body parts. Making the knuckles asymmetrical, so they do not sit linearly in any direction (refer to figure 4.7).

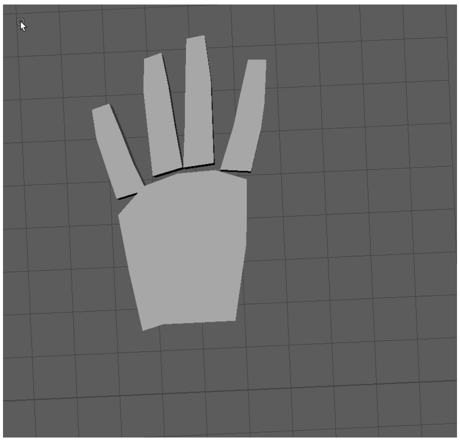


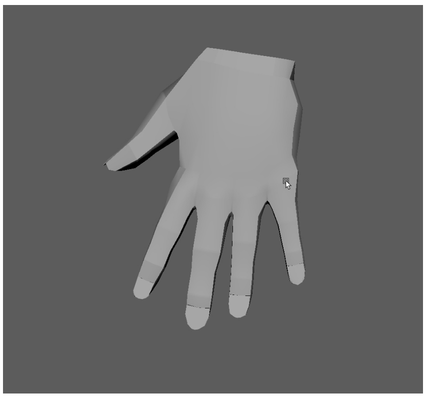
Figure 4.7: Palm

After that, Extruding those faces using Extrude options in the channel box include the ability to extrude faces independently; choosing option and separating the fingers independently. Changing the faces such that they remain generally square, flatten them out in one direction, and then adjusting their lengths so that they are almost proportionate. Using Insert Edge Loop to cut in the finger knuckles and taper the tips further. As the thumb is nearly as long as the index finger, replicating the face for the thumb using the index finger. Transforming the index finger into the thumb, and then attaching the thumb's pivot point to the thumb's corner. Then, snapping it to the corner by making a hole on the hand and repositioning the thumb to a more natural position, and then using the Bridge tool to join the fingers to the hand 4.8a. Initially, merging them by selecting all objects and using Mesh in Combine option.

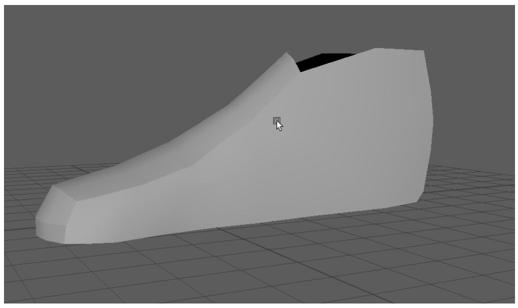
Adjusting the points to get a more seamless transition between the hand and thumb. After the hand's topology has been completed, linking it to the wrist by removing the hand's cap and combine it with the body. Then, adjusting the hand so that it corresponds with the arm and is resized to better fit the reference image.

If the number of vertices on the hand and the wrist differ. Simply merging the top three vertices of the hand on both the front and back to acquire the same number on both sides of the wrist. This will produce a seamless hand 4.8a. Modeling the fingers in the most relaxed position possible, which is slightly bent. To do this, using the Soft Select tool and button 'b' to turn it on and off.

Creating a cube and subdivide it three times down its length, then adding a single subdivision down the middle line to model a foot. On the side view, modeling the foot to match the reference. The back foot is usually the preferable reference for modeling the foot. Since the foot is narrow at the ankle, widens at the toe, and slopes down steeply from the top of the ankle to the toes while modeling the foot. So, the foot isn't exactly flat. Scaling the faces down to generate that roundness, and then pushing them up to make the arch on the insole. Then beginning to consider toes as they emerge from the front faces. Connecting up and down to make some slots, then beveling so that there are five of them, unlike the fingers.



(a) Palm



(b) Foot

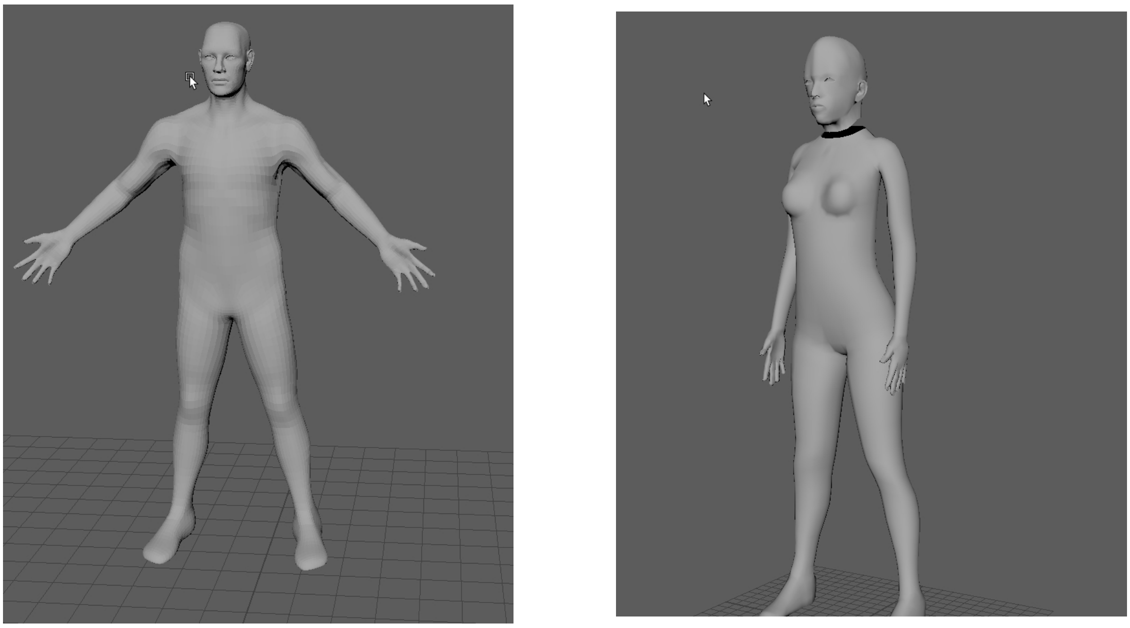
Figure 4.8: Agent's palm and foot

Instead of extruding the faces separately, grabbing the alternate faces and extruding them out one at a time. Adjusting the location of the toes in the smooth view. The toes generally bend inwards towards the big toe, which reflects the fact that most people wear shoes. The second toe is usually the same length as the big toe, if not slightly longer. Subdivisions on the toes are not necessary for animation, so only adding one set of subdivisions down the middle. Finally, deleting the faces at the bottom of the leg and place the foot into the proper position, combining the toes with the foot.

Observing the vertices between the foot and the ankle to match them up by cutting an extra set of vertices on the sides of the foot, matching the amount of subdivisions, and blending the body and the foot together. The back of the ankle should be quite narrow, while the front should be reasonably narrow. These two ankle bones will protrude from the sides, and since the inside ankle bone is higher than the outside ankle bone while arranging them. To get that bony back shape, changing the shape of the foot. To better mimic the standard posture that most people have while their feet are standing in, rotate the foot outwards. After that, design a shoe that exactly fix the foot 4.8b.

Finally, a body that closely resembles the photo reference is generated; which is well topologized, so it will work nicely for animation and sculpting.

After separately modeling each component of the body, all the models are brought together to produce a complete three-dimensional body 4.9. Attach each of the poly edges accurately to get the smooth body surface.

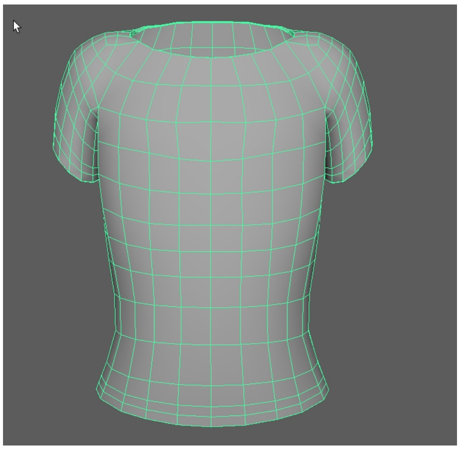


(a) Male body

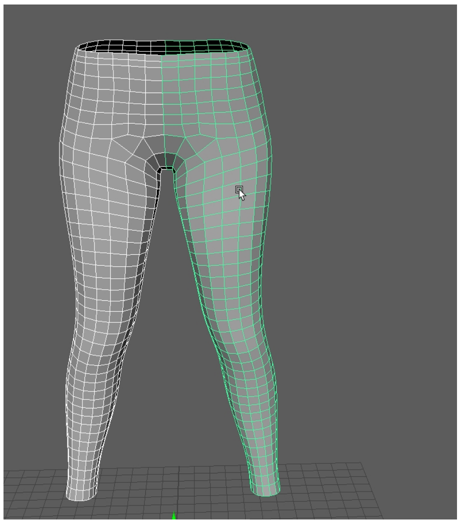
(b) Female body

Figure 4.9: Agents before texturing

For garments, after going into face mode and selecting required faces for pant and T-shirt. The edges are needed to be extracted, and using duplicate face option the extraction of the T-shirt and pant should be done and tweaking all the faces as per the requirement of male and female body structure. Figure 5.1 represent the garments before sculpting.



(a)



(b)

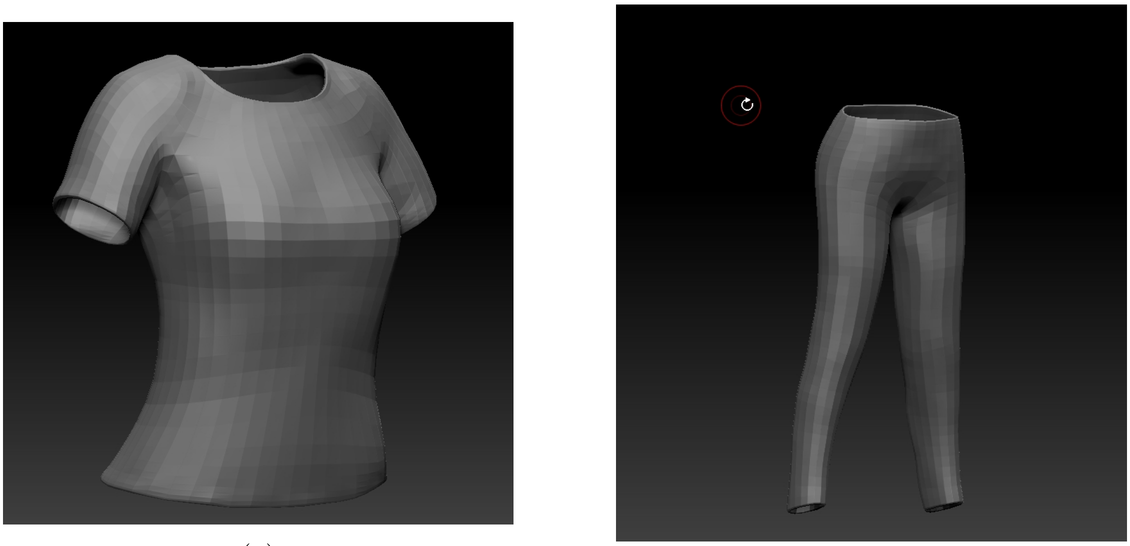
Figure 4.10: Female outfit before ZBrush

In order to get a realistic clothing feel, the unwrapped cloths are exported to ZBrush and sculpted to the requirements (refer to 4.11).

4.1.4 UV Mapping

In order to texture the model, UV-unwrapping mapping (refer to 4.12) is needed to be done. UV mapping is a process for transforming a 3D object model into a 2D shape that can be painted, such as a texture map, by splitting up the 3D surface and unfolding and flattening the pieces into something that can be painted to the UV map. Clothing is a good analogy since it starts as flat two-dimensional sheets of fabric that are torn up and sewn together to form the 3-dimensional shape, which is the body, and clothing also aids with UV mapping seam location. All seams on the inseam of the arm, down the side of the chest, and on the inseam of the leg should be placed in the same general location as the clothes. This indicates that if someone gets stuck trying to insert a UV map seam, they should look at the human wearing clothes for imagination, while physically unwrapping the UVs first would be efficient before going on to easier ways, and working symmetrically on half the body by grabbing the front faces on the arm and then in the UV texture editor, holding shift key and right-click mouse and picking planar mapping from the menu would be efficient.

Maya will automatically project UV mapping from a random direction and do the same thing on the back of the arm. The issue is that the UV shells are distorted, so press comm and shift-RMB again and choose Unfold UVs. Unfold UVs will automatically shape UV shells into the least distorted shape Maya can come up with, and now just remove UV mapping seams. As a result, the seam should appear to be on the top of the arm rather than under it. Because the seam should not be visible, sew UV shells together at the top seam by choosing the top seam, then right-clicking and selecting Move and Sew in the UV texture editor while holding shift. UV shell with minimal distortion and UV distortion with a regular pattern like a checkerboard. It is necessary to unwrap the torso, which should be done in the same manner as the arm, by making multiple selections of faces and using the planar map in the UV texture editor to use Unfold UVs once more.



(a) (b)

Figure 4.11: Sculpted female outfit

Because the arm will cover the torso after it is put together, using the Move and Sew UVs to position the side torso seam beneath the arm and using the unfold UV tool as well as another tool, the Smooth UV tool, again. Because it is in the same menu as Unfold UVs, so it will start the smooth UV tool when the UVs are selected, and then a small yellow box will appear. By clicking and dragging on the unfold to relax the UV mapping, grabbing the offending face and planar map it in case of face sticking up, then re-scaling and moving it near the hole it corresponds to, and then selecting the edges in that area, and use Move and Sew UVs. After that, the UVs must be unfolded again to smooth and polish everything, as well as verify the UV mapping for distortion by using the checkerboard material once more. The checkerboard size differs between the two items, so scaling the object in UV shell to make the checkerboard roughly the same size. This is important since it ensures that the pixel density across all parts is consistent, making textures appear more cohesive.

A similar process is followed for the leg as it was for the arm. So by simply grabbing half of the leg's faces and planar mapping them in the UV texture editor, then grabbing the other half of the leg's faces and planar mapping them as well, so by simply using the same tools over and over for this mapping approach, for the desired output, the inseam should be the leg's seam, so by grabbing this outer center seam and using the Move and Sew UV tool and then unfolding UVs, the foot will start by grabbing the top faces and planar mapping them.

In some circumstances, the automatic tools won't be able to help, so the Smooth UV Tool is used to just ease certain faces in order to get much less overlapping between the toes. The process had to be done manually by moving the vertices to remove overlap. The top of the other foot will have the same issue, with a lot of overlapping between both the toes after unfolding or smoothing, so it needs to be manually repaired with the hand and handled in the same way as the foot and the following step grab.

After projecting all of those individually, using the Move and Sew tool along the sides of the thumb, and merging these together so that it looks like a butterfly unwrapped of the hand, that leaves the head and the neck to create the neck as a one plane map, and subsequently to grabbing the corners at the back of the neck and using Cut UVs to divide them away, and then to using the unfold UVs to spread out all those UVs, if the UVs came out upside down, selecting those UVs and flip them vertically. So, to have mirroring tools at the top to flip it over, to see it turn red, indicating it is oriented improperly. If it is flipped in the other direction, it goes back to blue, and it is in good shape. Grabbing the full head and do a one planar projection for the rest of it. After this, cutting straight up the center of the back line using Unfold or Smooth UVs to just basically peel it apart. That leaves the large seam in the middle of the head, so instead of trimming along the sides of the face to combine the center altogether, one can cut along the sides of the head to make the sort of T-shape, in which the tip of the skull moves upward and the side of a skull pulls outwards.

The colored checkerboard can be accessed by clicking the button at the top of the toolbar. This will give the object a colored checkerboard texture. It can be used to check for UV mapping distortion. Because the checkerboard is such a predictable pattern, it will be obvious if it is correct or not.

As a result, it may switch that button on and off as needed to see that pattern. It is now a little easier than constructing one's own checkerboard material because it is fused from the neck to the skull by trimming the ears, so they may sit individually. This will eventually create the texture within the region faster, and it will also indicate that all the character's specific parts have been UV unwrapped, letting the priority shift to the entire body.

To get the full body in the UV texture editor, going to the Image menu and turn on Shade UVs to duplicate the arms and legs and flip them across the middle line, using negative scale. This creates the blue and red background for the UV shells, and by combining the color changes, it will have a purple color, which is caused by the overlap of blue and red shapes.

To fix this, selecting the red shells and using the mirror tools on the top toolbar to flip them until they turn blue, then merge the mirrored components, so the legs will need to merge at the front of the pelvis, and then combine the torso in, and finally lay out UVs in such a way that they all fit into a single texture.

So, simply navigating into the Polygons menu and selecting the Layout option, as

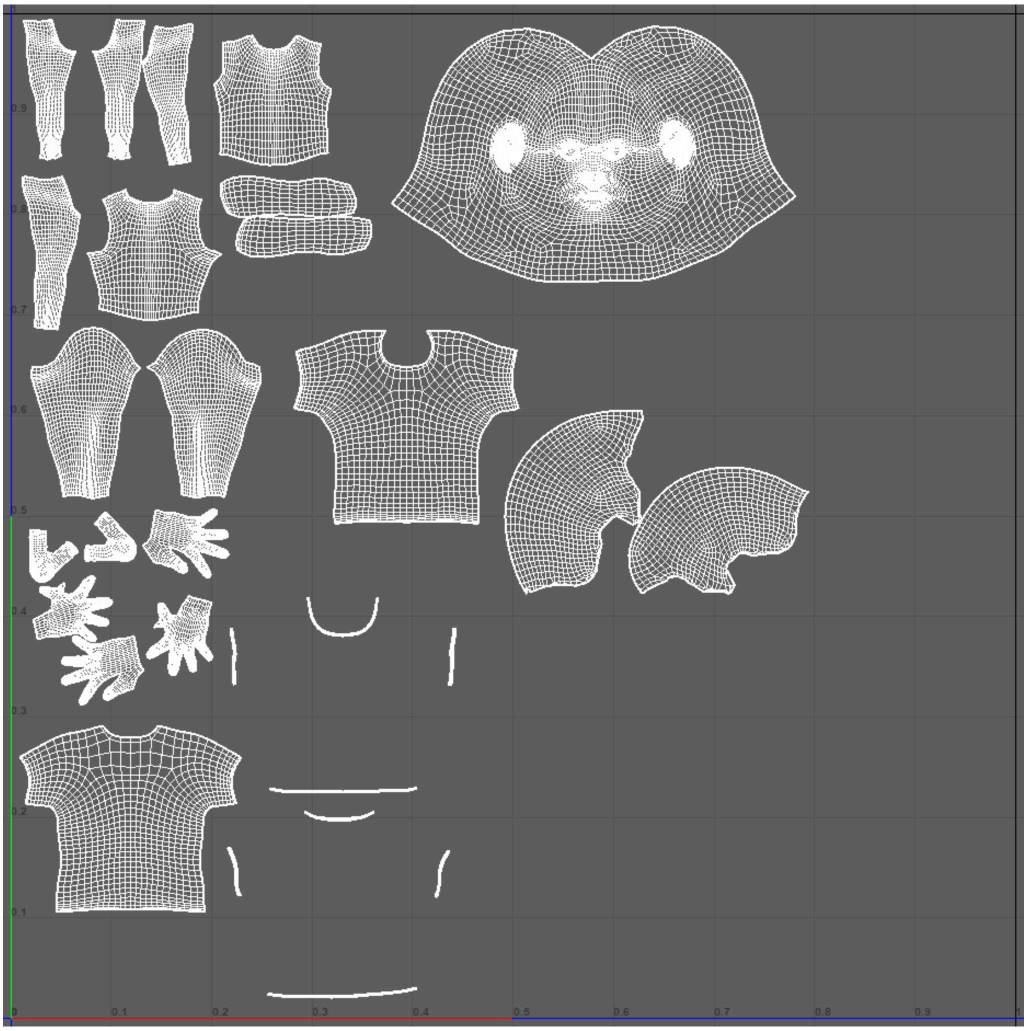


Figure 4.12: UV layout

well as generally going into the Layout options and disabling rotation and making sure that the scale settings are correct. It is not a good idea to rely on the layout tool for many choices because that will often make the wrong solution. By enabling it, all UVs are placed in a single zero to one area, however while the layout tool is simple to use, it may not always provide the best solution. So, manually making edits to the UVs, and then laying them out by hand, and turning on the checkerboard in the UV Texture editor, just to make sure that all the UV shells have about the same level of pixel density.

That implies the squares on them are approximately the same size, and each square with in UV Editor represent a texture, so fit the body into one of the squares, and then put the head into its own square to connect it to the rest of the body, signaling that each component of the torso obtains the distinct texture. It must be assigned to a different material than the head, with a different texture, before being executed on the body. This is the manual way, for example. Let's have a look at the second strategy, which is to use the additional tools.

To work on this tool, it must be installed in the users' system, and this will speed things up considerably. Starting with the process, the same way it was done for the manual process, but this time by using the Bonus Tools menu, choosing UV edit, and then choosing the Auto Unwrap UV tool. By hitting 'Enter Tool' the Auto Unwrap UV tool, by defining the seams where it is needed, UV seems to be on the object, and the tool will do everything else. So, by defining a seam on the back of the head, and by clicking the Add borders button, and at this point, it is just a matter of selecting the edges, as done in the previous example, and just adding borders.

So, all the borders are the same whether going around the ears or around the head. The difference is that this program will handle all projections for the user. By getting all the borders selected, by clicking that Continue button, and after that, the UV texture editor, to see the UVs that have been generated by seeing that they are almost the same as the UVs that are created in the first demonstration. So, to do the torso, activate the Auto UV Unwrapping tool again and selecting the seams down the side of the body and over the shoulders, and then hitting continue. It will generate the good UVs.

If somehow the seams are off-center, move and rotate them, but overall, it speeds up the procedure significantly, and it can all be accomplished by repeatedly going in, applying the tool, picking all the seams, and then letting the tool do the rest. So, to go along because the procedure is repeating repeatedly, consider the last example, mirroring the agent over the axis, combining the portions, and then laying down the UVs again, as in the initial phase.

The final method is going over the entire body at once, using the additional tools, which will be even faster. Starting with the completed base mesh, and by applying the Auto Unwrap UV tool, and again, by selecting the object and starting defining the seams. As a result, utilizing the same seams as the rest of the samples.

The difference is that because it involves the complete body, selections should be made with carefully and precision. As a result, a bottom-of-arm edge row that runs directly up and across the torso and downwards into the leg, as it is being extremely cautious to define the seams exactly where they are needed. Now, examining basic seam placement by placing seams to reduce mesh distortion, and evaluating mesh distortion with the checkerboard texture by also placing seams to cover it. As a result, texture seams might generate visible gaps in the texture, hence they are hidden in places where the viewer is unlikely to notice them such as the leg's inseam, under the arm, and the side of the torso.

These are all components of the body that may not be readily visible and are hidden by other body components. As a result, those seams are in the same places on clothing for the same reason: to keep them hidden from view. Next, a remark about the hands and feet: they can be protected in a variety of ways. So there was the projected multiple plane manner in the first case. Another option is to split the fingers in half. So, creating the seams at the base of the fingers and splitting them down the bottom, so that by unwrapping each finger as its own cylinder and then unwrapping the hand, the palm, and the back of the hand as its own object, this does add more seams, and it is probably only a good idea when using projection painting to ensure that there are no texture seams.

After all the seams are placed correctly, by pressing the continue button, and UVs will be generated automatically 4.12. The main disadvantage of this strategy is that Maya will make some questionable positioning decisions for the objects.

In general, it is necessary to manually modify the layout because the Auto Layout tools do not function properly; for instance, the legs are inverted, and the arms become tilted. Everything should ideally be at right angles to the object's interaction with the outside world. After UV generation, begin texturing by creating normal or displacement maps.

4.2 Texturing

For texturing, the substance painter is used. Importing the low poly with UVs generated in Maya to substance painter; choosing the 4k resolution for high quality, it works great at first but becomes slow as layers are added; resolution can be changed at any time through the settings. Firstly, going to the texture and selecting Bake mesh maps from the drop-down menu. To export later, selecting high poly and the same resolution or as high as desired. The default settings are adequate. Increasing the number of samples for more accurate findings. One can add skin details in Substance Painter as well, but for sculpting, ZBrush is preferable because it provides a more accurate preview and better control.

To get a good and quick start, starting with the face skin smart material. Dragging and dropping materials from smart materials onto the skin. If necessary, skin pores/wrinkles or a black mask can be added after that. Using a blue filter to merge the height information into the skin. Adjusting the remaining layers' scale and intensity as well. In compositing, it is preferable to use subtle Ambient Occlusion rather than lighting. Adjusting the mask so that the Subsurface scattering (SSS) is focused on the ears, rather than the face, where it is generally only or more evident. Beginning by adding the face's color zones, which are wide gradients of color with low intensity.

Black micro hairs/ stubble in the beard area can make the skin appear slightly bluish. Adding blur to smooth, then reducing it till it's barely visible. Replacing the blue color with red and repeat the process. More capillaries near the surface area, such as the cheeks and ears, cause the redness. Where the bones lie close to the skin, such as the forehead, using yellow or other bright color. Making a fist to see how the knuckles react. It is important that layers be grouped and named appropriately, as this saves time when adjusting the layers afterwards.

For complexity, adding a mask to which a fill layer with a fitting procedural is added. This resembles skin damages, like burst blood vessels, that one can easily detect on the reference images. This can also be done, by adding a paint layer and altering manually.

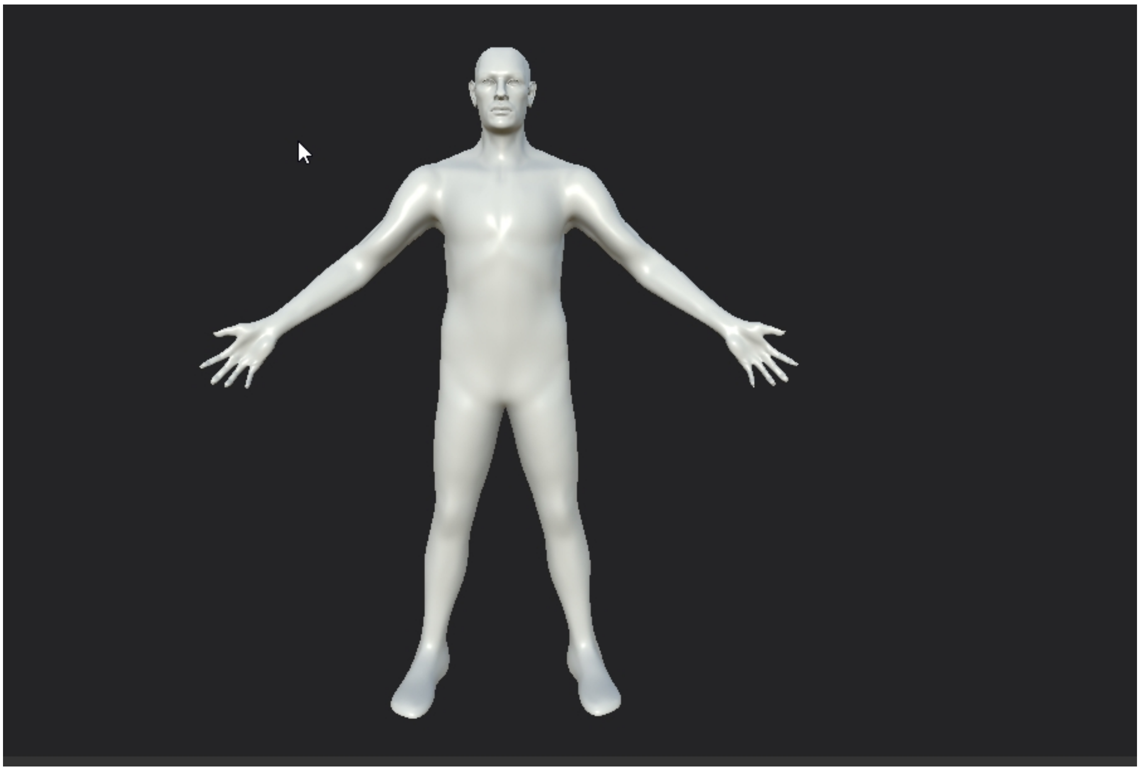


Figure 4.13: Male body after importing to substance painter

Figure 4.14: Male body after texturing

Filling in the eye bag area with a blue or purple fill layer, which can be enhanced to provide a fatigued appearance.

The color zones are as follows: blue or purple under the eyes, desaturated node bridge, blush cheeks, pink lips, and yellow Labii inferioris.

Then, similar to the red spots, adding white or bright spots. By hitting 'c,' one can toggle the channel and then add some blue veins. Adding a base color pass to the lips, then a darker and lighter version on top lip. If necessary, adding more white spots to the base color to refine it further. In the eyelids, use a few brighter, pinker tones.

It is preferred to use filler layers because it is non-destructive and easy to change colors in the future. Also, it is important to remember that the substance painter will get slow if there are more fill layers. Checking the reference image and, if necessary, apply extra blue tones to the eye bag area.

(a) Female outfit (b) Male outfit

Figure 4.15: Agents outfit after Texturing

Next, using the available pre-sets from the smart materials to generate moles and freckles, then add a second fill layer with a procedural in subtract mode to erase details unevenly. Adding a second freckle or mole pass, this time with a lower scale and less intensity. Layer by layer, increase the realism. To add a little more realism, using the dots brush to paint in certain stubble area. To bring even more sculpted features, using the curvature map. Adding a fill layer and a bitmap mask, then choosing the curvature map.

After that, adding a level, selecting 'invert,' and modifying the levels to remove some minor details. Finally, smoothing the skin with a blur filter and reduce the layer's intensity until it is barely visible. Add a paint layer to removing some curvature map effect if necessary. As eyelids, eye bags, and lips are more specular, adding a roughness paint layer and use the dirt brush to paint in some roughness variations. Because pores are less specular, the curvature layer should have higher roughness. Using the hairline brush to paint in some eyebrows.

Adding a standard layer in 'pass-through' mode before exporting. This will merge the information from the layers beneath it. Then, to enhance textures, applying a Contrast filter. Simply layer an HSV filter on top of the Contrast filter to reduce saturation. Finally, applying a 'Sharpen' Filter to bring out additional details in

Maya software rendering with 8k pixel textures and targa format (RGBA can be edited using targa format).

Choosing the renderer's config preset for exporting; in this project, Arnold in Maya is used. Create a custom preset in the configuration tab if the preset does not match. To make changes, simply right-click + replicate an existing preset. Copy the naming to ensure that the exported maps are named correctly.

4.3 Rigging and Animation

After texturing, in order to animate the model, rigging 4.16 and skin-weights paint 4.17 is need to be done to control the animation. For rigging, digital skeleton as to be created. Rigging a 3D character can be a lengthy and complex procedure, depending on what the character is expected to be able to do. Maya has a Quick Rig tool that can rig any object. The Quick Rig tool may be found under Skeleton, Quick Rig in the 'Rigging' menu set. Simply choosing the character mesh and press the Auto-Rig button to utilize it. Maya develops a comprehensive Human Inverse Kinematics (HIK) control system for the mesh in a matter of seconds. It is possible to control the movement of objects using this method. The auto-rig, on the other hand, isn't flawless.

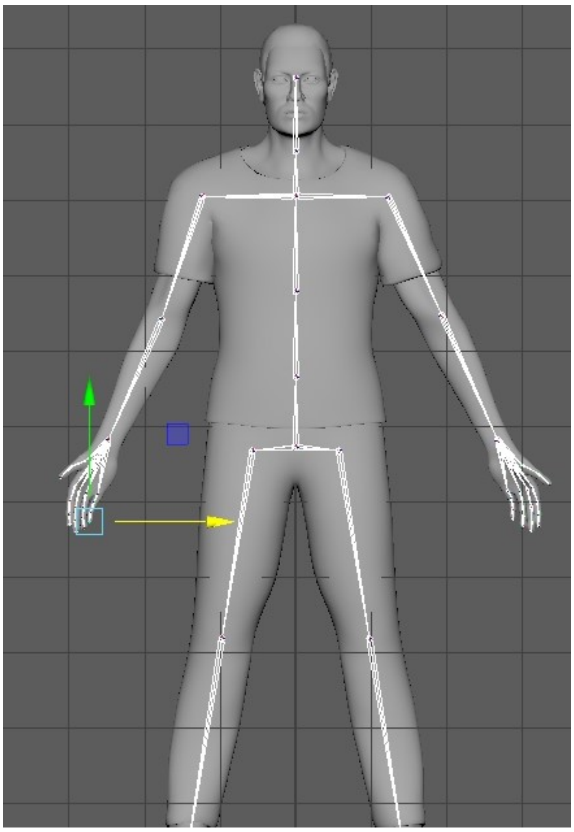


Figure 4.16: Male Rigging

The wrist control will move away from the actual wrist, resulting in an erroneous bend in the hand. The same may be said for a few other effectors, which could also benefit from better positioning. Manual rigging can fix these issues. Creating a new Character Definition using the Quick tool. To begin, selecting the mesh and drag it into the Geometry area. Setting the Embed Method to Imperfect Mesh in the Guide section because the mesh isn't completely waterproof (there are holes for the eyes and inside the mouth).

For a starting point, a resolution of 256 will suffice, then clicking Create. Within the mesh, Maya creates a sequence of guides. These are only the starting points for making a skeleton, not the actual skeleton. They do, however, reveal where the original auto-rig went awry. By pressing the space bar on the keyboard, shows 4-View such as front, side, top and bottom view. Translating the left wrist joint to a more acceptable position in all views using the Move Tool. Using the Mirror button in the User Adjustment of Guides area to line up the matching right wrist joint automatically.

'T-Stance Correction' is enabled in the Skeleton and Rig Generation section. Even though the model is in A-Stance, this allows Maya to automatically align our joints to a flawless T-Stance. This will ensure compatibility when transferring animation to and from other T-Stance characters. Making sure Skeleton and Control Rig are chosen before clicking 'Create' to transfer animation. Maya, like the 'Auto-Rig', creates a Human Inverse kinematics (HIK) rig for the character automatically. This time, though, the controls are exactly aligned with the geometry. Then, in the Skinning area, clicking the 'Create' button to skin it. The appendages are now bent in the proper places. The fact that head features do not move with the head can be fixed by parent restricting them to the relevant joint. To switch to pivot mode, selecting the head features GRP and hit Insert. Hold 'V' to initiate point snap and middle drag to center the pivot on the head joint. To return to regular mode, pressing Insert once again. To build a parent constraint, opening the character skeleton and choosing the head joint, Ctrl + Select the head features GRP, and selecting Parent in Constraint. The features of the head will now follow the skull part. However, they move independently of the rest of the head. This is due to the weighing of the skin, which may be corrected by painting 4.17. Going to Skin, Paint Skin Weights, and checking the box after selecting the body geometry. This modifies the model's coloring to reflect how the geometry deforms when the specified joint rotates. Parts that are completely effected by the current joint are white, whereas areas that are not influenced at all are black. Scrolling down to the Influences' section of the Tool Settings and choose the Head joint. This will turn the head a light gray tint. This suggests that the head joint has only a minor impact on the skin in this area.

It would be preferable if it was completely influenced. Set the Opacity and Value to 1 and paint over the entire head. Hide the head characteristics briefly to make this easier. After that, unhide the head characteristics and rotate the head once more. Following that, the head and characteristics of the head spin at the same speed. To avoid any more unintentional modifications, locking the weights for this joint. Then, in the Character Controls, choosing the head control and click the

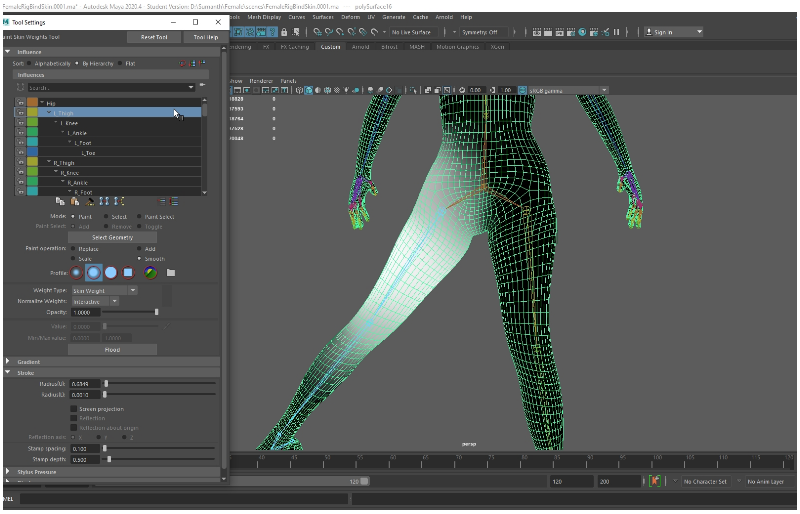


Figure 4.17: Paint skin-weights

Stance Pose button to return it to the bind position. Although the head is the most visible issue, it is by no means the only one. When a person raises their arm, note how it pulls their torso out and neck down. Returning to the Paint Weights Tool and painting a value of 1 all around it, allowing the body and head to move freely.

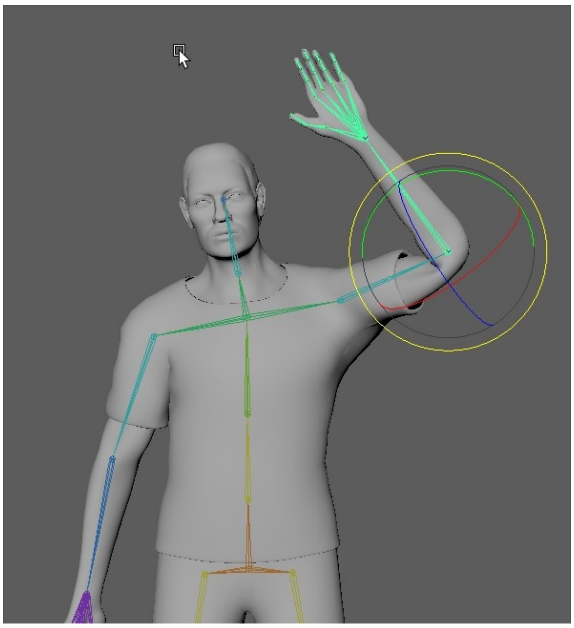


Figure 4.18: Rigging Test

To make smooth transitions from white to black, using the smooth brush at any moment. Continuing bending the joints in various directions and confirming that the skin reacts adequately across the remainder of the joints.

In general, maintaining vertices as uniformly distributed out as possible in various locations and minimize too much volume loss, especially around the underarms, elbows, and knees. Once one side is complete, using the Skin, Mirror Skin Weights command to apply weights from the left to the right side appendages. After that, the characters are ready to be animated.

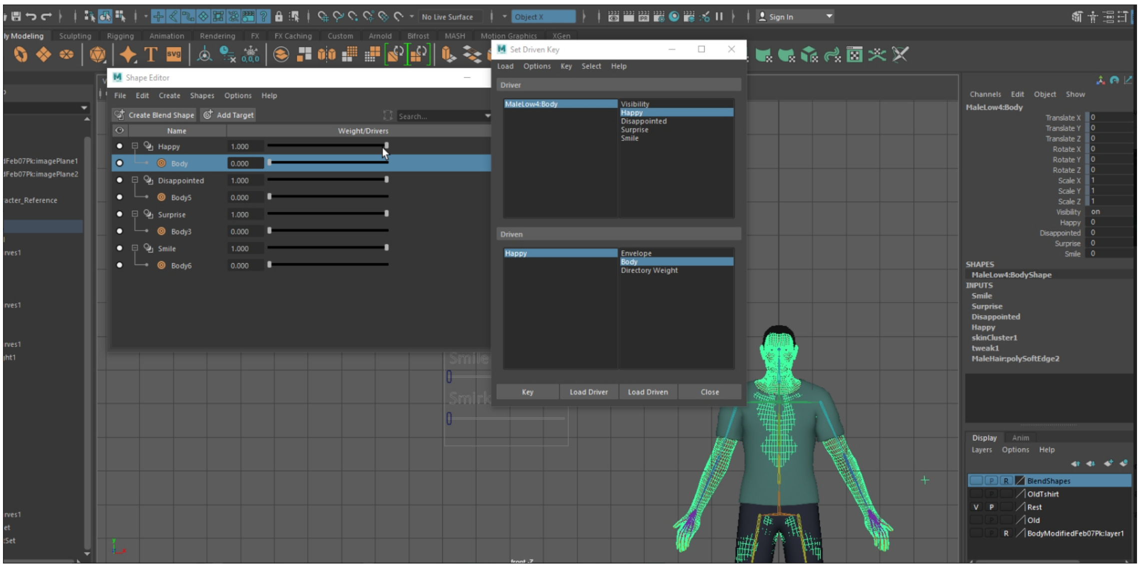


Figure 4.19: Maya interface for generating gesture buttons

For rigging, blend shapes are used from Deform Menu. For blend shapes to work on capital model, duplicating 5 models as shown in figure .4 from the original model and tweak the vertices to make the facial expressions and then use blend shapes and project those expressions on to the original model.

Before animation can actually start, there is one final step that must be completed in order to get the correct output to illuminate the Maya interface, which does not have any lighting. First, a manual light must be placed from the rendering menu, and then a directional light must be used to get the output. Next, a square must be created and scaled to fit the interface in order to have a background for the model.

For body gestures, animate the joints of the model and key certain positions in certain frames to obtain the output. For example, to get an animation with hand greeting, bend the elbow upwards and adjust the wrist and figures by imagining how the humans rise their hand when greeting someone.

For facial rigging, the basic version of the skeleton is loaded into Maya, then selecting the geometry of the face area where the face rig will take place, making sure to select a bit more area than required, then selecting the object area (face), then removing the polygon curve, so that they won't be removed accidentally while the rest of the process is completed.

Now, selecting all the elements that are required for the face; in some cases, the common error that may appear in this case is "skin cluster not found," in which case the problem can be solved by creating a new skin cluster; in this case, the problem can be solved by updating the objects; once again the left and right are to

Figure 4.20: Greeting gesture

Figure 4.21: Disappointment gesture

be selected and updated in the objects, but optional can also be selected for better output (eye, eyebrow etc.).

Once the facial selection is complete, the next step is to choose the model's design (symmetrical or asymmetrical), then going through a bunch of options that need to be focused on, such as the position of the eyeball, selecting the geometry for adjusting the edge loop, and then adjusting the eyelid by checking all the parameters.

For the lips, the edges must be checked to ensure that they are not merged into the skin and that the mean of the lip is properly adjusted; in the event of a problem during the process, there is an option to "help me," which will guide through the process; and then eyebrows can be adjusted by focusing on the following parameters: inner and outer vertex; if the eyebrows are complicated, advanced options can be used for better results.

Figure 4.19 shows the Maya interface for generated gestures and emotions with buttons after rigging. As shown in the figure, when the bar goes from 0 to 1 the gesture will turn on and turn off when the bar goes from 1 to 0.

These are the basic procedures for face rigging for any model. For the forehead, pre-vertices must be modified and pivoting must be changed for jaw functioning. For the nose, inner and edges should be picked for basic, advanced option can also be selected in complected scenarios.

Figure 4.22: Smile gesture

After the basic model selections have been completed, selecting the advanced face build options will run through a series of scripts that will create a custom graphical interface and some controls on the face. There will be two options after the basic model preparation has been completed: either selecting the advanced options, which will create a graphical user interface and some other controls for ease of work, or selecting the manually usable options.

Finally, after modelling the agents from head to toe, designing clothing, texturing using UV mapping and skin-painting for creating bone structure for the agents to acquire animation using the process of rigging, both male and female agents are obtained.

Figure 4.23: Astonish gesture

After the rigging and animation process, based on the number of frames selected in Maya, a total of 381 image frames for the male and 348 image frames for the female are obtained. These frames are then converted into a series of continuous frames (video) using the adobe photoshop.

The male video with 15 seconds and the female video with 13 seconds is generated. These videos consist of a total of four gestures, the gestures include greeting gesture 4.20, smile gesture 4.22, disappointment gesture 4.21, and astonish gesture 4.23.

5 Results

This chapter provides a brief overview of the developed male and female pedagogical agents, along with the evaluation results collected from the group of different users such as students, pedagogical experts and technological experts who participated in the survey.

5.1 Avatar developed as Virtual Agent for interactive learning scenario

Male and female agents are developed using Autodesk Maya, a 3D modelling tool, as shown in the below figures. The developed agents can be classified under the age group of 20–30 years old. These agents are developed based on the design criteria which were gathered from the literature survey of various scientific papers and other developed agents.

Figure 5.1: Modelled Male Agent

According to the literature review, some key design criteria were identified, including the need for the proposed system to resemble humans [17] with an age between of 20-30 years [19], the inclusion of both male and female agents for gender equality [17][19], and ethnicity representation in line with the where the agent is being developed [16][17].

Figure 5.2: Modelled Female Agent

As discussed in the chapter 2, most of the virtual agents such as Cyberpoty, AVARI, NEVA, etc. were developed using Haptek's PeoplePutty software, a software that provides some pre-developed models that can be used by the users by modifying the outlook with the "edit option." These agents were also used in some educational contexts, as mentioned in the state of the art. These studies provided a strong background to develop a 3D pedagogical agent, but unlike using some pre-developed models, this paper provides a series of steps, as shown in previous chapters, to develop the pedagogical agent from scratch.

The developed agents strongly support the design criteria, since the developed agents resembles the humans as suggested by [17]. Agent's age can be categorized between 20-35 years, which supports the paper [19]. Both male and female agents were developed as mentioned in paper [17][19]. Also, the developed agents almost resemble the European ethnicity as per requirements that are mentioned in [16][17].

The developed agents strongly support the design criteria, since the developed agents resemble humans, as cited in paper [17]. An agent's age can be categorized between 20 and 35 years old, which supports the paper [19]. As mentioned in the paper citations [17] and [19], both male and female agents were created. Furthermore, the developed agents closely resemble the European ethnicity as specified in

[16][17].

These developed agents can also be used as template for generating more ethnicity models with different age groups for different roles such as mentor, tutor, and teacher. More animation can be added with provided resources to handle the modelling and animation tools.

5.2 Evaluation Results

An open-ended survey (refer 7) was conducted regarding with the developed 3D pedagogical agents by creating a website for agents and sharing a questionnaire form with users. A total of 6 questions were presented in the survey, the Questionnaire includes the user experience about the appearance (age, gender, ethnicity, etc.) of the agent, features of the agent, level of realism and animation, and users recommendations for future work. These questions are structured based on the design criteria and Pedagogical Agents Levels of Design (PALD) model (refer 2.4).

Table 5.1: Questionnaire results overview

Questions	**Students (7)**	**Pedagogical experts (3)**	**Technological experts (2)**
Appearance of the Avatar as human	85.2% commented good	66.6% commented for improvements	50% commented as good
Evaluate the avatars' feature, role and type	71.2% evaluated as acceptable	33.3% evaluated as acceptable	50% evaluated as acceptable
Level of realism	71.2% are satisfied	33.3% are satisfied	100% are satisfied
Level of animation	57.2% commented as more animations are needed	100% commented to improve animation	50% commented to improve animation
Outlook of the agent	85.2% satisfied	33.3% satisfied	100% satisfied
Overall recommendation rating (1-Excellent, 5-Worst)	2.25/5	3/5	2.5/5

The questions were designed based on the qualitative approach of how an agent should be modelled and how users perceive the modelled agents in the learning environment. These designed evaluation questions give a detailed overview about the developed agents and any recommendation on new features or gestures that are needed to be added in later versions.

A total of 12 user responses were noted, which included responses from 7 students, 3 pedagogical experts, and 2 technological experts. The table 5.1 presents an overview of the survey results collected from 12 users.

According to the survey, 85.2% of students, 66.6% of pedagogical experts, and 50% of technology experts felt the appearance humanly. 71.2% of students, 33.3% of pedagogical experts, and 50% of technology experts evaluated the agents features, role and type as acceptable. For level of realism of the agent, 71.2% of students, 33.3% of pedagogical experts, and 50% of technology experts found promising. Level of animation is criticized by most of the users like 57.2% of students, 100% of pedagogical experts, and 50% of technology experts commented for the improvements in animations. But when it comes to outlook, 85.2% of students and 100% of technological experts are satisfied. Some students commented that to improve the level of animation regarding the 'surprise', they suggested the addition of the lips and mouth movements would be great.

Contrary to the students response, some pedagogical experts are not completely satisfied with the current level of the animation and realism. They suggest an overall improvement in facial expressions is needed for acceptance in an E-learning environment.

As per the outlook of the agent, some students thought that the male agent was a North American male and the female agent was a European female, and they were quite satisfied with the available agents. Pedagogical agents suggested having different ethnicity agents with different age groups, so users can select the agent according to their will.

As per the age, students felt the age of the Avatars could be around 23–28 yrs, whereas other experts felt the age was around 30-35 yrs. Students also rated Avatars' as good; on average, the rate-scaling was 2.25 out of 5 (where 1 is excellent and 5 is worse). Technological experts rated the agents at 2.5 out of 5, and pedagogical experts rated the agents at anywhere from 3 to 3.5.

Overall, students and technological experts recommended the agents to be used in E-learning systems with a few modifications to gestures. whereas, pedagogical experts recommended the agents only with improvements that are accurate with animations and gestures.

6 Discussion

The post preliminary questionnaire is conducted to get the users view on the agents. Both positive and negative reviews are recorded from the users. An overall users rating was presented in the section 5.2, this chapter describes the comments from the users, limitation and future work of the modelled agents.

6.1 Users response on developed agents

Users' responses were divided into three categories, including student, pedagogical, and technological experts.

Students were delighted and felt Avatar was an actual human. Compared with the features and qualities of nature, it can be interactive to communicate, defined as the character of humanity. Students also responded with interesting comments for each survey question. Some direct comments from students are, "I felt the male avatar's expression is more defined than the female avatar. I feel female avatar expressions are a little hindered due to spectacles", "It is close to real human. The expression change is clearly visible." "It could have been better for 'Sad' feeling", "The posture of the Avatar is looking really nice. The avatar represents a young person/agent from Europe."

Students responded optimistically about the behavioral facts of agents, and most of them are excited and recommended these agents in E-learning. Few students also imagined and expressed their views in terms of gender and gave importance to each equally. Students are self-motivated with this concept to have a moral, intelligent agent and enhance their creativity and thinking abilities.

Pedagogical experts felt that Emotional visualization could be much better than the present.For instance, experts commented, "Invest more effort in the overall appearance," "Not very realistic, sad was rather angry/annoyed, hi was without any movement inside the face, surprise could not be recognized at all." They feel expressiveness should be more than just humans with intelligent agents meeting all the updated demands. Experts feel a few more changes are required for the pedagogy to incorporate this concept, have a positive emotional balance, and build a sound bridge/barrier for solving a problem logically. The characteristics and physical features of avatars were different from those of humans. These comments indeed help to improve the overall model with provided resources and time.

Technological experts reviewed the agents and commented, "In any field, users would benefit from interacting with such avatars." Their expressions were realistic and resembled those of humans." Depending on the area, the avatar could have a variety of roles and types. One of the experts felt that the agent would fit as a mentor agent rather than a student agent. It almost resembles human terms because the avatar is so realistic. It seems reasonable enough and also has room for improvement. One of the technical experts commented, "I would recommend such avatars for a learning scenario, as they seem interactive and efficient." As they are improved and technology is added, these avatars would make learning more enjoyable, especially for children.

The agents undoubtedly produce gestures and animations after comparing the results from implemented models with users' comments and reactions, but an overall improvement may be ideal for improved user interactions.

6.2 Limitations and Future work

Every study has limitations, and these developed agents are no exception. Limitations include limited resources from free available software, insufficient time to master the tools, PC with low level processing and configurations.These limitations caused backdrops in the developed agents such as fewer body movements, a lack of human expressions with mouth and lip movements, and the capacity to move only one hand. Despite the fact that students and technical experts in the survey are pleased with the concept of agents and developed avatars, pedagogical experts believe some improvements would be beneficial. The present agent can only make a few facial expressions and wave their hand. However, for agents in an E-learning context, this could be a terrific beginning point.

These constraints are enforced due to inexperience with modeling tools and animation, and also fewer tools to generate animations and rendering. Time is also vital because it might take days or even months (for someone with no experience) only to design a section of a body with a human level of realism.

Since the Maya interface is very complicated because of the number of tools and options available, it takes months to get adapted to the environment. As per my experience, it was very difficult to remember all the options on the keyboard and almost complete model is designed by tweaking the faces and vertices using 'Mouse', it was very complicated to design and also due to size of Maya software the processing was very slow. For instance, it took 2 days just to create 15 seconds male animations. Therefore, the configuration of the system on which the agents are developing is very crucial. These constraints can be resolved by gaining greater skills with modeling and animation software with provided sufficient time and resources, such as a PC with high processing and configuration. The currently established agents can also be utilized to further improve models in order to make the necessary modifications with provided sufficient time.

In the future, these agents can be further modified and modelled with more gestures and facial expressions. It is also possible to develop the agents with different age groups, with different races from across the world and then integrated in different E-learning scenarios.

7 Conclusion

This study provides an overview of how avatars and virtual agents came to be used and how they can engage users, beginning with the use of ELIZA to present realistic agents. Some examples, such as SAMIR, NEVA, STEVE, AVARI, Cyberpoty, and others, are actually implemented and tested with users in real-time. These examples provide a brief overview of how to design a virtual agent and the key criteria that must be considered when designing an agent.

As technology advances, pedagogical agents are seen as the user interface in virtual learning platforms. The steps for modeling a pedagogical agent with facial expressions and gestures are provided in this document, together with background information on the modelled pedagogical agents in the E-learning environment to date. In addition to AutoDesk Maya for modeling, rigging, and animation, Substance Painter was used to texturize the agents' skin and clothing.

On the basis of the literature review and the survey, it appears that users are more likely to prefer 3D pedagogical agents than traditional chatbots because they are better able to stimulate their interests, engage them, and increase the frequency of communication between computers and students. Design criteria from the literature research reveal that a number of factors, including an agent's characteristics, type (human or animated), age, degree of animation, and realism, play a very significant part in creating a pedagogical agent. According to a survey I conducted on the subject, users are less concerned with the agent's age, gender, and outlook, and they primarily prefer educational agents to regular chatbots.

Even though the students are satisfied with the agents, pedagogical experts are not completely satisfied with the level of animation. But on the good part, these developed agents Maya files (.ma) can be utilized as a prototype to improve the animations and design more ethnically diverse agents with distinct ages for various roles, such as mentor, tutor, and teacher. With the resources available to manage the modelling and animation tools, more animation can be added. Therefore, in coming years, these types of pedagogical agents can be used in real-time virtual learning by assisting the users as mentors, tutors, and helper agents.

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Appendices

1. What are you studying?
   O Master
   O Bachelor

2. What is your gender?
   O Male
   O Female
   O Other

3. Which ethnicity do you belong to??
   O European
   O American
   O Asian
   O African O Other

4. Have you ever used chatbots?
   O Yes
   O No

5. Have you ever used 3D virtual agents?
   O Yes
   O No

6. What would you prefer?
   O 3D agent
   O Standard chatbot

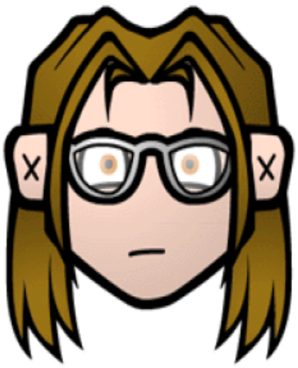
7. Would you prefer 3D virtual agent of your own ethnicity or others?
   O Yes
   O No

8. What would you prefer?
   O Male agent
   O Female agent
   O Doesn't matter

9. What would you prefer?
   O Human agent
   O Animated agent
   O It doesn't matter

10. What would be the age of the virtual agent you prefer?
    O 19–24 years
    O 25-30 years
    O 30 and above
    O It doesn't matter

Miscellaneous Images

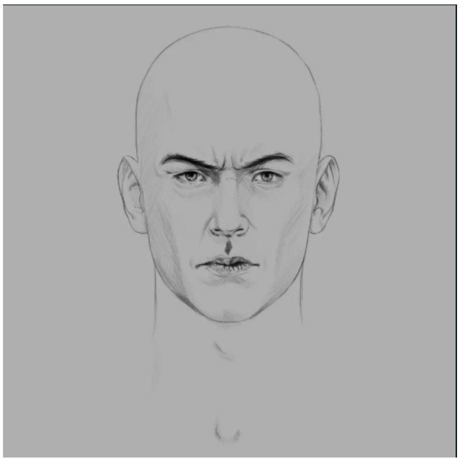


(a) cartoon image avatar

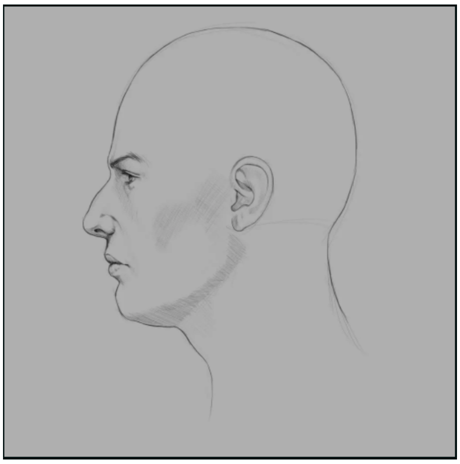
(b) Seonaid ("Shona") a flexible presentation avatar

Figure .1: Example Avatars [7]

Figure .2: ALICE [21]



(a) Front view



(b) Side view

Figure .3: Male reference images

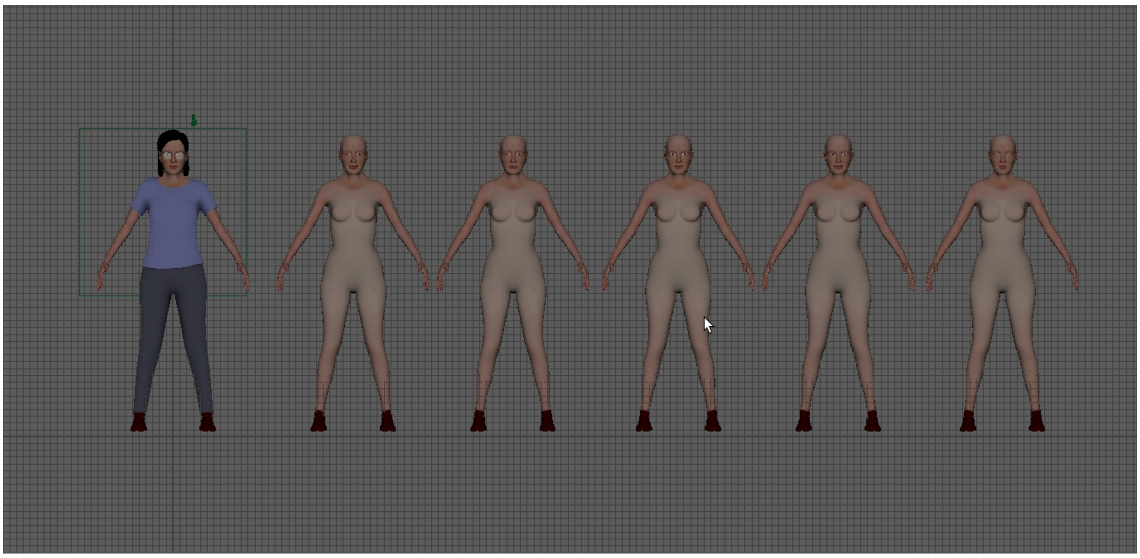


Figure .4: Blend Shapes

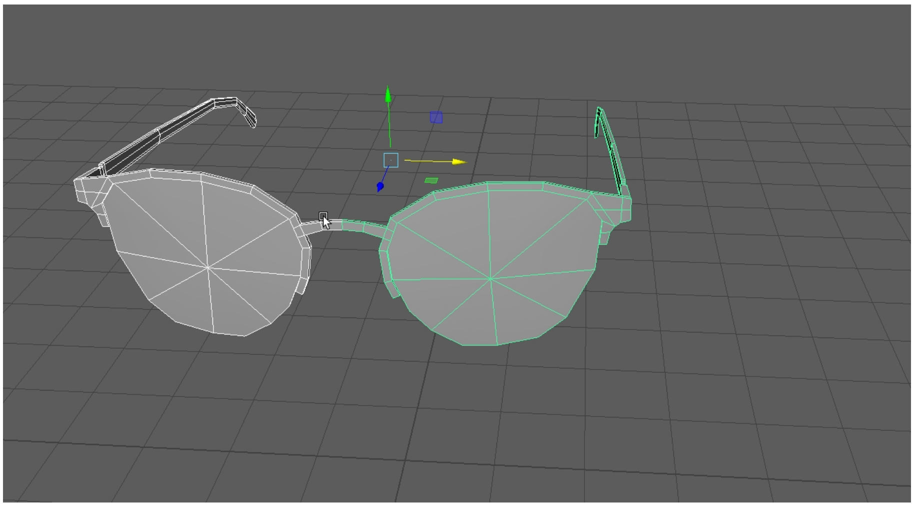


Figure .5: Female agent spectacles

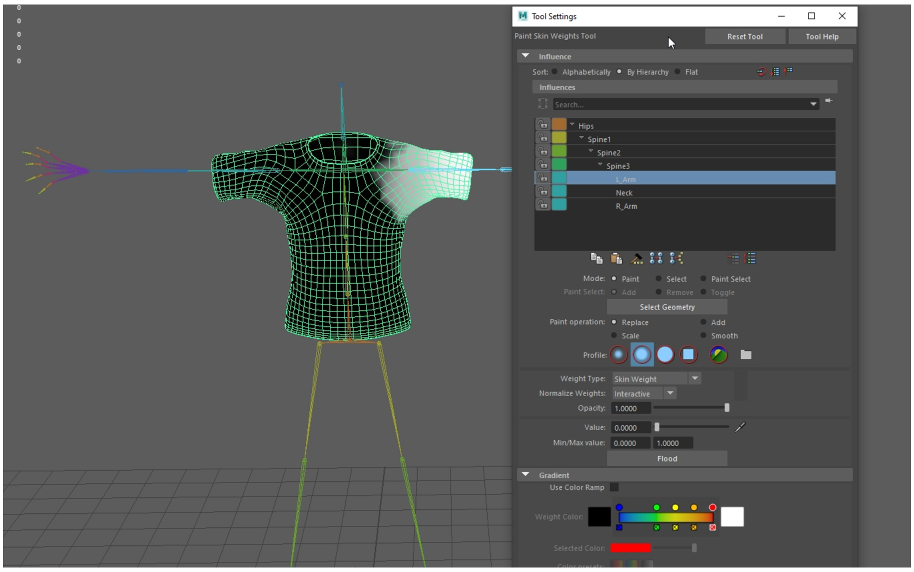


Figure .6: Agent's skeleton

Evaluation Questions Form

Evaluator's information

- I am: Student/ Pedagogical Expert/ Technological Expert (Please highlight)
- Please visit the following link to experience the avatars of Pedagogical Agent: `https://snazzy-eclair-7109a4.netlify.app/`

From your experience with the avatars of the Pedagogical Agent, could you please answer the following questions:

1. How have you felt with the appearance of the Avatar as human?
   User Response:
2. How would you evaluate the avatars' feature, role and type?
   User Response:
3. What do you think about the level of realism of the avatar?
   User Response:
4. How would you rate the level of animation of the avatar (Out of 5, 1=Excellent to 5=Worst) and why?
   User Response:
5. What do you think about the outlook (Age, Gender, Ethnicity, Gesture) of the avatar?
   User Response:
6. What is your overall recommendation to implement such avatars in a learning scenario?
   User Response:

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