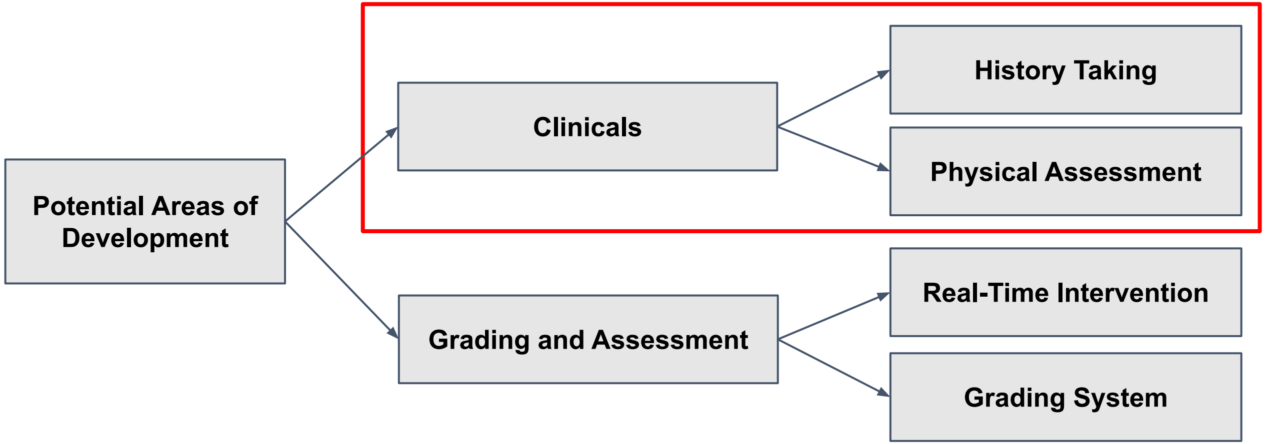
7 Prototyping

Overview: Setting of Prototype Scope



Prototyping focus will be on Clinicals for Template C.

Figure 1: Identifying the Potential Areas and Setting the Focus of Prototyping

Prototyping was based on the data of an anonymized patient obtained from NUH Orthopaedic Spine Clinic

Some key characteristics of this patient include:

- A 60 year old chinese female
- Cleaner at shopping centre
- ADL independent, ambulant in community without walking aids
- Back and leg pain for 6 months duration
- Diagnosis: L4/5 Degenerative Spondylolisthesis*

** Details found in the appendix (Page 34)*

7 Prototyping

Conversational Agent: What's Next

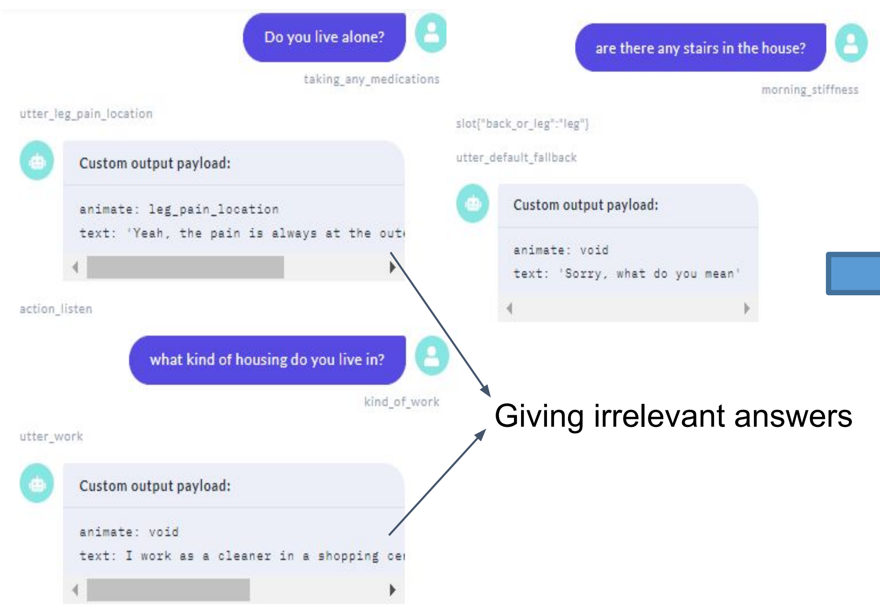
From the evaluation and areas of improvements identified in Template B, we came up with possible methods to develop *Mandy* further.

Evaluations/Area of Improvements identified	Proposed Solutions
The medical student highlighted that *Mandy*'s database needs to be further expanded to respond to inputs related to cancer, weakness and numbness of body, as well as Activities of Daily Living (ADL) independency *(most insightful)*	*Mandy's* database was further expanded to address these questions.
Mandy is unable to understand sentences when there are multiple possible answers (e.g. "When do you feel the most pain?" can be answered with the time of the day - morning/night, or when the leg is in a specific position - flexed/extended)	No direct solution. *Mandy* was to answer and if it was wrong, the doctor would clarify what he meant.
Mandy is unable to understand user inputs if they are phrased very differently from the training data	No direct solution. The only solution was to train *Mandy* with as much data as possible.
Mandy is unable to understand a user input with multiple intents *(least insightful)* (i.e. "Did the back pain and leg pain start at the same time?")	*Mandy* was trained to answer questions with multiple intents (e.g. PS_pain_duration_question_same_for_both_pains is an intent to ask for both leg pain and back pain).

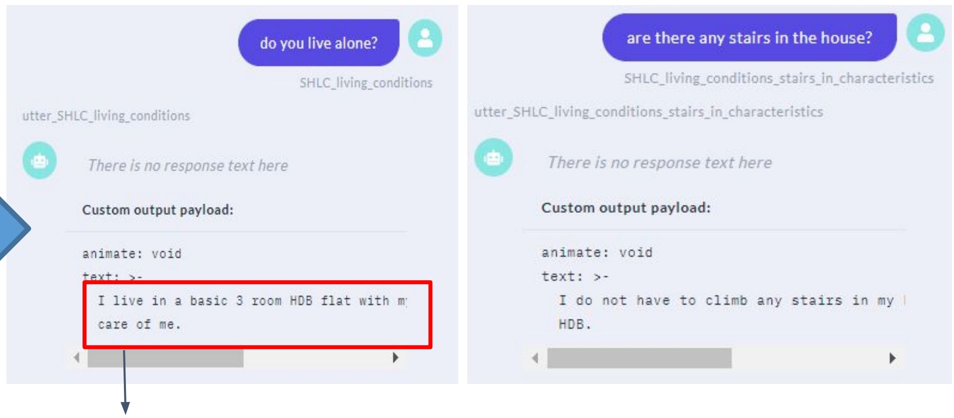
7 Prototyping

Conversational Agent: Recognising Questions on ADL

BEFORE TRAINING



AFTER TRAINING



I live in a basic 3 room HDB flat with my husband and daughter. They take good care of me.

Figure 2: *Mandy* is unable to answer questions on ADL

Figure 3: *Mandy is* able to answer questions on ADL

7 Prototyping

Conversational Agent: Recognising Multiple Intents

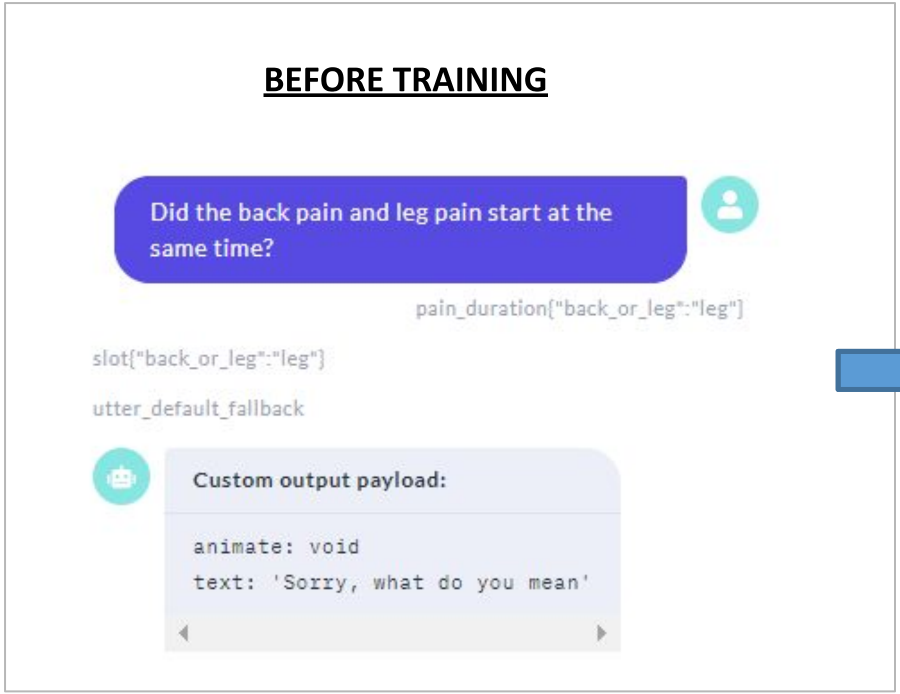


Figure 4: *Mandy* is unable to recognise multiple intents

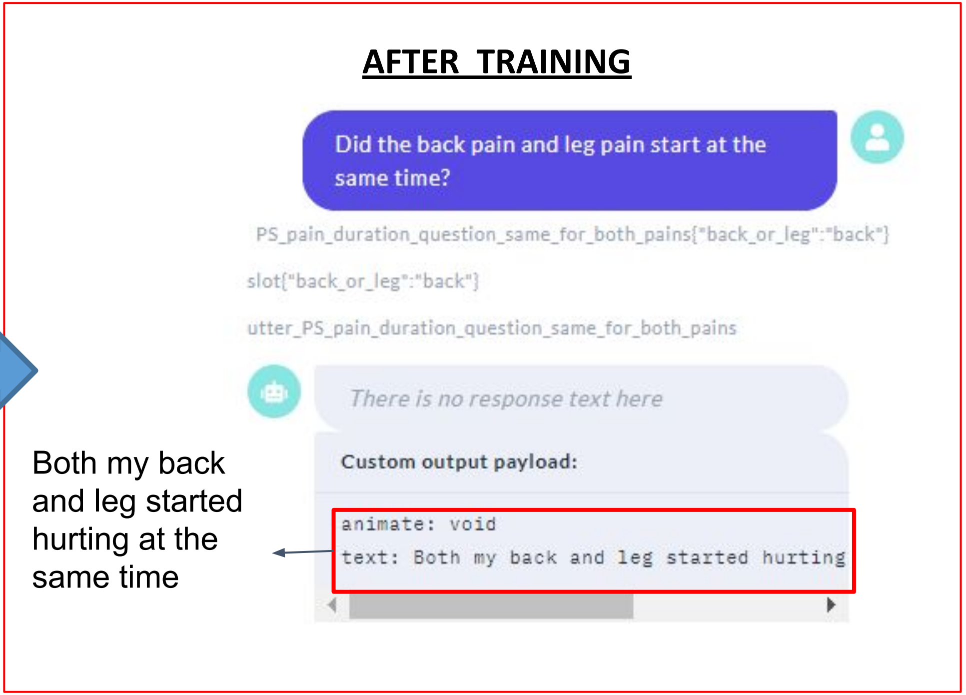


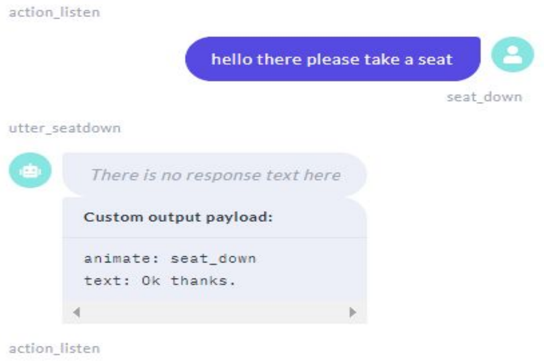
Figure 5: *Mandy* is able to recognise multiple intents

7 Prototyping

Conversational Agent: Integration into Virtual Environment

The resident’s speech is recognised and converted to text through Microsoft Azure.

The text is sent to the RASA system to get a response. The response is sent to the patient along with an action instruction if necessary



Mandy utters the response along with the action

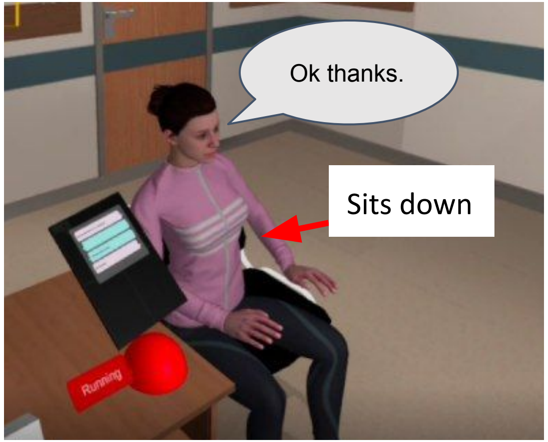


Figure 6: Workflow of the communication between the Resident and the Patient in Virtual Environment

7 Prototyping

Conversational Agent: Integration into Virtual Environment

Function of the feature

1. Allow the residents to keep track of the whole history taking process

2. Allow the consultant to review the conversation to give feedback to the resident regarding the history taking process

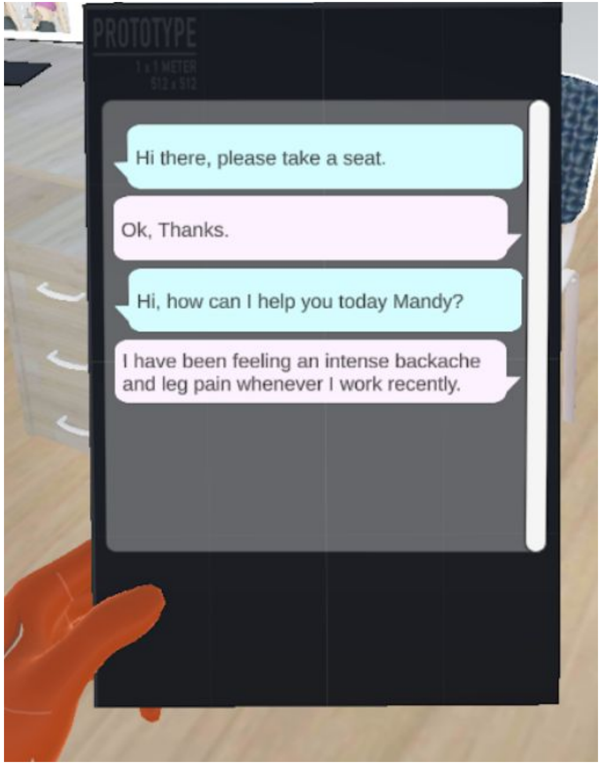


Figure 7: ipad showing the conversational history between the resident and the patient

7 Prototyping

<u>Conversational Agent: Testing *Mandy* with Year 4 Medical Student, *Shiwei*</u>

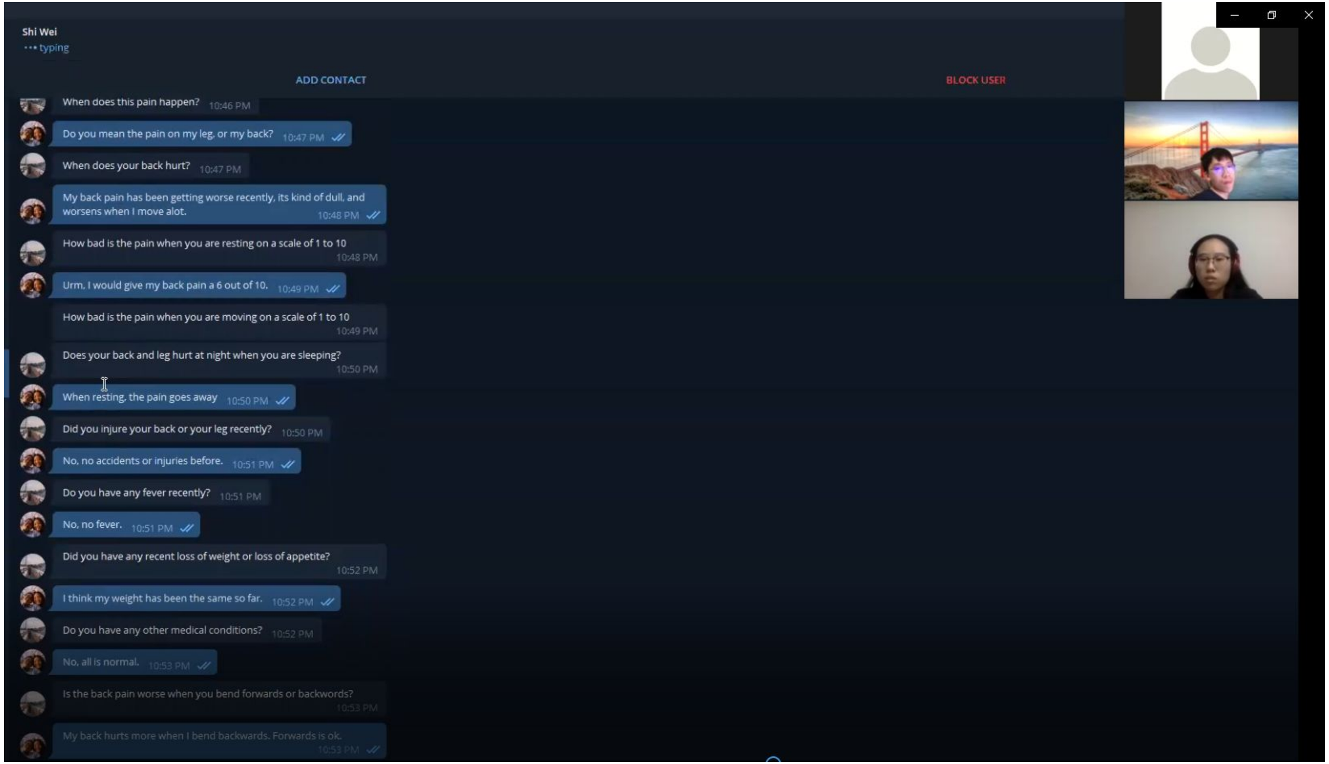


Figure 8: Interaction of *Mandy* with *Shiwei* through telegram

7 Prototyping

Conversational Agent: Evaluation

After further training, a mock history taking session was tested against the same medical student to validate our improvement process.The process was then evaluated, where % accuracy were compared and areas of improvement were identified.

% Accuracy (number of questions answered correctly/ total number of questions asked * 100%)	**Preliminary test (Before training)**	**Second test (After training)**
	7/24*100%= **29.2%** (3.s.f)	19/26 = **73.1%** (3 s.f.)

Key findings identified from the user testing of *Mandy* with Shiwei	
Strengths	Despite *Shiwei* occasionally having slight deviations from the set of questions she asked in Template B, *Mandy* was still able to answer with a significantly higher accuracy than before.
Limitations	● There was no resting pain scale (only moving pain scale which was 6/10) ● Answers were too detailed (3 instances) e.g. *Shiwei* asked for weakness, but *Mandy* replied that she had both weakness AND numbness (numbness was not asked at all).
Evaluation	*Mandy* is a feasible conversational agent that can be incorporated into our Virtual Reality Simulation Tool. *Mandy* has improved drastically from our previous versions and is sufficiently robust to handle the rigour of history taking during Clinicals. *Mandy* was in fact too detailed and unnatural this time around.

7 Prototyping

Animation: What's Next

From the evaluation and areas of improvements identified in Template B, we came up with possible methods to develop *Mandy* further.

Evaluations/Area of Improvements identified	Proposed Solutions
With Blender, we are only able to use predefined models from Mixamo and other online sources.	MakeHuman is used to create customizable characters for an expandable portfolio of models to cater to different patient conditions.
Animation creation in Blender is time consuming and lacks the realism of creases in the skin and muscles as each bone is manually rotated per frame to create animation.	Blender will be used as a pre and post processing tool to prepare the model for the mapping of motion capture data and the cleaning up of inaccurate motions.
Kinect 360 is feasible in creating custom animations quickly, with some inaccuracies especially when the subject's body part is behind another.	Further exploration of Microsoft (MS) Kinect, the latest version of Kinect 360, as a motion capture system while taking note of details such as positioning of MS Kinect and colour of the user's clothings.
In general, motion capture is a feasible method to efficiently and accurately recreate realistic simulations of patients' motions.	Redirected our focus to using motion capture systems for animation creation. In addition to MS Kinect, we explored Vicon Motion Capture (MX) System as an alternative.
Scripting in Unity allows greater flexibility to customize triggers for the *Mandy's* motions.	Delved into the utilization of speech as trigger for *Mandy's* motions.

7 Prototyping

Animation: Revised Animation Workflow

Rigging of *Mandy*'s face and body → Motion animation of *Mandy* → Controlling *Mandy*'s animation (Model control)

Rigging of *Mandy*'s face and body

Process of creating interconnected digital bone structure in *Mandy*

Using **MakeHuman** for the customization and rigging of the character

Motion animation of *Mandy*

Process of recording and animating *Mandy*'s motions

a) Using **MS Kinect** and **Vicon MX System**, we recorded custom animations through our physical body motions

↓

iPi Mocap Studio (MS Kinect) and MotionBuilder 2020 (Vicon MX System) to map the recorded motions to the bones of *Mandy*

Controlling *Mandy*'s animation (Model control)

Process of controlling *Mandy*'s animations with resident's input

Importing *Mandy*'s 3D model and animation into **Unity**

↓

a) Using **Unity's Graphic User Interface (GUI)** to map our recorded animations to *Mandy's* character model

b) Using **scripting** in **Unity** to trigger *Mandy*'s actions with speech inputs for user testing

7 Prototyping

Animation: Rigging and Character Design

Initial character design using patient characteristics such as age, height and weight and ethnicity.

After character modelling, we rigged the character with 53 bones, optimizing it for export to Unity.

The newly created character model can then be animated in Unity based on Kinect or Vicon MX systems.

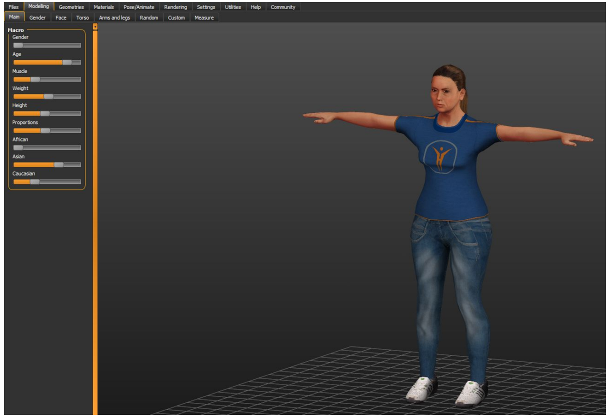


Figure 9: Character design from patient characteristics in MakeHuman

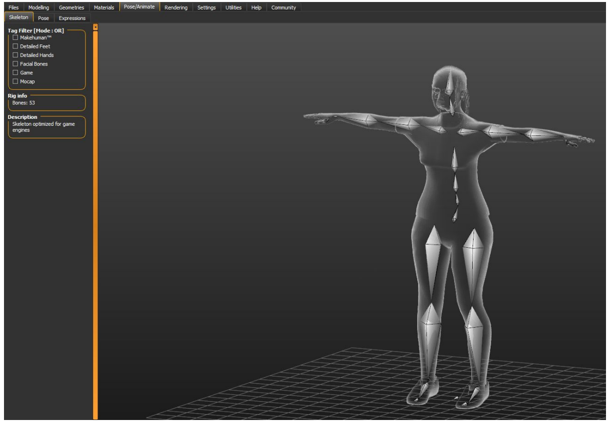


Figure 10: Rigging character with optimal bones for game design in MakeHuman

Figure 11: Exporting *Mandy* into the Unity environment

7 Prototyping

Animation: Selection of Gait for Motion Capture

Walking is dependent on the complex interaction between multiple organ systems – nervous, musculoskeletal and cardiorespiratory systems, while involving patient’s motor ability and adaptability. As such, in order to accurately diagnose patients, gait analysis are often conducted during Clinicals as part of the physical assessment, providing important indicators that reflect the patient’s overall health condition.

From our interviews with a medical student, *Shiwei*, 3 gait patterns (Normal, Antalgic and Broad-based) are frequently observed. Hence, we decided to record these gaits as animations for *Mandy* using Kinect and Vicon as motion capture tools.

Gait Type	Gait Description
Normal Gait	A person’s normal walking habit
Broad-based Gait	Can occur due to myelopathy, which is a severe compression of the **spinal cord** and the nerve roots which may result from inflammation, trauma, congenital stenosis. This may result in a loss of balance during walking, resulting in a Broad-based gait.
Antalgic Gait	A gait that develops as a way to avoid pain while walking. It is a good indication of weight-bearing pain, where the stance phase of gait is abnormally shortened relative to the swing phase.

7 Prototyping

Animation: Motion Capture with MS Kinect

Motion capture using real-life actor, *Eldred* → Mapping recorded motion into *Mandy*, our virtual patient → Importing and bringing *Mandy* to life in the virtual environment

Figure 12: Recording of Antalgic gait (Using MS Kinect)

Figure 13: Mapping *Mandy* with Antalgic gait (In Ipi Mocap Studio 4)

Figure 14: *Mandy* with Antalgic gait (In Oculus Quest)

7 Prototyping

<u>Animation: Motion Capture with Vicon MX System</u>

Motion capture using real-life actor, *Alvin*

Mapping recorded motion into *Mandy*, our virtual patient

Importing and bringing *Mandy* to life in the virtual environment

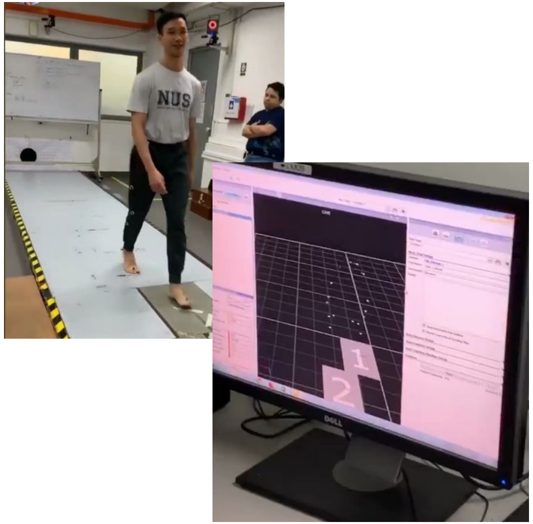


Figure 15: Recording of Antalgic gait (Using Vicon MX System)

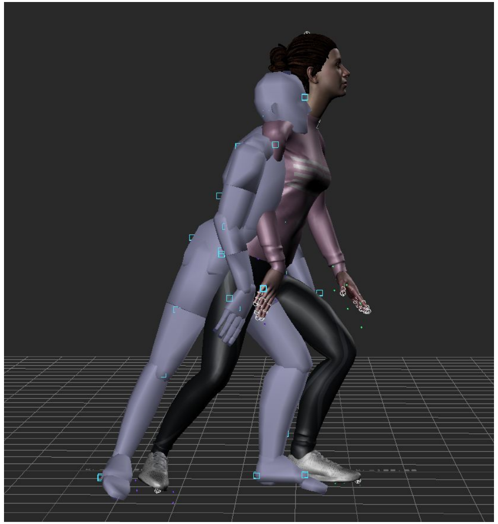


Figure 16: Mapping *Mandy* with Antalgic gait (In MotionBuilder)

Figure 17: *Mandy* with Antalgic gait (In Oculus Quest)

7 Prototyping

Animation: Model Control through Unity

Mandy was imported into Unity with gait animations recorded from Microsoft Kinect and Vicon MX systems, allowing for control of *Mandy* in Unity. We are working on its implementation into Oculus Quest using Microsoft Cognitive Services which is a speech recognition software powered by Azure.

Figure 18: Importing our custom rigged model to Unity

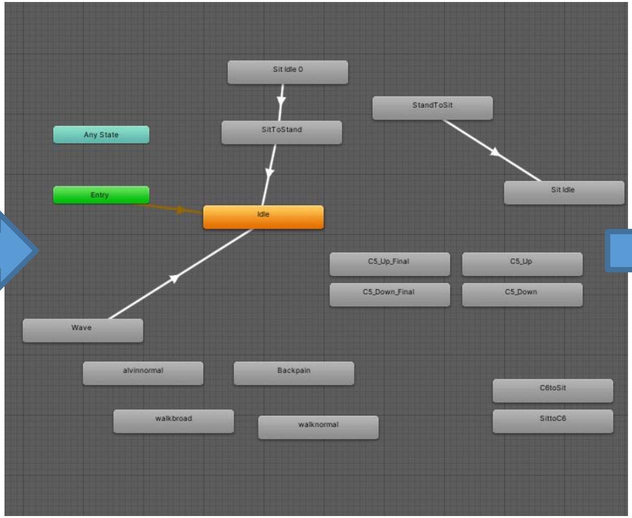


Figure 19: Adding all our animations recorded in Vicon MX and MS Kinect to Unity

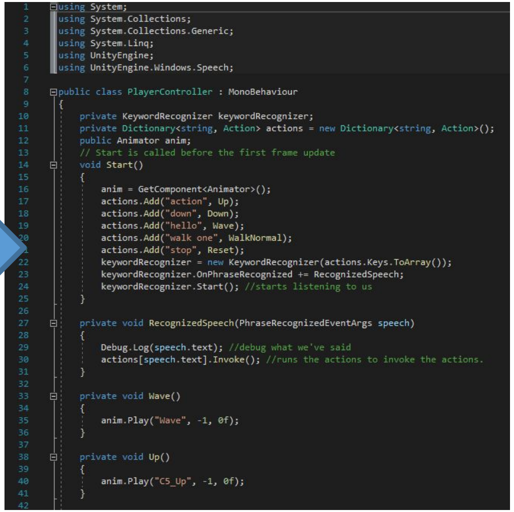


Figure 20: Scripting the speech recognition inputs to trigger our gait animations

7 Prototyping

<u>**Animation: Testing *Mandy* with Year 4 Medical Student, *Shiwei***</u>

A zoom session with *Shiwei* was conducted to test the feasibility of using MS Kinect and Vicon MX System to record and simulate patients' gaits. The recorded gaits were compiled into the video link below and through this video, *Shiwei* was tasked to identify the gaits shown - https://youtu.be/HIb5KfVu2RQ

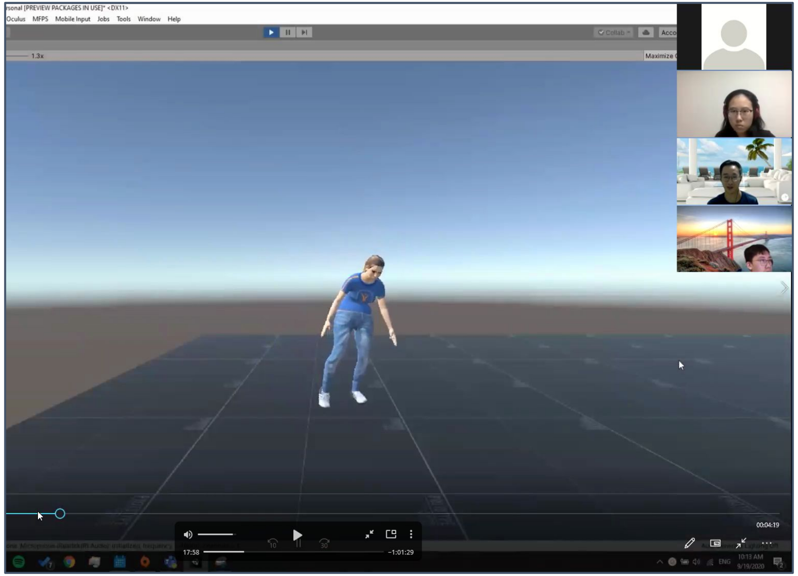


Figure 21: Testing recorded gaits from MS Kinect with *Shiwei*

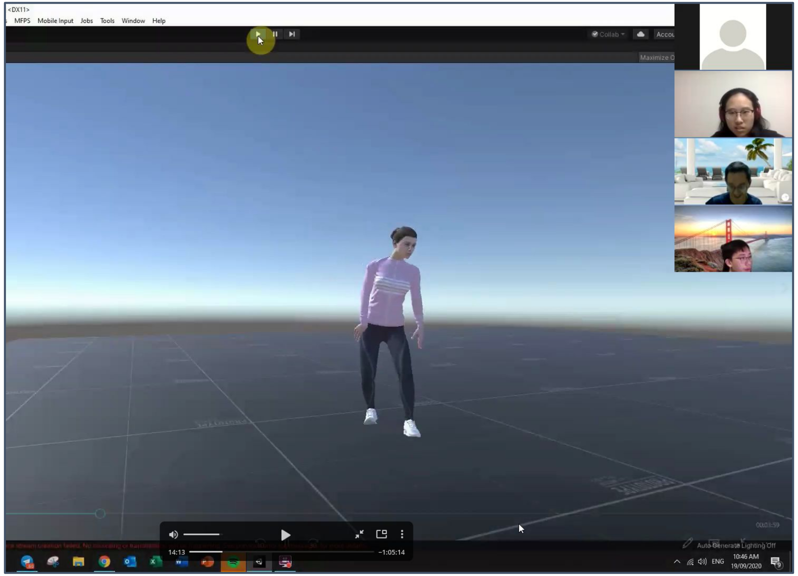


Figure 22: Testing recorded gaits from Vicon MX System with *Shiwei*

7 Prototyping

Animation: Testing *Mandy* with Year 4 Medical Student, *Shiwei*

Capturing the motion of 3 gaits (Normal, Antalgic and Broad-based) using the MS Kinect and Vicon MX System, *Mandy* is able to simulate these motions in the virtual environment for Orthopaedics Gait Assessment. The results are recorded in this video: https://youtu.be/EVsDLFewlOA

Normal

MS Kinect | Vicon MX System

Antalgic gait

MS Kinect | Vicon MX System

Broad-based gait

MS Kinect | Vicon MX System

% Accuracy (number of questions answered correctly/ total number of questions asked * 100%)	MS Kinect	Vicon MX System
	3/6*100%= **50%**	6/6 = **100%**

7 Prototyping

Animation: Evaluation

In the entire process of animating *Mandy* and the subsequent testing with *Shiwei*, we evaluated the process and identify potential areas of improvement for our next design iteration as shown below:

	MS Kinect	Vicon MX System
Strengths	*Shiwei* was able to correctly identify all instances of the Normal gait shown.	As the motions were clear and distinct, with a higher degree of precision, *Shiwei* was able to accurately and swiftly identify all gaits shown.
Limitations	Upper body of *Mandy* was unstable, causing *Shiwei* to be unable to differentiate between Broad-based and Antalgic Gait.	The speed of the animations were too fast to accurately represent an actual patient's gait speed.
Evaluations	● The character model was functional however it does not fit the appearance of a 60 year old chinese female according to *Shiwei*. However, she also validated that the appearance of the model does not affect the diagnosis made by the doctor as she was still able to identify the correct gaits shown. ● Inexperienced actor performing the gaits could have resulted in inaccurate animations, reducing *Shiwei's* ability to distinguish clearly between the different gaits. As such, the gait animations should have been recorded more distinctly and with a higher level of precision taking into account details such as speed of motions, joint angles, and movement of the whole body.	

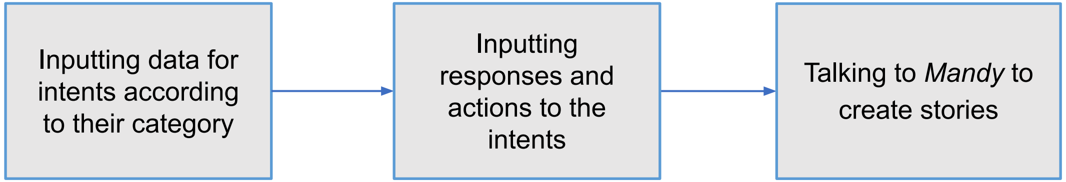
8 Detail Design

Conversational Agent: Connecting the Dots

Design Specifications	How RASA Fulfills the Design Specifications	How RASA Meets the Stakeholders’ Needs
Expandable Database	● If *Mandy* needs to be further trained, (e.g. addition of new scenarios or improvement of existing scenarios), it can easily done by inputting more data and training *Mandy*	● With the expandable database, the residents are able to experience a wide variety of scenarios to equip them with essential skills for different scenarios ● Improving the scenario will allow *Mandy* to depict an accurate human behaviour when the question is asked, improving the effectiveness of the practice
Adaptive Conversational Flow	● Through Natural Language Processing and Machine Learning, *Mandy* is able to adapt to the past conversational history	● With the adaptation with every training, *Mandy* will will be able to give a more accurate answer similar to that of a real patient, improving the effectiveness of the practice
Accurate Patient Behaviour	● Each response that *Mandy* gives in RASA is tagged to an action allowing the accurate behaviour of the patient according to the answer given	● With the accurate action tagged to the speech, *Mandy* is able to depict a more realistic patient behaviour and the residents will be able to have a more immersive simulation experience

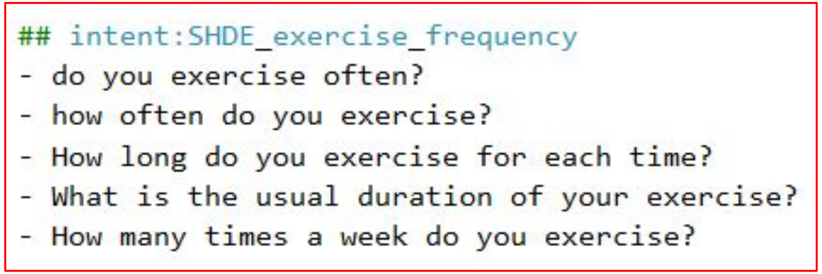
8 Detail Design

Conversational Agent: Training Workflow*



1 Inputting data for intents according to their category

Intents were categorised according to 8 basic sections of history taking** and for each intent, training data, which is the possible ways to ask the questions, was created.



```
## intent:SHDE_exercise_frequency
- do you exercise often?
- how often do you exercise?
- How long do you exercise for each time?
- What is the usual duration of your exercise?
- How many times a week do you exercise?
```

Figure 23: Intent where the doctor is asking a question regarding exercise frequency.

** Recap of workflow of how the conversational works is found in appendix (Page 35)*
*** Details on 8 basic sections of history taking are found in appendix (Page 36)*

8 Detail Design

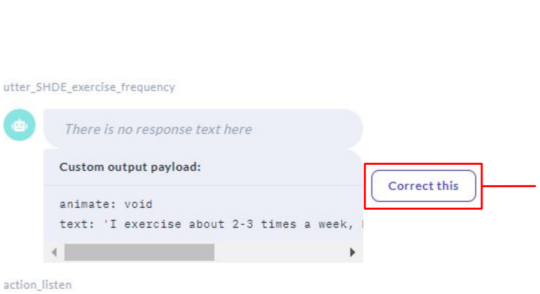
Conversational Agent: Training Workflow

2 Inputting responses and actions to the intents

```yaml
utter_SHDE_exercise:
  - custom:
      animate: void
      text: >-
        Hmm, I sometimes go for a stroll around the park. I will also use
        exercise machines under HDB.
utter_SHDE_exercise_frequency:
  - custom:
      animate: void
      text: 'I exercise about 2-3 times a week, between half to one hour each time.'
```

Figure 24: Possible responses to the question are keyed into the system

3 Talking to *Mandy* to create stories



With the new intent added, *Mandy* will match the new intent to response with the highest match. If the match is incorrect, it is immediately corrected.

```
## New Story
* SHDE_exercise_frequency
  - utter_SHDE_exercise_frequency
```

Upon correction, the new story of question and answer is created. *Mandy* will now be able to answer the question correctly to the question based on this story.

Figure 25: How stories are created and used to match the response to the intent

8 Detail Design

Rigging and Character Design (Animation): Connecting the dots

Design Specifications	How MakeHuman Fulfills the Design Specifications	How MakeHuman Meets the Stakeholders' Needs
Expandable Database	● Makehuman allows greater variability in character customization based on modifiable parameters (height, age, weight, gender, etc). ● This can be easily expanded to include contrasting patient types such as younger individuals due to sports related injuries which are also commonly seen in Orthopaedic Clinicals.	● After obtaining more anonymized patient scenarios from NUH Orthopaedic Spine Clinic, further custom characters can be designed in MakeHuman to achieve a wider variety of patient scenarios providing residents with more varied experiences in Clinicals.
Accurate Anatomical Features	● MakeHuman allows for 5 different preset rigs by default, varying from 53 to 163 bones and offering different levels of realism in human anatomical structure. ● We selected the rig optimized for game engines (53 bones) to balance between realism and the minimal bones required to construct and animate our 3D patient model.	● Accurate positioning of bones and joints according to the human anatomical structure is necessary, specifically for Orthopaedic Clinicals where misplacements of bone and joint positions can lead to an inaccurate diagnosis.

8 Detail Design

Animation Creation (Animation): Connecting the Dots

Design Specifications	How Motion Capture Fulfills the Design Specifications	How Motion Capture Meets the Stakeholders' Needs
Accurate Patient Behaviour	• *Mandy* will be able to accurately depict the nature and location of pain or weakness during impaired motion.	• With a high level of precision displayed in the motions, it reduces uncertainty and misinterpretation of the simulation. This ensures that any diagnosis made in the VR simulation by the residents is not affected by the technical limitations of the system. • As the clear and precise depiction of *Mandy's* conditions in the VR simulation emulates that of a real-life patient, it allows the residents to quickly identify symptoms displayed in Clinicals. This facilitates shorter diagnosis time with a higher degree of accuracy.
Accurate Anatomical Features	• As *Mandy's* animations are based on the recorded motions of real-life patients, *Mandy* will accurately emulate human's range of motion and limitations, while taking into account the body conditions and illnesses involved.	• Accurate range-of-motion of joints and body parts displayed by *Mandy* allows the immediate transfer of knowledge and skills learnt from the VR simulation into Clinicals with a real-life patient

8 Detail Design

Animation Creation: Detailed Workflow

Gaits was recorded with both MS Kinect and Vicon MX System and subsequently processed to create custom animations for *Mandy*. We documented the workflows in the form of videos that can be accessed via the links below.
MS Kinect: https://youtu.be/qbvmLgjAeR8
Vicon MX System: https://youtu.be/epN3Lknwu4Y

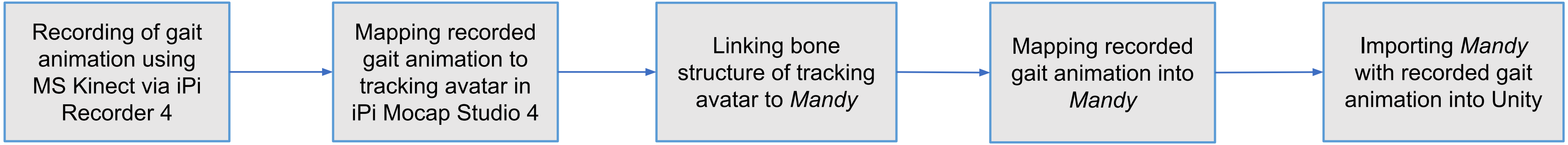


Figure 28: Creating *Mandy*'s animations using MS Kinect

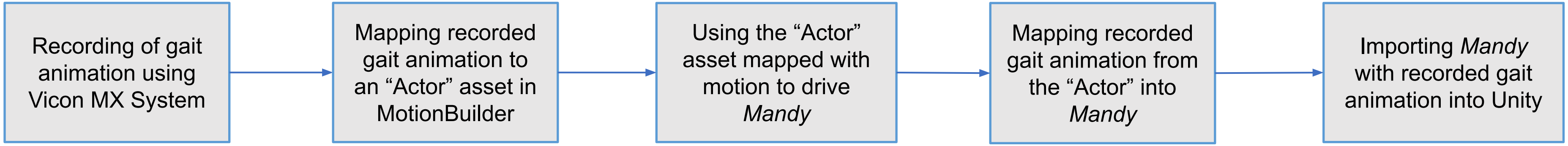


Figure 29: Creating *Mandy's* animations using Vicon MX System

8 Detail Design

Animation Creation: From MS Kinect recording to Animation Workflow

1 Motion capture using MS Kinect

The motion was recorded with MS Kinect and iPi Recorder 4. Using iPi Mocap Studio 4, we import and map the recorded motion into a “Tracking Avatar”.

Figure 30: Using MS Kinect to record antalgic gait motion

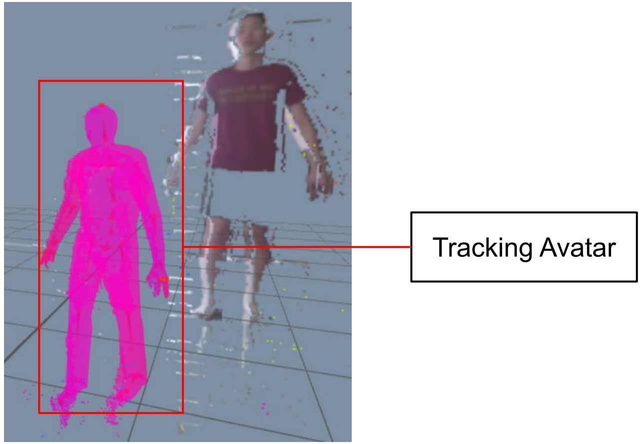


Figure 31: Mapping recorded motion into tracking avatar (In iPi Mocap Studio 4)

8 Detail Design

Animation Creation: From MS Kinect recording to Animation Workflow

2 Mapping of *Mandy* to the "Tracking Avatar"

Mandy was imported into iPi Mocap Studio 4 and her bone structure was matched to that of the "Tracking Avatar".

Importing of unrigged *Mandy*

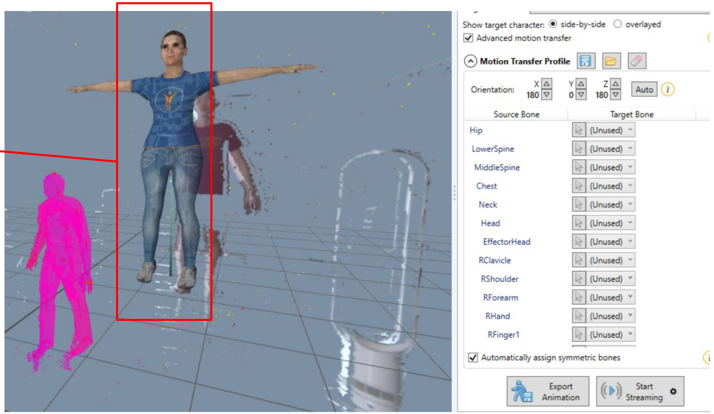
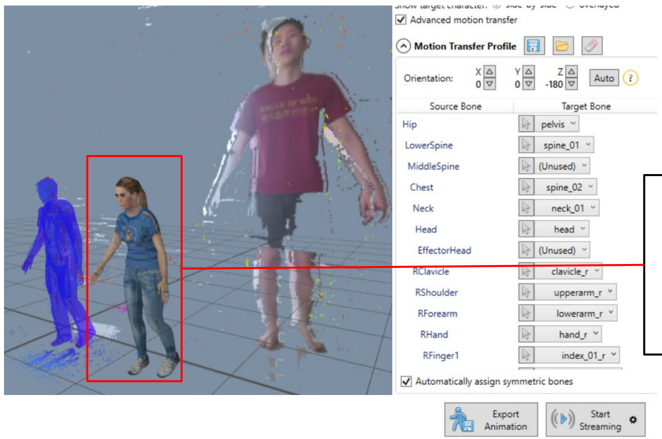


Figure 32: Before linking *Mandy* with the "Tracking Avatar"



Matching *Mandy's* bone structure with "Tracking Avatar"

Figure 33: After linking *Mandy* with the "Tracking Avatar"

8 Detail Design

Animation Creation: From MS Kinect recording to Animation Workflow

3 Animating *Mandy* with recorded motion

Using iPi Mocap Studio 4, we transferred the recorded motion from the "Tracking Avatar" into *Mandy*. This creates the animation, preparing *Mandy* to be exported for use in our production pipeline.

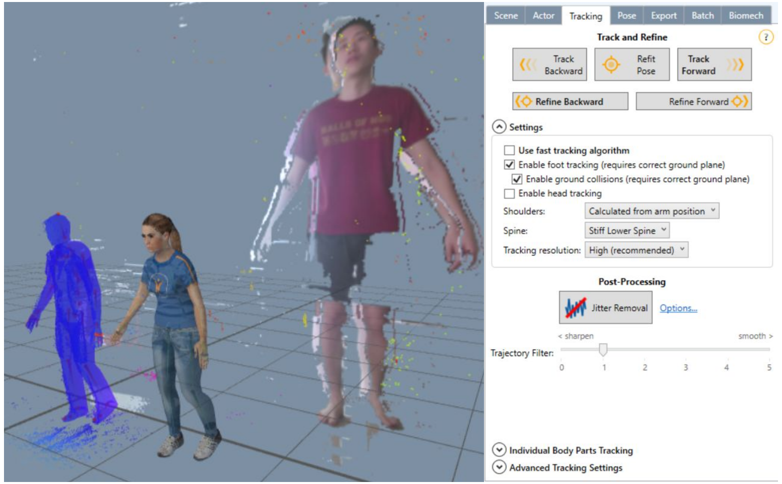


Figure 34: Transfer of Antalgic gait motion into *Mandy*

Figure 35: *Mandy* with Antalgic gait (In Oculus Quest)

8 Detail Design

Animation Creation: From Vicon MX System to Animation Workflow

1 Motion capture using Vicon MX System

Using Vicon MX System, we attached the retro-reflective markers on *Alvin*, our human subject, based on the Plug-In Gait Full Body Marker Set*. The 3D locations of these markers will be captured by a network of infra-red cameras and stored in C3D (Convolutional 3D) file format, allowing the system to reconstruct *Alvin*'s motion in-silico.

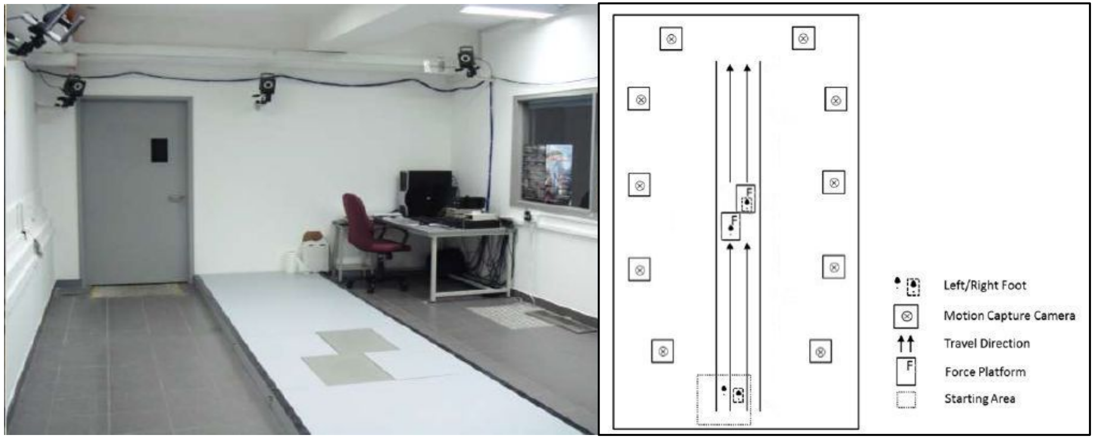


Figure 36: Vicon MX System at NUS Biomedical Engineering Gait Lab

Figure 37: Marker placement on *Alvin*

* *Details are found in the appendix (Page 37)*

8 Detail Design

Animation Creation: From Vicon MX System to Animation Workflow

2 Characterizing *Mandy*

By characterizing *Mandy* using the “Character” asset in MotionBuilder, it allows MotionBuilder to recognize her as a character. This prepares *Mandy* for animation with C3D motion data.

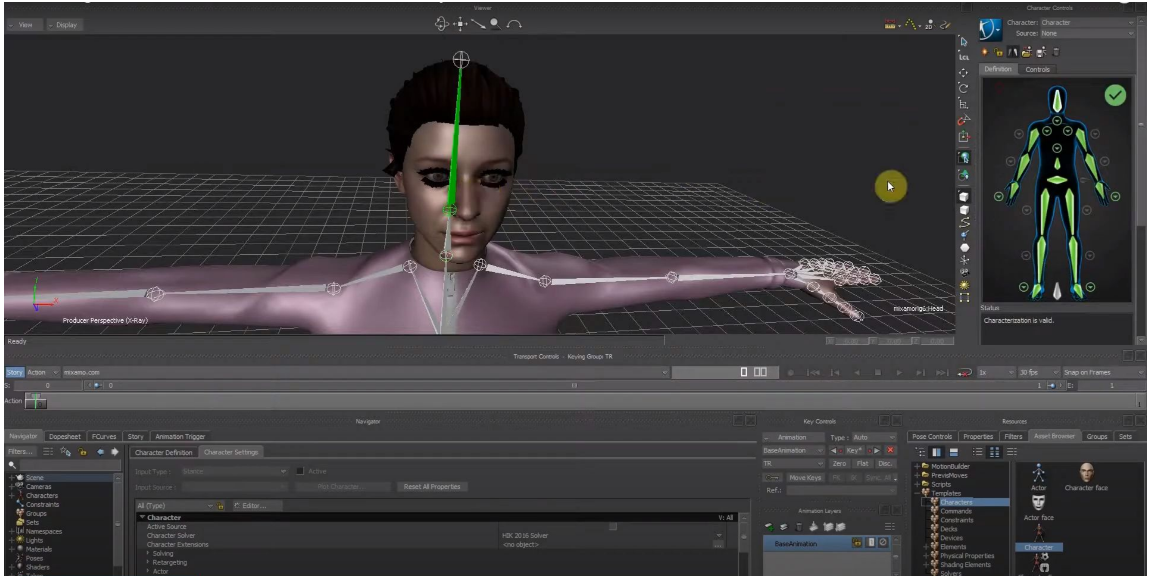


Figure 38: Matching each bones in *Mandy* to a “Character” asset

8 Detail Design

Animation Creation: From Vicon MX System to Animation Workflow

3 Mapping C3D motion into an "Actor"

Matching the C3D motion data to the body parts of an "Actor" asset, we were able to preview *Alvin's* motion data on the "Actor" in MotionBuilder.

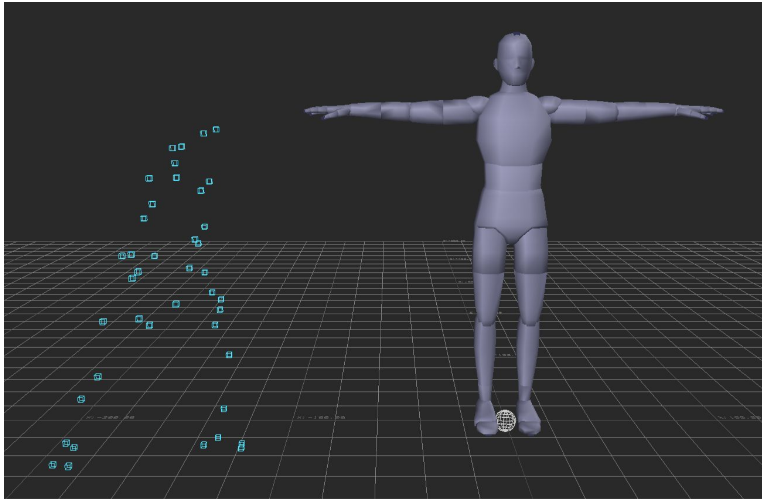


Figure 39: C3D antalgic gait data on the left, "Actor" on the right

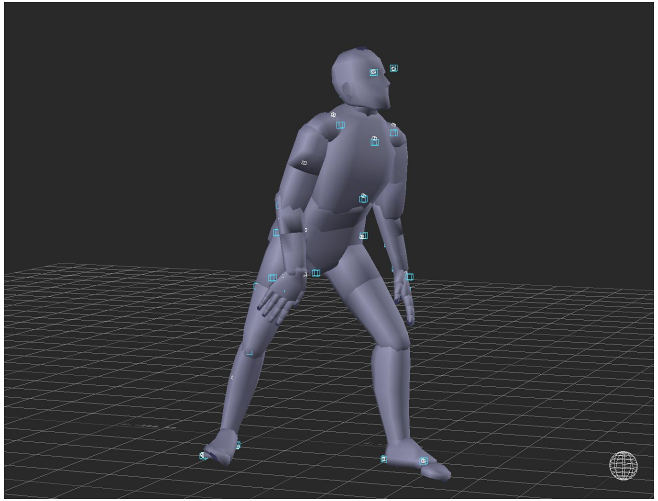


Figure 40: Preview of *Alvin's* antalgic gait on the "Actor"

8 Detail Design

<u>Animation Creation: From Vicon MX System to Animation Workflow</u>

4

<u>Animating *Mandy* with recorded motion</u>

We transferred the C3D motion data from the "Actor" into *Mandy* in MotionBuilder. This creates the animation, preparing *Mandy* to be exported for use in our production pipeline.

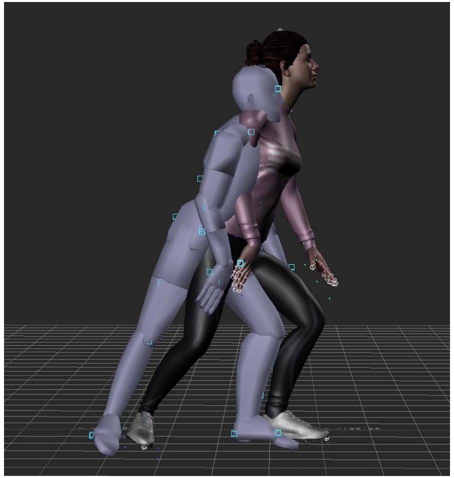


Figure 41: Using the "Actor" to drive *Mandy* (In MotionBuilder)

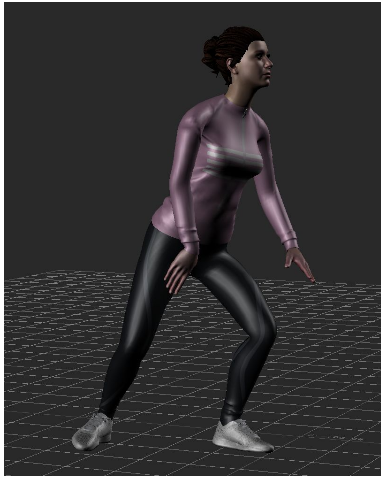


Figure 42: *Mandy* with Antalgic gait animation (In MotionBuilder)

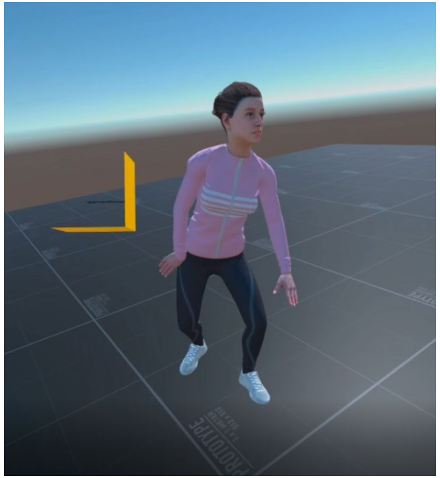


Figure 43: *Mandy* with Antalgic gait (In Oculus Quest)

8 Detail Design

Animation: Scripting in Unity for Model Control

Scripting was performed using C# as a programming language to control *Mandy*. Windows Speech Recognition was explored as an Application Programming Interface (API) that we integrated with Unity, to trigger animations using speech input.

Mandy is now able to listen to our speech input, and match our uttered phrases to a list of keywords we have defined (in this case, the keywords are “hello”, “walk” and “stop”). This will trigger *Mandy* to wave, walk and reset to an idle position.

```
using System;
using System.Collections;
using System.Collections.Generic;
using System.Linq;
using UnityEngine;
using UnityEngine.Windows.Speech;

public class PlayerController : MonoBehaviour
{
    private KeywordRecognizer keywordRecognizer;
    private Dictionary<string, Action> actions = new Dictionary<string, Action>();
    public Animator anim;
    // Start is called before the first frame update
    void Start()
    {
        anim = GetComponent<Animator>();
        actions.Add("hello", Wave);
        actions.Add("walk", WalkNormal);
        actions.Add("stop", Reset);
        keywordRecognizer = new KeywordRecognizer(actions.Keys.ToArray());
        keywordRecognizer.OnPhraseRecognized += RecognizedSpeech;
        keywordRecognizer.Start(); //starts listening to us
    }

    private void RecognizedSpeech(PhraseRecognizedEventArgs speech)
    {
        Debug.Log(speech.text); //debug what we've said
        actions[speech.text].Invoke(); //runs the actions to invoke the actions.
    }

    private void Wave()
    {
        anim.Play("Wave", -1, 0f);
    }

    private void WalkNormal()
    {
        anim.Play("walknormal", -1, 0f);
    }

    private void Reset() => anim.Play("Idle", -1, 0f);
```

Figure 44: *Mandy’s* script for animation control

8 Detail Design

Summary of Prototyping Achievements and Future Plans

Design Requirements	Prototyping Achievements	Future Developments
A scenario database that can be expanded by uploading past medical diagnoses and patient conditions.	A custom character model was designed using MakeHuman to fit the patient traits as given to us.	More patient scenarios can be added with different custom characters designed in MakeHuman.
Able to change the conversational flow by reacting to the user's input	Natural Language Processing (NLP) allows development of a reactive and adaptable patient dialog model with an accuracy of 73.1%.	More training stories can be used to further improve the patient dialog model to increase its reactivity and adaptability.
Able to accurately depict the nature and location of pain through facial expression and impaired motion	2 motion capture methods were explored to simulate gait characteristics of 1 normal and 2 impaired gait patterns in VR environment.	Facial expressions can be animated once a suitable workflow is deemed feasible. 25 facial bones can be added to the character models for animation of facial expressions.
Able to realistically reconstruct 3D model of a human patient, with special attention to bone structures and joint movements.	Our character was modelled with 53 bones to balance anatomical realism and optimization for game design in the VR environment.	Inverse Kinematics can be explored to ensure interconnected bone movements during physical assessments.

Appendix:

Overview: Orthopaedic Spine Clinicals

L4/5 Degenerative Spondylolisthesis is characterized by the slippage of the L4 and L5 vertebrae (Figure 45) in the backbone due to degeneration of the surrounding structure. This results in back pain and leg pain as the nerves innervates the legs as shown in Figure 46.

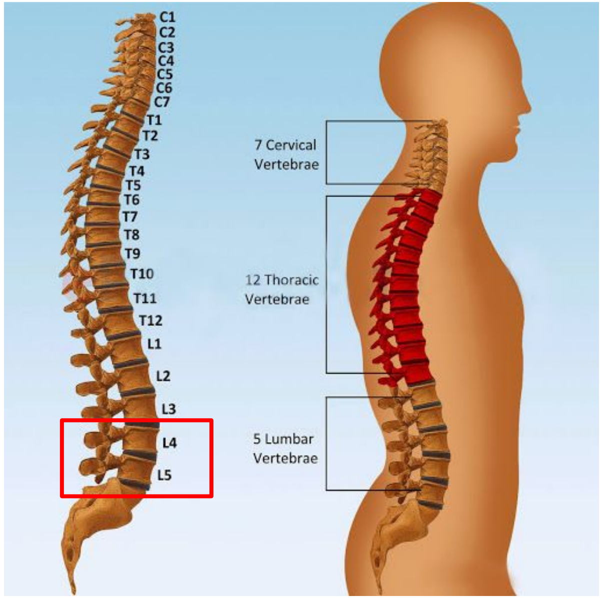


Figure 45: Slippage of Vertebrae

Kalpataruayurvedaindia.com. [Online]. Available: https://www.kalpataruayurvedaindia.com/. [Accessed: 25- Sep- 2020].

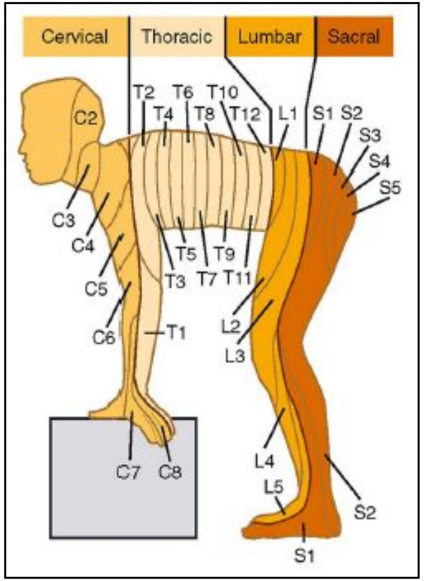


Figure 46: Representation of spine anatomy

*"Easiest Way to Remember Dermatomes," *Faculty of Medicine*, 13-Jun-2017. [Online]. Available: https://forum.facmedicine.com/threads/easiest-way-to-remember-dermatomes.30257/. [Accessed: 25- Sep- 2020].

Appendix:

Conversational agent: Recap of Workflow

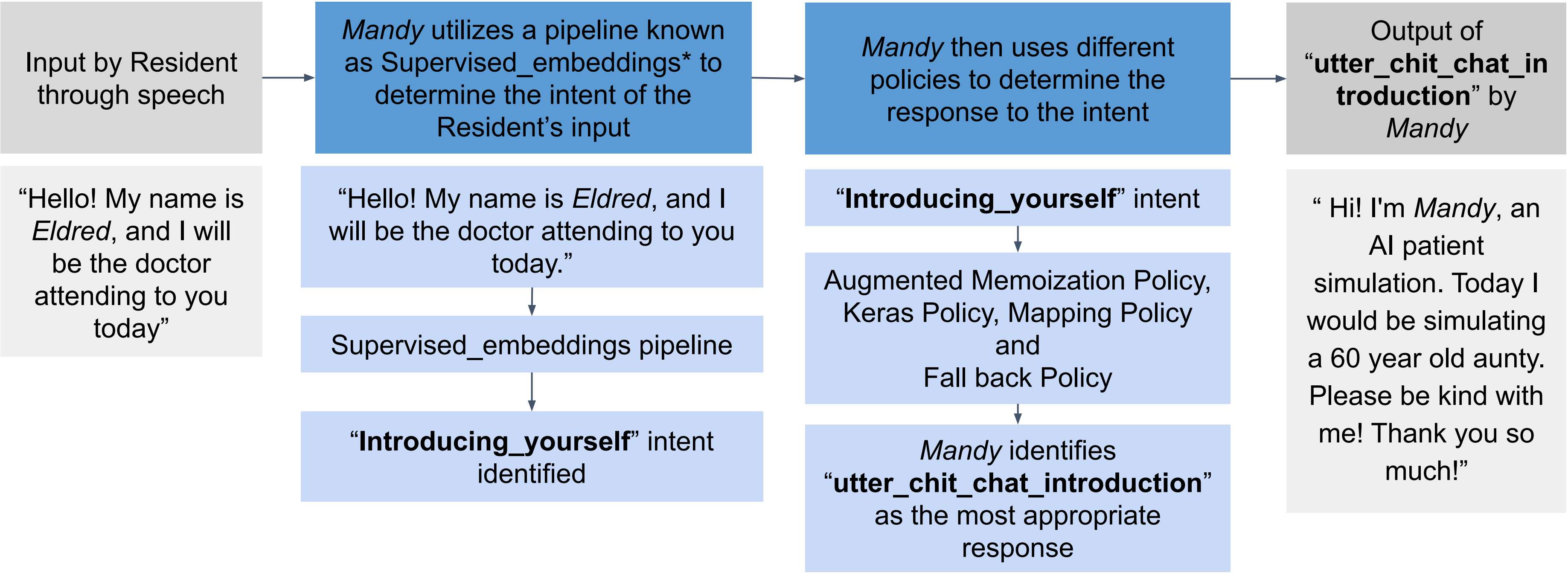


Figure 47: *Mandy*'s thought process

Appendix:

Conversational Agent: 8 Sections of Basic History Taking

No.	Section	Purpose
1	Patient's personal information (Name, age, race and sex)	Collect basic information about the patient
2	Presenting symptom (PS)	Understand the symptoms and duration of the pain
3	History of the presenting illness (HPI)	Understand the characteristics of the pain, such as site, onset, alleviating or exacerbating factors, severity and timing
4	Drug and treatment history (DH)	Identify the current treatments and the potential allergic reactions of the patient
5	Past history (PH)	Identify past medical, surgical or hospitalisation history
6	Social history (SH)	Identify lifestyle patterns of the patient that could have contributed to the pain, such as diet, hobbies, financial situations
7	Family history (FH)	Identify family background and hereditary diseases that may exist in the family
8	Systems review (SR)	Identify diseases that may be present in other systems in the body, such as circulatory, urinary, skeletal and others

"PHASE II COMMUNICATION WITH PATIENTS (CWP) Student Guide Fourth Edition". Division of Family Medicine, Yong Loo Lin School of Medicine. AY2017/18. Accessed: 25-Sept-2020

Appendix:

Animation: Plug-in Gait Marker Set

The marker placement, based on the Plug-In Gait Full Body Marker Set, allows the system to reconstruct the motion of the subject in-silico, whereby key kinematics information, such as joint angles, can be derived.

Plug-in-Gait Marker Placement

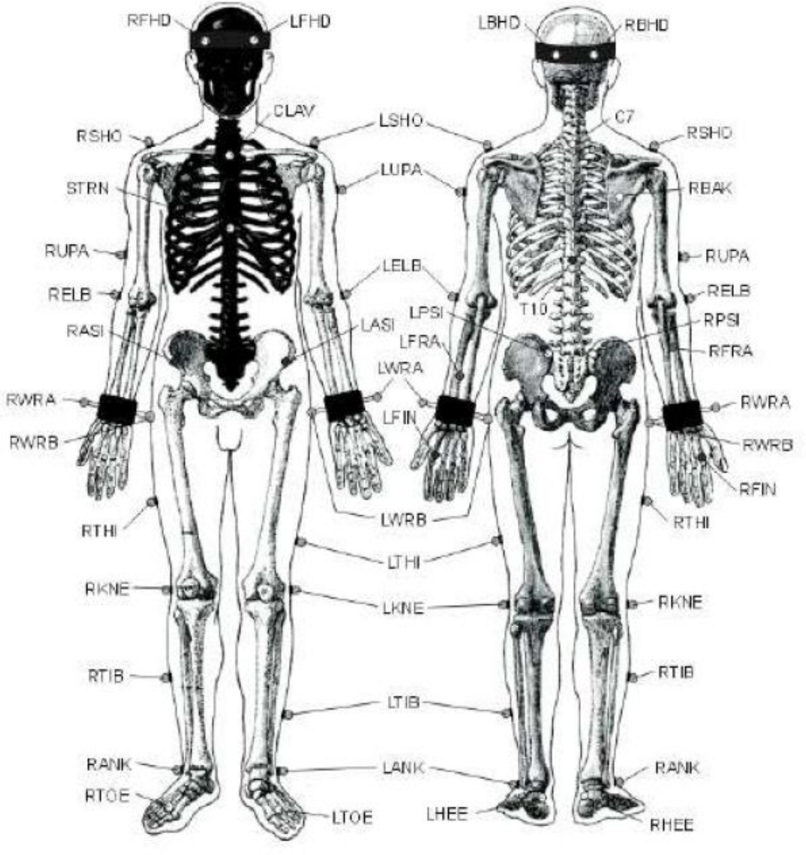


Figure 48: Plug-in gait marker placement

"LifeMOD Appendix | Marker Placements", Lifemodeler.com, 2010. [Online]. Available: http://www.lifemodeler.com/LM_Manual_2010/A_motion.shtml. [Accessed: 25- Sep- 2020].