UNIVERSITY OF TECHNOLOGY SYDNEY

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Human Body 3D Scanner (Virtual me)

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Contents

List of Figures

List of Tables

Engineering Reseach Problem

1.1   Reseach Question

"Human Body 3D Scanner: The development of software for 3D data reconstruction of a Human body scanner with multiple sensors"

1.2   Project Contextualization

The project is based on creating a Human Body 3D scanner. It will have two specific streams that include the development of the mechatronic design of a 3D scanner for a human and the software development for 3D data reconstruction. This proposal is based on developing the software for 3D data modelling and reconstruction of the Scanned data.

Similarly, with the 3D reconstructed model of the human has the aim to be utilised to test different fashion clothing items. This has the intent to adjust the sizing of the clothes fittings based on the Scanned data. The clothing models will adjust automatically depending on the dimensions of the data of the scanned model. The project will have different stages that range from testing different sensors for data acquision, testing different data stitching frameworks to the deployment of the software in the 3D scanner mechatronic device.

1.3   Problem Definition

Being able to scan different object and models is crucial for many industries. Many application are in the used in the fashion industry, medical industry, manufacturing ,etc. However, many of the given implementations are extremely expensive , thus making the technology inaccessible for many companies and users in general. There are many forms of implementations , as there are multiple technologies in the market that facilitate the process in which several devices and software techniques are used. Nevertheless there are no current industry application that

maximise the potential use of the Human body 3D models. Many of the challenges faced is that the software implementation for 3D reconstruction of the models is not particularly accurate, therefore creating imperfect models that in many occasions will need to be discarded.

Hence, this project component will contribute and develop the technology in order to produce software that will be able to produce accurate models from the gathered data from the sensors. These models will be utilised to try different fashion items and adapt the size fittings accordingly. With the competition of this project many stakeholders, industries and institutions could rely on accurate software that will allow to create a 3D model of a person or object.

1.4   Background

The human society has the world comprenhension of the surrouding world through visual perception. This principle allows to differenciate distintive kinds of shapes, objects,colours, textures and the spatial pose of the surroudings. Based on this information, it is possible to analyse the number of objects in a determined location, object type, object size, object pose in different coordinate frames. Thus, it impacts how as a society we interactuate with objects ot scenes. As a result it is essential to imitate this perception in order to acquire real world data in different formats that include:

- RGB images

- Depth images

- 3D point clouds

- Multispectral images

- Laser readings

All these acquire data can be obtained from a wide variety of comercial or industrial sensors. With this data it will be possible to use computer processing techniques in order to model the object or scene (Murcia, Monroy & Mora 2018).

1.5   Applications

In the recents years the use of 3D body scanners has gain importance in several industries. Within the fashion industry it can aid clothes manufactures to obtain accurate body measurement data of body dimensions. As mentioned by Sturm, Bylow, Kahl & Cremers (2013), this new technological approach has the potential to alterate the future of the fashion and clothing manufacturing industry.

With the raise of innovatoin of 3D image reconstruction, the interest from to gather precise measurements of the human has raised. Due to the fact, that in the clothing industry is extremedely important to create better fittings for different shapes of human bodies. Furthermore, virtual try-on solutions has gain popularity in physical and online retail stores (Spahiu, Shehi & Piperi 2014).

On the other side 3D scanners have gain in particupation in the medical industry. These systems are described as "non-invasive and low cost" , thus making it appealing for epidemiological surveys and clinical uses. (Treleaven & Wells 2007) The geometrical measurements could be associated with shape, size, volume and surface area of the body parts. It could aid to be a sustainable approach to screen children and patients with obesity, deformities or specific anatomic defects. Therefore, it will ease the diagnose process and allow to treat and monitor medical conditions holisticly and improve the life quality of patients with non-invasive tests. The table below illustrates the use of 3D scanner in the medical field with the purpose to identify and monitor various medical conditions. Frpm which the diagnose, treatment and monitor procedures willd differ based on the acquired data.

Application	Epidemiology	Diagnosis	Treatment	Monitoring
Measurement				
Size	Anthropometric surveys	Growth defects	Scoliosis	Fitness and diet
Shape	Screening	Abdominal shape	Prosthetics	Obesity
Surface area		Lung volume	Drug dosage	Diabetes
Volume			Burns	
Visualization				
Head		Melanomas	Eating disorders	
Chest			Facial reconstruction	
Whole body			Cosmetic surgery	

Table 1.1: 3D Scanning Applications
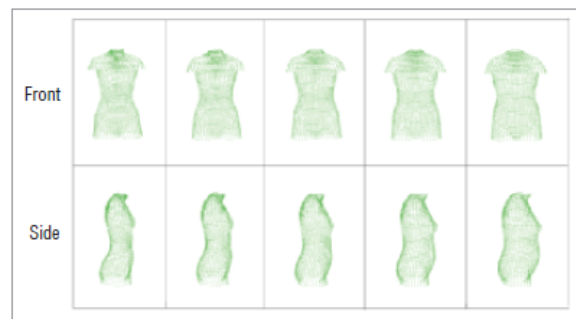(Treleaven & Wells 2007).

Figure 1.1: Front, Side results of 3D Scanning
(Treleaven & Wells 2007).

3

Related Works

Being able to scan different objects and subjects has been challeging task for researchers. Getting an accurate spatial location of the objects is crucial for this type of application. The use of 3D point clouds has facilitated this process as it allows to obtain the following parameters:

- Depth

- Intensity

- Pulse width

- Light echo

This information can be obtain with different kind of sensors. There is a wide variety of off the shelf sensors that can procide 3D point clouds. These sensors could either be stereo or multiview vision cameras, lasers, time-of-flight sensors (*TOF*) and structured light sensors as stated by Murcia, Monroy & Mora (2018).

Many Scanning devices will use single or multiple of the above-mentioned sensors in order to acquire data. Once the data is obtained, it essential to have a framework for 3D data modelling and reconstruction. The principle behind 3D data recontruction is obtained with data fision from RGB-D sensors. This kind of sensors provide 3 channels images RGB (red,green, blue) and the depth images are mapped to each pixel. Based on this data 3D point clouds could be generated for data recontruction. One of the most common frameworks is known as **Dynamic Fusion** which is referenced to *"reconstruction and tracking of Non-rigid Scenes in real time"* (Newcombe, Fox & Seitz 2015). Another recent powerful 3D Data recontruction framwork is **SurfelWarp** which is defined as *"Efficient Non-Volumetic Single View Dynamic Reconstruction"* (Gao & Tedrake 2019).

2.1 Dynamic Fusion

Dynamic fusion is the based on three different technologies focused on 3D scanning and data recontruction. These techniques are:

DART (Dense Articulated Real Time Tracking)
> This technology is speciaclised on Real Time body template skeleton tracking.

Animation Cartography
> It is a 3D reconstruction technique focused on intrinsic data reconstruction of shapes and motions.

Kinect Fusion
> This technology is applied for real-time tracking and condence surface mapping.It is intended to be used in static scenes and objects with only a moving camera sensor.

The principal focal point of the 3D data recontruction feature of *Dynamic Fusion* is that it will look for a solution for for the volumetric flow based on the gathered data. As mentioned by Newcombe, Fox & Seitz (2015) there will be a transformation of the state ot the scene at each time interval to a fixed canonical frame. The created canonical frame is described as the initial frame that is obtained from the non-rigid object that has been detected and tracked.The shape of the detected object is defined as "canonical model" which is the correspoding shape of the object in the canonical frame. Therfore, the canonical model will be utilised as reference model for all the subsequent frames. From this approach there will be progressing adjustment on on the canonical model and frames, as more data is acquired. With the new refinements each point in the canonical frame, the point clouds will be transformed and updated to the new location in real time based on the received data.
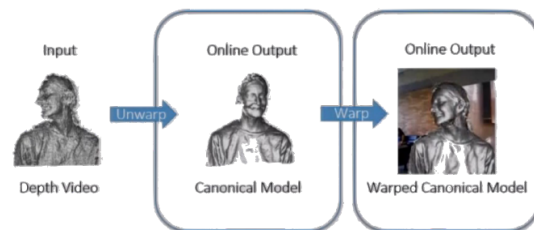
Figure 2.1: Transformation Between Depth Video to Warped canonical Model

(Newcombe et al. 2015).

The data acquired from sensors that includes RGB and Depth images will help to determine the warp parameters. Based on the determined warp parameters the volumetric flow field can be estipulated. The state of the wrap field W_t is defined as a function of time. It is modelled by the values of a set of "n" deformation nodes, which are described as the points or pixels in the actual image. The image below describes the process in which the canonical model and

(a) Initial Frame at $t = 0s$ (b) Raw (noisy) depth maps for frames at $t = 1s, 10s, 15s, 20s$ (c) Node Distance

(d) Canonical Model   (e) Canonical model warped into its live frame   (f) Model Normals

Figure 2.2: Dynamic Fusion methodology
(Newcombe et al. 2015)

frame are determined based on the initial frame and depth data.

The State of the warp field W_t can be modelled with the below equation.

$$N_{warp}^t = \{dg_v, dg_w, dg_{se3}\}t$$

dg_v: is described as the 3D position of each node in the canonical frame.
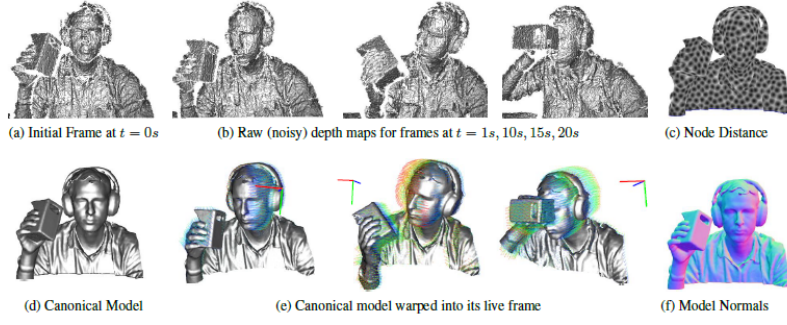
dg_{se3}: is the Special Euclidian transformation where $T_{ic} = dg_{se3}^i$ is the rigid transformation for every node i.

dg_w: It controls the extend impact of the deformation around each node.

The current set of point clouds will be stored as a "polygon mesh" with the normal pair of points within the canonical frame and allow to calculate the warp field parameters. The principle will allow effective surface reconstruction as suggested by Slavcheva, Baust & Ilic (2018) as once the warp field parameters are obtained, surface recontruction can be modelled with a principle of marching cubes. This process will be followed by a rasterization rendering pipeline of the Acquired Point cloud values (Newcombe, Fox & Seitz 2015).

The patterns from the figure 2.3 illustrate the triangulated cubes for the 15 basic patterns used in marching cubes for surface recontruction. These patterns are able to reconstruct all 256 possible solutions using rotational and complementary symmetry as suggested by Fang, Zhao, Wen & Zhang (2018). Once the canonical model and frame can be modelled with the warp field parameters based from the intial raw depth image maos ad data frame, the tracking nodes will be created. Based on this it is possible to obtain the canonical frame warp parameters which are estimated based on this process. As soon as the canonical model is constructed, the life frame will be warp around it based on the warp parameters. As a result the model will be 3D reconstructed model will be succesfully created and normalized.
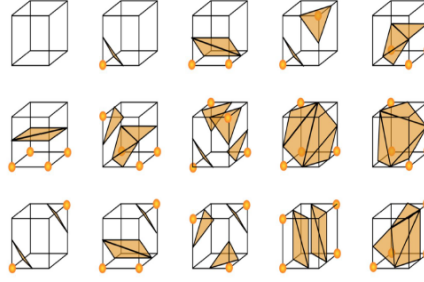
6

Figure 2.3: Triangulated patterns
(Fang et al. 2018).

2.2 SurfelWarp

SurfelWarp is defined as "Efficient Non-Volumetric Single View Dynamic Reconstruction. It will present a standard graphics pipeline and GPGPU computing can be utilised for efficient implementation of all data recontruction operations (Gao & Tedrake 2019). It eliminates the use of volumetric data structures, which represent resouce intensive volumetric operations such as dense deformation field updates, volumetric fusion and marching cubes. This represents a significant performance improvement as the explicit surfel representation allow to directly recover from tracknig failures or topology changes as proposed by Gao & Tedrake.

2.2.1 Overview

As illustrated in figure 2.4, SurfelWarp is built in a frame by frame methodology to process an input depth stream data source. When a new depth image is received, the deformation field that is aligned to the reference frame geometry will be solved. This is calculated by startting the deformation field from the previous image, which is followed by an iterative optimization problem similar to Newcombe, Fox & Seitz (2015). Once the deformation field is update, the data fusion process is carried out. This will trigger an accumulative process to fuse the current depth observations into a geometrical representation.

The deformation field $W = \{[p_j \in R^3, \sigma_j \in R^+, T_j \in SE(3)]\}$ where j is the node index, p_j is the position of the jth node. σ_j is the radius parameter, T_j is the 6DoF transformation. For any point in "x" the deformation can be interpolated by equation 2.1
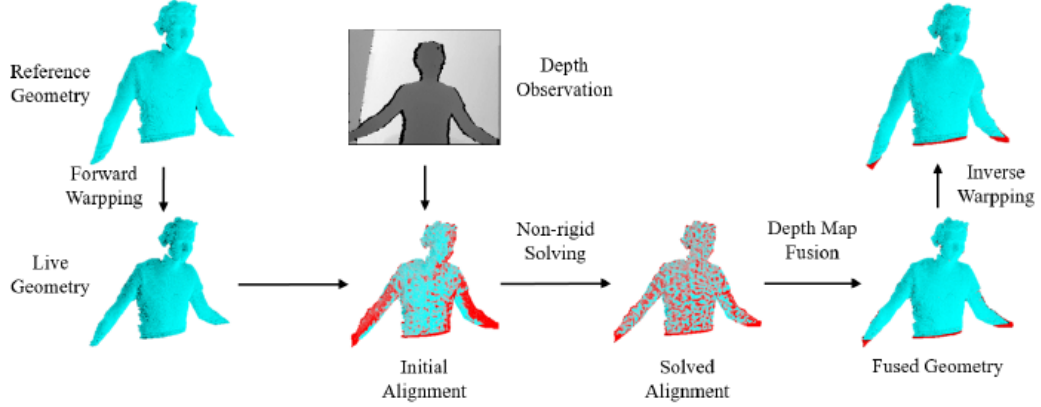
Figure 2.4: SurfelWarp methodology
(Gao & Tedrake 2019).

$$W(x) = normalized(\Sigma_{k \in N(x)} w_k(x) \hat{q}_k) \tag{2.1}$$

From equation 2.1 the following components can be described:

- $N(x)$: is the closest set of points x

- $W_k(x)$: is the weight that can be computed as $\exp\left(-\frac{|x - p_k|_2^2}{2\sigma_k^2}\right)$

A surfel S could is described as the tuple composed in which the following components can be modelled :

- position : $v \in R^3$

- normal : $n \in R^3$

- radius : $r \in R^+$

- confidence : $c \in R$

- initilization time : $t_{init} \in N$

- most recent time : $t_{observed} \in N$

Therefore a surfel can be illustratedby the deformatin of field W in equation 2.1 (Gao & Tedrake 2019). Furthermore the deformed vertex position and normal can be modelled with the following equations:

$$v_{life} = W(v_{ref})v_{ref} \tag{2.2}$$

$$n_{life} = rotation(W(v_{ref})n_{ref}) \tag{2.3}$$

From equations 2.2 and 2.3 v_{life} and n_{life} are the deformed vertex position and normal. Whereas v_{ref} and n_{ref} correspond to the vertex position and normal before the deformation process.

2.2.2 Depth Map Fusion & Warp Fiel Update

In order to get the warp fiel estimate, it is neccesary to perform a mathematical prediction of the visibility of the live surfels models S_{life} with the proposed method of Newcombe, Fox & Seitz (2015) to cast the deformation estimation into a optimization problem. The estimation process is performed by predicting the visibility of the life surfels S_{life}.
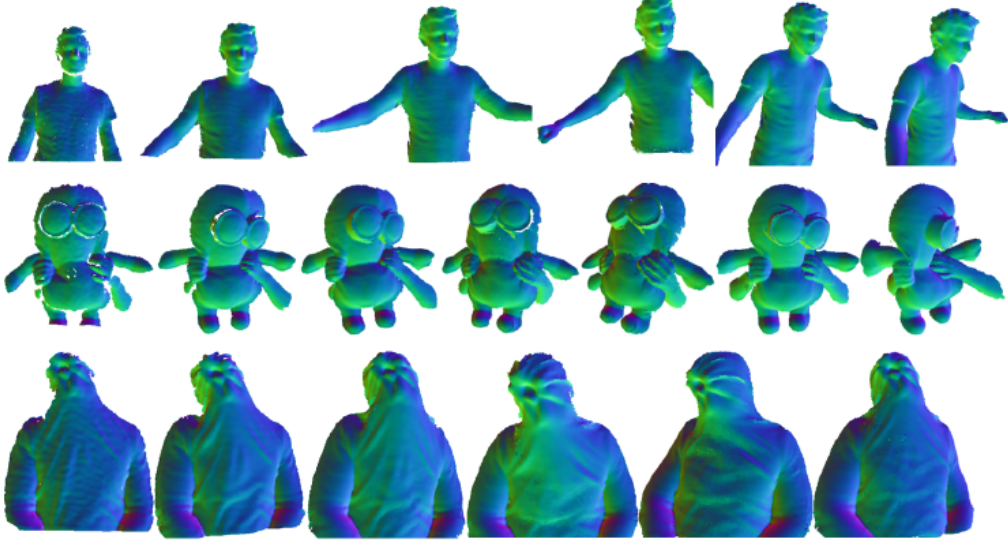
Figure 2.5: SurfelWarp Reconstruction
(Gao & Tedrake 2019).

Similarly, to the approach of Keller et al. (2013) the life surfels S_{life} are rendered as an overlaped disk shaped surface splat. These shapes are spanned by the position V_{life} ,normal n_{life} and radius r_{life} of the live surfel s_{life}. With all these parameters it is possible to model the warp fiel based on the Dynamic Fusion framework proposed by Newcombe, Fox & Seitz (2015).

Once the deformation is solved, the depth map fusion obtained from sensors along with the warp field update will perform data fusion in the live frame. This live frame warps the live surfel back to the starting reference frame. Afterwards the warp field is recurrently updated based on the new observed surfels reference. This process can be exemplified with image 2.5 .

Methodology

As mentioned in the initial section, this project is focused on an engineering design. Hence, it will be focused on creating a prototype for a 3D scanner. This include the hardware and the software for the 3D model reconstruction, from which this section will be focused on the 3D model data reconstruction of the project. The methodology will be divided into 3 sections that include:

- Data Acquisition

- Conceptual Design

- Design Implementation

3.1 Data Acquisition

As mentioned above the project can be described as en engineering deging problem, whereby this approach includes the 3D software reconstruction model components for a 3D scanner. This includes in gathering sensor data from the model that will be scanned. Many of the possible ways to gather data can be perform with comercially availible sensors as proposed by Siena, Byrom, Watts & Breedon (2018*a*).

Gautier et al. (2020) mentions that many 3D software reconstruction frameworks similar to Dynamic or SurfelWarp use comercially availible sensors. One of the most common approach to get data for 3D scanning will be to use RGB-D cameras. The proposed sensor that will be used for data acquisition is the **"Intel RealSense D435i"**. This Sensor is an depth camera with a stereo solutoin which is used in a wide variety of applications which include:

- Robotics

- 3D Scanning

- Skeleton and Human Tracking

- Drones

- Objects Measurement

- Facial Auth

Therefore, making this camera ideal for this project application.

Figure 3.1: Intel RealSense D435i
(Intel 2020*a*).

This model of camera has a propietary software development library and SDK which is used to interactuate with the computer. This SDK will allow to calibrate the camera and obtain certain calibration parameters that will be used for data acquision. Furthermore there is a software wrapper that will allow to connect with ROS (Robot Operating System). This ros wrapper will allow to interaction between the middleware, which is ROS, the camera and the compouter. With aid of this wrapper it is possible to integrate all the components of ROS and the camera. One of the benefits of using ROS is that it allows to record certain set of data based on the information that is being acquired by the sensor. The wrapper will start the camera based on different configuration and it will publish data both RGB and depth images in the following topics:

- /camera/color/camera_info

- /camera/color/image_raw

- /camera/depth/camera_info

- /camera/depth/image_rect_raw

- /camera/extrinsics/depth_to_color

- /camera/extrinsics/depth_to_infra1

- /camera/extrinsics/depth_to_infra2

- /camera/infra1/camera_info

- /camera/infra1/image_rect_raw

- /camera/infra2/camera_info

- /camera/infra2/image_rect_raw

- /camera/gyro/imu_info

- /camera/gyro/sample

- /camera/accel/imu_info

- /camera/accel/sample

- /diagnostics

The above topics will contain all the data that the sensors perceive in real time. As it can be seen from the above list, there will be data for the RGB, Depth sensors, Infrared sensors, IMU as well as all the extrinsics and status of the camera parameters. Furthermore, all this data will be process with different formats such as raw or compressed. Based on the data perceived from these topics, it will be possible to create 3D point clouds in realtime and run 3D data reconstruction frameworks such as Surfelwarp as the sensors acquire and perceive the environment.

On the other side, ROS allows to record data from the above topics. From the above topics it is possible to record the data messages as a "rosbag" or "bag", which is a file format in ROS for storing message data. Hence it will allow to record the data that the camera is sensing. Furthermore, these bags allow to susbcribe to specific topics, which implied that only the required topics will be stored for 3D data recontruction, and storing the received messages data in an efficient file structure. The data acquisition process for the development phase will be perform by storing several rosbags, to be used in the development phase of the 3D recontruction for the scanner.

3.2 Conceptual Design

The conceptual design will be focused on the development of the 3D software recontruction for a 3D scanner. The Intial design will be to test with the field of view of the Intel RealSense D435i for both RGB image and Depth image sensors. From which for the Field of view (H $\times$ V $\times$ D) of the RGB corresponds to 69.4° $\times$ 42.5° $\times$ 77° ($\pm$3°), whereas depth of the field of view for the Depth sensor corresponds to 86° $\times$ 57° ($\pm$3°)(Intel 2020a).

Based on this results there will be a testing phase, which involves on evaluating what is the ideal configuration for the Camera. The ideal configuration will be based on in which pose the

sensor will be able to obtain the most accurate and useful data. Hence a manequin will be used for this testing purpose from which the ideal pose for the sensor will be determined.

Once the ideal pose for the sensor is found, there will be the need to evaluate and test which is the fastes and most accurate way to obtain data of the model.All the testing purpose will perfomed by recording several rosbags and visualise them . This has the intent to find the ideal location and number of all sensors that will be able to scan all the model. With this method iw will be possible to determine the speed and realiability of the Scanning process. Based results of this it will be possible to determine a prototype for the mechatronic design of the scanner as well as the methodology of how to fuse the data and run the 3D reconstruction framework.

The Design implementation of the 3D reconstruction software will be to adapt and adjust the 3D modelling data recontruction frameworks. Hence, it includes on developing the correspoding ROS nodes that will allow to use the data from multiple sensors and fuse it. With the fuse data, the intent is to run the 3D reconstruction framework which will output the Scanned model.

Once the process of generating the 3D scanned model is stable. The software will be ported to a small machine such as the Intel NUC, which is a small form factor computer. The software will be installed into the Intel NUC with the purpose to be incorporated with the mechatronic design of the 3D scanner. This will facilitate easy operation of the entire 3D scanning device.

Figure 3.2: Intel NUC
(Intel 2020*b*).

Project Management

This section will provide guidelines and illustrate the management procedures that will be implemented into the feasibility and development of the software reconstruction for a 3D Scanner. It provides a projected timeline for deliveries and identifies specific methodologies implemented for the execution of the project from the beginning to the competition of all tasks. The project plan will be updated throughout the development of the project in order to reflect deliverables that may be affected by potential shortfalls. In order to prevent this it will be necessary to circumvent any affected task and resolve it in an adequate timely manner. This will be a collaborative project, that involves creating the hardware device that will allow to place the sensors, the 3D data reconstruction of the Model, and the post utilization of the model for different uses such as testing virtual clothes. As the agreed allocated task was the 3D data recontruction this section and document will be focused on the 3D software for data recontruction.

4.1 Scope

There are multiple ways in which a 3D scanner is defined. Many connotations include of creating the actual hardware of the device or how is software going to be developed in order to create a 3D model. Based on this, the scope of this project component is to develop and deploy the software for 3D reconstruction of a scanning device as it was previously mentioned. The software will retrieve data from multiple sensors and cameras to then perform data fusion and create a 3D representation of the model that is scanned. Whereas the other components of the collaborative task will include the device creation as well as different applications for the obtained models.

The allocated 3D reconstruction part will include two phases to approach the engineering design problem that is targeted. The initial phase will be focused on gathering data from a wide variety of sensors that include RGB and Depth Cameras and test which is the most

effective way to collect data of the model. The second phase will be to develop a framework and methodology to fuse the acquired data from the sensors in order to create a 3D model representation of an object, which in this particular case will be a person. The project will span for over 35 weeks inclusive of Spring 2020 , Summer Break 2021 and Autumn Session 2020 UTS academic semesters. This will include working with various teams that are in charge of the development of the hardware prototype as well as the uses of the model. The subsequent details are located in the sections below.

4.1.1   Project Specifications

It is important to outline all the specifications of the project in order to ensure, that the design will satisfy the purpose and it matches the scope of the project. As this is collaborative project, the other team member will need to elaborate their corresponding details for their allocated sections. All of this will be reflected on the Work Breakdown Structure and Gantt Chart, however the details for the 3D data model reconstruction will be explained below.

4.1.1.1   Sensing & Data Acquisition

There are multiple ways to achieve data acquisition that will satisfy the project. The proposed way would be to use sensors, especially, RGB and Depth Image Cameras The sensors should be able to provide with the following:

- RGB Colour images of the object or model

- Provide Depth images in order to get Distance for every point in the image

- Have a large enough field of view that could fit the entire object or model

The data acquired from this sensors should be reliable in order to ensure the fidelity of the final 3D reconstructed model. This data sensors will be converted to Point clouds via data fusion, where each point in the model will be mapped. Hence creating a 3D reconstruction model where its corresponding location in space is known. Therefore the proposed sensor that will be used will be the Intel RealSense D435i. From which the SDK and ROS wrapper will allow to obtain the data and facilitate the process.

4.1.1.2   Data Fusion & Timing

Once the data is acquired from the sensors it will be required to fuse the data in order to be able to create the model. The Data fusion is proposed to be perform in Realtime as the objects are scanned. This data fusion process will be perform by processing the data from multiple

sensors and running them to a 3D recontruction framework such as SurfelWarp. Thus, creating a visualization preview of the object or person scanned.

On the other hand, the timing would be critical, as in most application the scanning time should not take more than a couple of minutes that could vary from 2 to 5 minutes. Therefore, ideally the 3D reconstructed model from the scan should finalize within that time frame.

4.1.2 Project Overview & Deliverables

The project overview can be exemplified in fugure 4.1 and it is associated with all the possible deliverables for the project
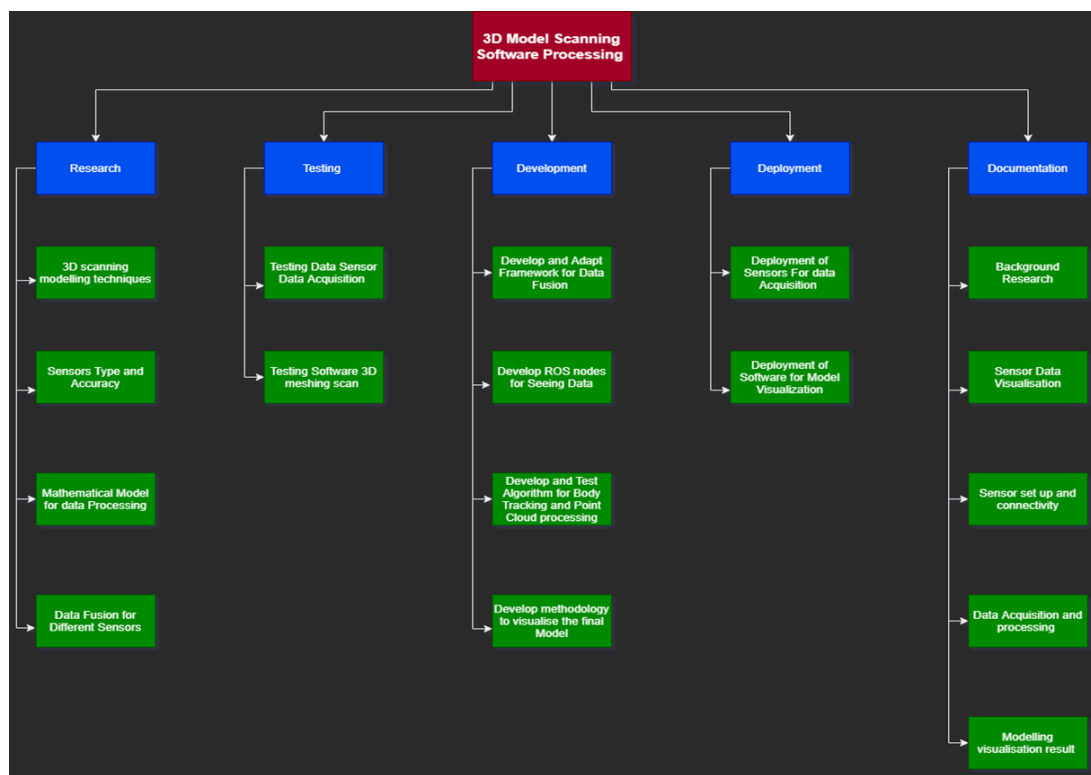
Figure 4.1: Constrained WBS for 3D data reconstruction component

Furthermore, it is imperative to demonstrate and illustrate the entire work break down structure of the project. This will include other sections and components such as:

- Developing the hardware device to do the scanning methodology.
- Integrating the sensors for data acquisition and 3D reconstruction for model.
- Uses the model for different applications.

The details will be located in the appendix on figure A.1

4.2 Project Timeline

The timeline shown in figure 4.2 depicts the problem solving approach that is proposed in order to fully complete the optimum deliverable for the project. The below image summarises and synthesis the process in a waterfall approach. As there has to be a certain number of deliverables that needs to be accounted for an agile approach would not satisfy the needs of the individual components. Once most components are developed with the waterfall approach, an agile methodology will be necessary in order to integrate all the other components of the project.

These include:

- Hardware development of device

- 3D software for data reconstruction and modelling

- Uses and applications of 3D model

The proposed timeline from start to finish for the proposed project will be approximately 35 weeks. Including both UTS academic semester (Spring 2020 & Autumn 2021) and the corresponding university summer break

Figure 4.2: Transformation Between Depth Video to Warped canonical Model

holiday. All the detailed tasks and proposed deadlines are located in the Gantt Chart, located in the appendix. The proposed plan is inclusive of contingency scenarios as extra allocated days are added for different tasks. Any potential date changes will be updated accordingly in the plan, in order to keep the project completion as accurate as possible for the 3D reconstruction component.

4.3 Progress & Milestones

It is imperative for any project to identify and define particular milestones for the project. Once the milestones are identified , they can be properly analysed in order to establish the

corresponding requirements, processing, development and execution. After all these parameters have been established a corresponding timeline could be proposed. All these milestones will be considered for the 3D model reconstruction component.

This project component includes two particular and independent phases. Phase one will include the design proposal and data acquisition and processing, whereas phase two will focus on data fusion and 3D model data reconstruction. These phases could be subdivided five into smaller interdependent subprocesses that would contribute to the corresponding milestones that are part of the project deliverables. Thus, a holistic approach should be implemented with a waterfall implementation. The five major work areas include:

- Research and Conceptualization

- Testing

- Development

- Deployment

- Documentation

The section below will delve into a deeper details of each project and illustrate the major milestones within itself. All do this will be illustrated for the 3D data model reconstruction component. All the other details for the other components are located in the work breakdown structure located in the appendix C.

4.3.1   Milestones and Stages

4.3.1.1   Stage 1: Research and Conceptualization

The research component of this project will rely on exploring different robotics parameters and 3D data modelling reconstruction. The corresponding limitations will be analysed via research into different 3D reconstruction techniques that have been developed and what are the current developments in this 3D scanning field. The already existing solutions will aid to conceptualise the project to ensure optimal functionality that will produce accurate 3D scanned model of persons or objects Potential solutions of software implementation will be investigated in detail in order to grasp the different algorithms basics and how they behave in different scenarios.

Furthermore, different kind of sensors will be investigated in order to use the most appropriate equipment to grasp the data. Different fata fusion frameworks will analysed in order to make a collection of them in order to develop the data reconstruction prototype.

A recommendation will be made to the supervisor and team regarding optimal sensors that could be implemented and what type of data reconstruction could be utilised.

4.3.1.2 Stage 2: Testing

The testing phase for the 3D reconstruction component will be based on testing the different features and component that the d435i has availible. The corresponding included SDK's will be used to see the camera parameters and different ways to grasp the Data. Furthermore, different tools will be tested with the purpose of meshing raw data in order to test the reliability of the acquired data. On the other side, the meshing components will allow to grasp the idea of how different techniques allow to do model meshing under different circumstances for the 3D data reconstruction framework.

4.3.1.3 Stage 3: Development

The development phase will consist in developing and adapt a framework for Data fusion. The data will be provided with the sensor that were chosen from the previous stage. The results obtained will allow to fuse all the data from all the components from the different sensors and visualise them into a single output.

Furthermore, there will be the development of the ROS nodes that will allow to collect the data in real time that will be pass onto the data fusion framework. The ROS nodes will allow to properly map all the sensors and allow them to work simultaneously. Additionally, there will be the development and corresponding test for Body tracking of the scanned models and to convert the data from the sensors into Point clouds. These point clouds will be tested for accuracy of the Scanned data in the visualised model.

From this acquired and processed point clouds a methodology will be develop to work in conjunction with the Data fusion framework to visualise the final model. All these processes will be tested under different conditions in order to ensure that it will work under most circumstances and will allow a much easier deployment process.

4.3.1.4 Stage 4: Deployment

The deployment phase will be subdivided into two main tasks. The initial one consists of the deployment of all the sensors that will be utilised for data acquisition. This will include in deploying and installing the sensors into the actual hardware device that will be used. These Sensors will be mounted and interconnected between then for enhanced sensing. This will be worked in conjunction with the hardware team.

Similarly there will be the deployment of the software tools that include the ROS nodes, Data fusion Framework and Model visualization methodology. All of this components will be deployed into the final device that is part of the hardware team.

4.3.1.5 Documentation

The documentation process is one of the crucial components of this project. Especially for the 3D data reconstruction component. All the corresponding stages of the research, testing, development and deployment will have their proper documentation with a high level of detail. There will be the corresponding documentation regarding the background research of the project. It will include all the necessary research, use to determining the scope of the project and what are the current solutions for it.

Similarly, the documentation for all the sensor data visualization will include what type of sensor was used. It's characteristics, and what SDKs and libraries were used. The corresponding method of visualising the data will be documented as well as all the commands necessary for its use. Furthermore, all the necessary diagrams for connections and set up will be fully documented. As this will help massively the other teams.

There will be a detailed explanation on how the data acquisition process is carried out and what are the methodologies are used for data fusion. This with also include topics such as: what are the best scenarios and circumstances for using the developed technology. Finally there will be the included detailed explanation on how the 3D model is generated. All other content such as risks an limitations will be included as the project is developed

4.3.2 Gantt Chart

Please refer to Appendix, figure A.2, to visualise the Gantt Chart. The proposed Gantt Chart provides a detailed timeline, that includes dates and duration for each milestone. It will include milestones that are part of the hardware team and the use case team. Therefore it will include all the proposed milestones for the entire project. It is important to know that the proposed timeline and dates might change, especially the ones that belong the other teams (hardware and use case).

It is crucial to note the following:

- The work schedule and load differ between each academic semester. Thus extra time was added to counteract this effect.

- The finalisation date and showcase was planned for the last week of the Autumn 2021 semester.

- There is a continuation of work through the UTS summer break with the purpose of maximising efficiency. This is reflected on the Gant Chart.

4.4   Resources

Resource planning is essential for any successful project. Different steps and different teams will require different resources and support. For this project, the principal resources can be split into human and technical.

4.4.1   Human Resources

As this project is non confidential, it will not have any external relations. Hence, The main people involved in every component are the following:

Academic Supervisor – Dr. Teresa Vidal Calleja

Teresa is the Deputy Head of School (Research), School of Mechanical and Mechatronic Engineering as well as Core Member for CAS - Centre for Autonomous Systems. Her Interest Include Robotic perception, automatic recognition, alternative sensing, visual SLAM, aerial and ground robots cooperation, and autonomous navigation and manipulation.

Hardware Component lead – Asher Katz

Asher is the other capstone student of this project. He will be in charge of developing the hardware ad mechanism for the scanning device.

Use cases Component Lead – Mark Liu

Mark will be in charge of use case of the project. He will use the 3D scanned models to try out clothing sizes virtually for different fashion items.

Cedric Le Gentil

Cedric will help in the process of creating the 3D scanner as well as facilitating the use case to adapt fashion items to the scanned models.

Nico Pietroni

Nico will be in charge of making the adaptation process between the 3D scanned models to the use case. Where he will develop the software for adding the clothes meshes to the 3D scanned model.

4.4.2   Technical Components

The technical components will include all the required sensors and software that will be implemented. The following resources are critical for the development , testing and deployment phases of the project.

4.4.2.1 Sensors

The proposed sensor that will be used for both testing and development isthe Intel RealSense D435i. This components will need to be purchased in order to start with the project. Is estimated that the price for the D435i is 200 $ USD These sensors are crucial and will need to be imported from the US.

The corresponding software controllers and SDK for this sensors are available online and would only need to be installed and compiled. Depending on the outcome of the testing phase it will be necessary to determine the number of sensors that would be used. Hence the total overall price for the sensor is not fully establish yet.

4.4.2.2 ROS

As mentioned previously ROS (Robotic Operating System) is a robotics middleware. It provides with the necessary services that are designed for computer cluster that include :

- Hardware abstraction

- Low Level device control

- Synchronization for multiple sensors

- Real time data acquisition of recording for sensors

- Sensor Data visualization in real time.

ROS is free and can be installed easily in a Linux machine. All of the proposed sensors have the corresponding ROS driver that will allow to connect the sensors with ROS with ease. This middleware will allow to collect, synchronise and initialise all the sensors. As well as visualise all the acquired data in real Time. ROS allow an easy implementation of the framework for data fusion and Model reconstruction.

4.5 Uncertainties & Risk Control

All projects face some particular level of unforeseen risks and uncertainties. Good project planning will consider all possible areas of failure and introduce mitigation plans to try to control and prevent the consequences. All these uncertainties and risk matrix will be considered only for the 3D model data reconstruction component. The other components will need to be considered by the responsible respective teams.

The Uncertainties of the project float around the next parameters:

- How is the 3D data reconstruction going to work.

- How accurate is the data acquisition from the sensors.

- How long is the scanning process going to take.

- How long is the Testing and developing processes going to take.

- How is the deployment process going to work.

- How is the use case going to be applied for virtual clothing.

On the other side the risk Matrix will explore all possible identified risks of the project. There is a severity scale from low to high that will illustrate the potential impact on the project and whether it will hinder the competition of itself. Additionally, the likelihood of each risk is analysed to reflect the priority risk mitigation. The risk mitigation table will be located in appendix on table A.1.

4.6 Communication Management

The predicted communication plan was completed and developed after identifying all key stake holders, participants, communication channels for this endeavour. The major stake holders include:

- Capstone supervisor

- Hardware device capstone student

- User case team

- Engineering research preparation staff

As mentioned before the planned proposed time is expected to cover 35 weeks (27/7/2020 -30/6/2021). This include both UTS academic semester as well as UTS summer break. The proposed communication plan will be located in appendix on table A.2.

Progress Statement

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Appendix

Risk	Affected Phase	Severity	Likelihood	Consequences	Mitigation Plan
Lack of resources access for sensors	Research, Testing, Development and Deployment	Medium-High	Unlikely	Time setback and delays in the milestones for the delivery which could hinder the final demonstration and showcase.	Ensure that all sensors and hardware are purchased accordingly . Ensure that all SDK and driver are installed in workstations
Pandemic Progression	All Phases	Medium	Very Unlikely	The situation might trigger further adjustments to the scope of the project. As well as supervision availability	Moving all communications channel to MS teams and Zoom.
Supervisor unavailability and Low Guidance	All Phases	High	Very Likely	Lack of support could trigger a delay in the project competition	Establish as Well defined communication method and Look for other sources of guidance.
Excessive testing for Data Fusion framework and data modelling	Development and deployment	Medium	Unlikely	Loss of time for the final integration process for the 3D data reconstruction model.	Establish a reasonable time frame for testing all data visualization techniques.
No Finalization of developing framework for Data fusion and 3D reconstruction	Development	High	Unlikely	This will cause that the project wont finalise successful at the end	Try to gather as much sources as possible in order to get finalise the project.
Inability to fully integrate with the components from the other teams	Deployment	Medium	Unlikely	The consequence is that the project will get delay and the components will work independently but not combined.	Try to develop a an organised schedule that will give the proper timing for the correct integration with the other components and teams.

Table A.1: Risk Matrix

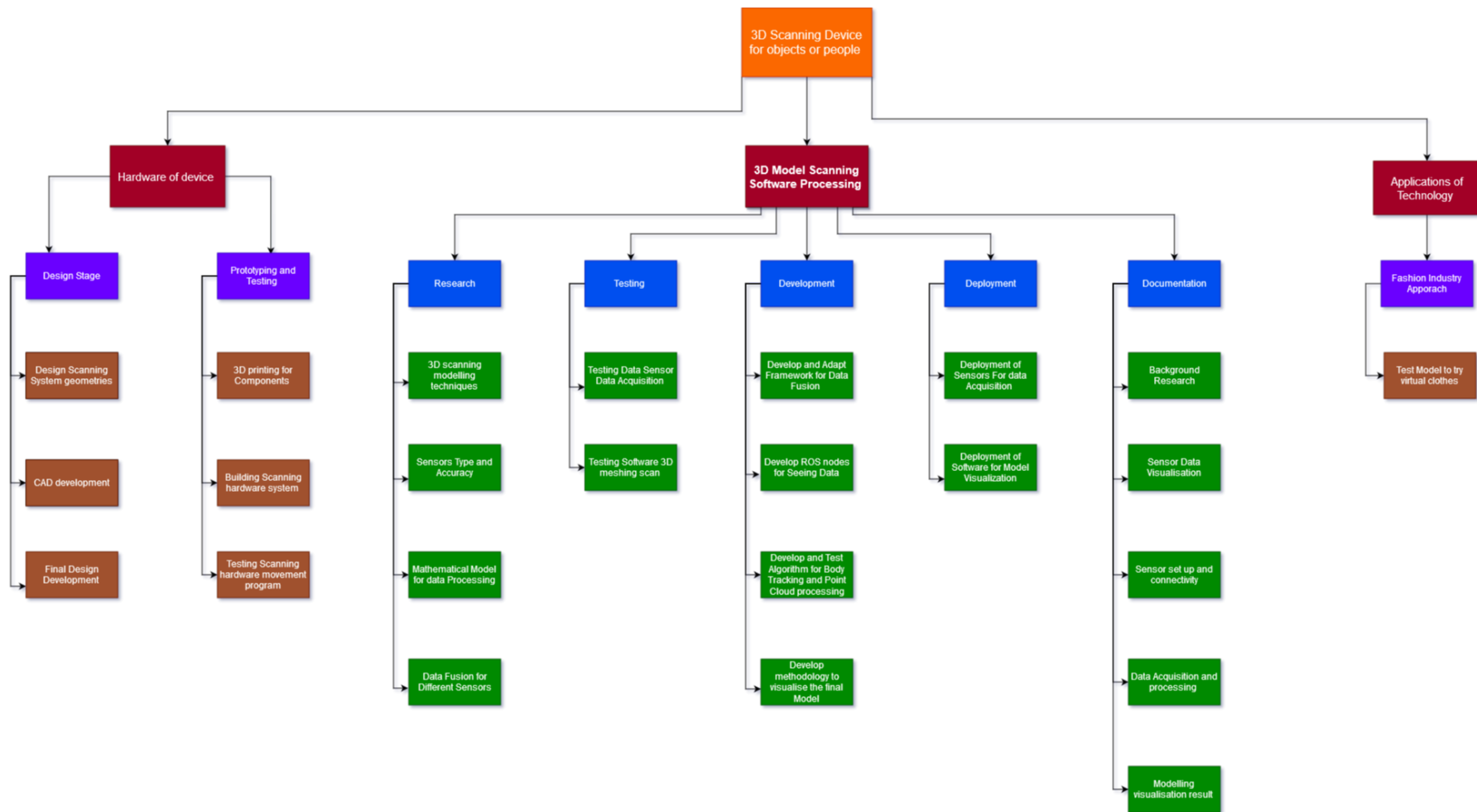| Subject	Contact	Channel	Discussion Topic	Frequency	Notes
Supervisor Meeting 1. Initial Project Discussion	Dr Teresa Vidal Calleja	Zoom	Introduce the proposed topic and discussion about how the components were labelled and divided.	One time occurrence 15/7/2020	Agreement on division of different components of the project. Establish requires skills.
Initial team discussion	Teresa Vidal Calleja, Asher Katz, Mark Liu	Zoom, Teams	Initial discussion about different components and Scope of the project	One time meeting 29/7/2020	Introduction of all team members and project discussion.
Team Meeting	Teresa Vidal Calleja, Asher Katz, Mark Liu	Zoom Teams	Weekly Discussion for all topics regarding the project and advancement.	Weekly 1 hour meeting every Tuesday until 20/6/2021	General Discussion about project status and updates.
Initial Data Acquisition Testing	Teresa Vidal Calleja, Asher Katz, Mark Liu	In Person	Initial scanning of model. Initial glance at sensor model.	One time occurrence 25/8/2020 3 Hours meeting	Initial testing with Intel real sense d435i
Engineering Research Preparation consultation	Xi Jin	Zoom	Assessment Task consultations and feedback	28/7/2020 18/8/2020 29/9/2020	Assessment task related questions and overview
Discussion on Software and hardware for Scanner	Asher Katz	TBA	General discussion and planning for integration and deployment	TBA	Lay out and planning or integration of the hardware component and 3D data reconstruction component
Final Report Submission	Teresa Vidal Calleja	Face to Face or zoom	Get final approval of project from supervisor	Single occurrence TBA	Get Final mark and sign from supervisor.
Project Showcase	Academic panel	TBA	Presentation of project	TBA	TBD
TOTAL HOURS COMPLETED				Expected	Actual
				65 Hours	TBD

Table A.2: Comunication Plan

Figure A.1: WorkBreakDown Structure

Figure A.2: Gantt Chart