Virtual Tailor

Human Body Parameter Determination using a Kinect Sensor

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Submitted to the Department of Electrical Engineering at the University of Cape Town in partial fulfilment of the academic requirements for a Bachelor of Science degree in Mechatronics.

November 7, 2017

Declaration

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1. I know that plagiarism is wrong. Plagiarism is to use another's work and pretend that it is one's own.
2. I have used the IEEE convention for citation and referencing. Each contribution to, and quotation in, this report from the work(s) of other people has been attributed, and has been cited and referenced.
3. This report is my own work.
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Nevarr Pillay

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Acknowledgments

Abstract

- Open the **Project Report Template.tex** file and carefully follow the comments (starting with %).
- Process the file with **pdflatex**, using other processors may need you to change some features such as graphics types.
- Note the files included in the **Project Report Template.tex** (with the .tex extension excluded). You can open these files separately and modify their contents or create new ones.
- Contact the latex namual for more features in your document such as equations, subfigures, footnotes, subscripts & superscripts, special characters etc.
- I recommend using the **kile** latex IDE, as it is simple to use.

Contents

Chapter 1

Introduction

1.1 Background to the study

A very brief background to your area of research. Start off with a general introduction to the area and then narrow it down to your focus area. Used to set the scene [1].

1.2 Objectives of this study

1.2.1 Problems to be investigated

Description of the main questions to be investigated in this study.

1.2.2 Purpose of the study

Give the significance of investigating these problems. It must be obvious why you are doing this study and why it is relevant.

1.3 Scope and Limitations

Scope indicates to the reader what has and has not been included in the study. Limitations tell the reader what factors influenced the study such as sample size, time etc. It is not a section for excuses as to why your project may or may not have worked.

1.4 Plan of development

Here you tell the reader how your report has been organised and what is included in each chapter.

I recommend that you write this section last. You can then tailor it to your report.

Chapter 2

Literature Review

Technology background

1. Depth Sensor technology + How Kinect works
2. Point cloud map

Coding references/Getting started

3. Code references and and blog posts?
4. Previous example
5. Hand Example

Mathematics Used

6. Papers on ellipse circumference

Improving Accuracy

7. Skeleton Joints filtering
8. Error Model

Further developments

9. Augmented reality paper

Imaging Processing Background

10. Basics of an image - RGB
11. Matlab

12. Camera Model

Uncertainty Measurements

13. Gaussian

14. Triangular

Once upon a time engineers and researchers believed... In this area of research, they used the following methods... [2]

Write this section first as it will take you the longest. I suggest you start writing this as soon as you have done your initial research at the beginning of your project. You can then return to it once you have completed your work to edit and adjust it.

A literature review forms the theoretical basis of your project. You need to read a large number of journal papers, sections in books, technical reports etc. relevant to your work at the start of project. This will give you a good idea of the field of research.

When writing your review start of with the general concepts and move to the more specific aspects explaining the necessary theory as you go. This section is NOT a copy and paste from others work or a rewrite-but-change-one-word section. I suggest you read all your material, and then put it down and write this section, referring back to the work only when you need to check something.

See your PCS textbook for more details on how to write a literature review.

If you include a figure or a table in your text please see the example in Fig. 2.1 as to how to caption it. Please make sure that all text in your figures is readable and that you reference your figures if they are from another source.

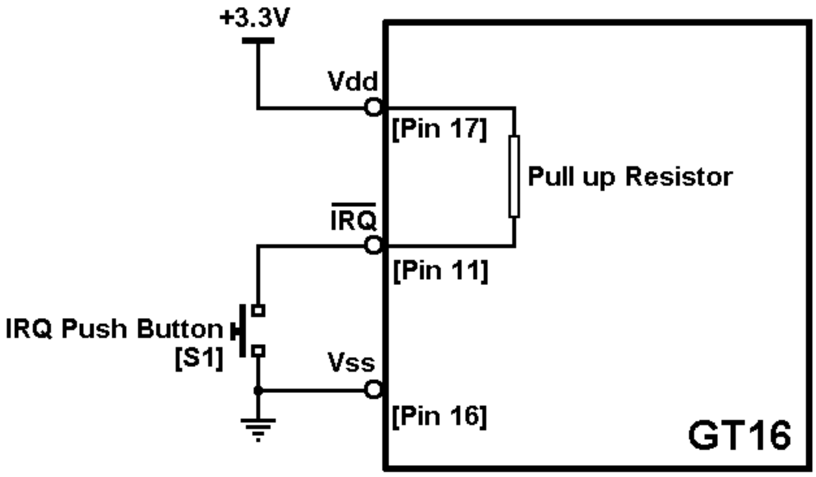

Figure 2.1: A block diagram illustrating the connections to the IRQ pin on the MCS08GT16A microcontroller (Please note that your headings should be short descriptions of what is in the diagram not simply the figure title)

Chapter 3

Background Information

Skeleton tracking
Known errors
Guidelines for measurements

Chapter 4

Solution Design

4.1 Implementation Design

1) Online profile of people - Used for online shopping and retail shops
2) Take measurements at a retailer - Virtual Dressing room - A part of the shopping experience and will reduce hassle of trying on clothes
3) Amount wasted in trying on clothes or online returns?
4) Could be used for personalised tailoring 5) Example of UI - Explanation of how it works

4.2 Component Selection

1) Choice of Kinect
2) Choice of Windows SDK

4.3 Algorithm Design

1) Windows examples used - Background Removal, Colour Stream and Skeleton Tracking

2) Run through of algorithm - Background Removed frame - Send image to separate

class for processing - Create array with background removed pixels - Draw skeleton on image - Create axes for measurement - Perpendicular or straight depending on particular measurement

4.4 Experimental Design

- Constraints - Men, distance from Kinect, Number of views, 3D Modelling - UI to run simulated dressing room - Volunteer to pose as instructed by person controlling UI - Take measurement of front - Take left - Take back - Take right - At each point, take actual readings with uncertainty - For one volunteer, take 5 readings in relatively the same pose - Determine uncertainty

Chapter 5

Methodology

This is what I did to test and confirm my hypothesis.

You may want to split this chapter into sub chapters depending on your design. I suggest you change the title to something more specific to your project.

This is where you describe your design process in detail, from component/device selection to actual design implementation, to how you tested your system. Remember detail is important in technical writing. Do not just write I used a computer give the computer specifications or the oscilloscopes part number. Describe the system in enough detail so that someone else can replicate your design as well as your testing methodology.

If you use or design code for your system, represent it as flow diagrams in text.

1. This is a bullet point test
2. I hope this works

5.1 Aim

The aim of this project was to create a system that enabled the measurement and 3D modelling of different parts of a human body through a well designed user interface, to aid in the choosing of clothing and/or custom tailoring.

5.2 Hypothesis

To determine if the above aim is met, the following three hypotheses, each with their own unique sub-hypotheses, will be tested:

1. The extremities and/or specific lengths of a human body can be measured and perform within the following criteria:
    (a) The overall measurement of the extremities of a human should perform within an average accuracy tolerance of 25%.
    (b) The measurement of lengths necessary for clothing choices should perform within an average accuracy tolerance of 20%.
    (c) Each measurement "view" should perform within an average accuracy tolerance of 25%.
    (d) Each individual limb measurement should perform within an average accuracy tolerance of 25%.
    (e) The presence of loose clothing should not affect the above performance criteria by more than 10%.
    (f) Each reading should have an uncertainty of less than 10%.
    (g) The system should be robust and able to accurately detect the human body and take all necessary measurements.
2. The measured extremities of the human body can be used to create 3D models of relevant body parts:
    (a) The circumference of modelled body parts should perform within an average accuracy tolerance of 25%.
    (b) Using an ellipse to model human body parts will yield more accurate results than using a rectangle model.
3. The user interface should allow for the successful processing of a person:
    (a) The user interface should be robust and limit the affect that user mistakes have on the measurement process.
    (b) The user interface should be easy to use and as autonomous as possible.

Chapter 6

Results

These are the results obtained from the investigation outlined in 5. Seven volunteers were used in determining the accuracy of the system. They were first measured by the system and then their physical measurements were obtained for comparison. This chapter explores the results obtained for the measurement of the extremities of a human body and the modelling of 3D body parts, together with the observed performance of the user interface respectively.

6.1 Length and Extremity Measurement

This section begins with a presentation of the overall results of the system and a comparison with the aim of the investigation. Subsequent subsections present further performance of specific areas of the system that form the basis of analysis presented in Chapter 7. These sections focus on the following major areas of the system:

- The accuracy of measuring key lengths.
- The accuracy of each view of measurement (Front, Left, Back and Right) for measuring extremities.
- The accuracy of measuring the extremity of each individual limb.
- The impact that clothing worn by a person being measured has on the system's accuracy.
- Other empirical insights obtained through use and observation of the system.

6.1.1 Overall Results

Below is a summary of the aggregate accuracy of the system and the accuracy per volunteer, together with their personal characteristics. (Table 6.1)

Table 6.1: Overall results of accuracy of system per volunteer

Volunteer Number	***Average Error***	***Build***	***Height***	***Clothing***
1	28.44%	Athletic	Tall	Tight
2	17.27%	Athletic	Average	Tight
3	16.45%	Athletic	Tall	Vest
4	40.75%	Slim	Average	Loose
5	20.72%	Big	Average	Loose
6	19.60%	Slim	Short	Tight
7	18.83%	Big	Average	Vest
Total Average Error		23.15%		

As seen in Table 6.1, despite the average error of some individual volunteers being outside the desired range of 25% accuracy, the total average error of the system is 23.15%.

6.1.2 Length Performance

Seen below in Table 6.2 are the results of the average accuracy of key lengths obtained after measuring the volunteers in the "Front" view. These lengths are used using joint locations determined by the Kinect's Skeleton Tracking. Insert reference

As seen in Table 6.2, all length measurements fell well within the desired accuracy range of 20%. The most accurate length on average was the "Left Leg" with an accuracy of 3.12% and the least accurate length on average was the Torso with an accuracy of 8.53%.

6.1.3 View Performance

Each "view" (Front, Left, Back or Right) of the system has a unique set of characteristics. It is useful to investigate the performance of each of them to better understand their

Table 6.2: Results of the average accuracy of key lengths per volunteer

Volunteer Number	***Left Arm***	***Right Arm***	***Left Leg***	***Right Leg***	***Torso***
1	6.59%	4.35%	5.64%	3.38%	19.52%
2	11.88%	7.66%	3.22%	10.53%	9.55%
3	12.75%	19.49%	0.54%	0.99%	12.15%
4	8.76%	10.64%	1.43%	0.07%	0.51%
5	2.25%	10.17%	8.35%	7.79%	5.64%
6	4.57%	3.08%	2.36%	3.17%	9.38%
7	2.29%	2.54%	0.27%	2.47%	2.98%
Total Avg Error	***7.01%***	***8.27%***	***3.12%***	***4.06%***	***8.53%***

effectiveness in the system as a whole.

Seen below in Table 6.3 are the results of the average accuracy of each view obtained after measuring the volunteers in each of the respective views.

Table 6.3: Results of the average accuracy of each view per volunteer

Volunteer Number	***Front***	***Left***	***Back***	***Right***
1	21.82%	29.90%	32.61%	31.04%
2	16.58%	15.81%	20.45%	14.60%
3	17.27%	19.01%	15.53%	13.37%
4	35.58%	58.15%	33.58%	44.77%
5	21.06%	10.39%	24.92%	23.47%
6	11.65%	44.58%	14.09%	17.07%
7	20.72%	19.51%	20.60%	12.06%
Total Avg Error	***20.67%***	***28.19%***	***23.11%***	***22.34%***

As seen in Table 6.3, the accuracy of the views in descending order are as follows:

1. Front
2. Right
3. Back

4. Left

The only view that performed outside the desired accuracy range of 25% was the "Left" view with an average accuracy of 28.19%. The Front view performed the best with an accuracy of 20.67%.

6.1.4 Limb Performance

Each extremity being measured is subtly different due to various factors such as position, orientation and size. Therefore, understanding how the system performs in these different cases is useful.

Due to the large number of measurements being taken, the results have been split up in terms of upper and lower body measurements.

Below is a summary of the aggregate accuracy of the system in measuring upper body limbs per volunteer: (Table 6.4)

Table 6.4: Results of the average accuracy of Upper Body Limbs

Volunteer Number	***Chest***	***Upper Left Arm***	***Lower Left Arm***	***Upper Right Arm***	***Lower Right Arm***
1	49.50%	29.90%	10.10%	26.35%	11.02%
2	27.84%	23.16%	9.84%	17.74%	13.24%
3	14.58%	10.99%	24.14%	7.33%	12.27%
4	79.55%	12.20%	26.74%	33.79%	5.47%
5	45.85%	21.22%	8.41%	15.16%	14.82%
6	23.39%	6.64%	15.91%	8.46%	8.63%
7	30.70%	12.34%	12.71%	12.02%	7.95%
Total Avg Error	***38.77%***	***16.64%***	***15.41%***	***17.26%***	***10.48%***

As seen in Table 6.4, measurements of the lower and upper portions of both arms fell well within the desired accuracy of 25%. However, the chest measurements seemed to be significantly more inaccurate with an average of 38.77%, which is far outside the desired range.

Below is a summary of the aggregate accuracy of the system in measuring lower body limbs per volunteer: (Table 6.5)

Table 6.5: Results of the average accuracy of Lower Body Limbs

Volunteer Number	***Waist***	***Upper Left Leg***	***Lower Left Leg***	***Upper Right Leg***	***Lower Right Leg***
1	32.09%	31.47%	13.58%	28.07%	44.04%
2	25.36%	15.32%	14.18%	13.21%	6.61%
3	20.51%	13.09%	24.62%	20.01%	10.12%
4	80.55%	13.36%	27.94%	25.40%	48.15%
5	26.74%	16.08%	8.56%	24.17%	15.81%
6	35.04%	20.78%	43.78%	9.58%	17.38%
7	19.53%	23.78%	22.77%	26.17%	16.17%
Total Avg Error	***34.26%***	***19.13%***	***22.20%***	***20.95%***	***22.61%***

As seen in Table 6.5, measurements of the lower and upper portions of both legs fell within the desired accuracy of 25%. This was similar to the behaviour of the arm measurements, mentioned above. However, they seemed to be slightly more inaccurate with all of the leg measurements having an accuracy tolerance of more than 19%, whereas the arms all fell within 17.5%. The waist measurement also followed the behaviour of the chest measurement above, where seemed to be significantly more inaccurate than the leg measurements. It had an average accuracy tolerance of 34.26%, which is also outside the desired range.

6.1.5 Impact of Clothing

The nature of the system is such that it is sensitive to clothing worn by the measured party. One aim of the system, as stipulated, in section 5.2, was to make the system more robust to clothing, such that the results are less prone to error.

As such, each of the above measurement results tables have been adjusted to remove the effects of clothing. This has been done by analysing the data set after volunteers with observed "loose" clothing were removed.

Below is the clothing adjusted version of Table 6.1.

Table 6.6: Overall results of accuracy of system per volunteer after adjustments for clothing

Volunteer Number	***Average Error***	***Build***	***Height***	***Clothing***
2	17.27%	Athletic	Average	Tight
3	16.45%	Athletic	Tall	Vest
6	19.60%	Slim	Short	Tight
7	18.83%	Big	Average	Vest
Total Error Average		***18.04%***		

It is clear from Table 6.6 that the system performs significantly better when loose clothing is not worn by the volunteer. The new overall average accuracy of the system improved to 18.04%, which is well within the desired range of 25%.

The same behaviour can be observed for the accuracy of the views and the different limbs.

In the adjusted version of Table 6.3 (Table 6.7), the performance of all the views improve. Additionally, the "Left" view now also falls within the desired 25% range and all the other views fall within 18%.

Table 6.7: Results of the average accuracy of each view per volunteer after adjustments for clothing

Volunteer Number	***Front***	***Left***	***Back***	***Right***
2	16.58%	15.81%	20.45%	14.60%
3	17.27%	19.01%	15.53%	13.37%
6	11.65%	44.58%	14.09%	17.07%
7	20.72%	19.51%	20.60%	12.06%
Total Avg Error	***16.55%***	***24.73%***	***17.67%***	***14.27%***

As for the adjusted upper and lower body measurements (Table 6.8 and Table 6.9 respectively), all of the measurements, except for the "Lower Left Leg" measurement (increased to 26.34% which is outside the desired range) either improved in accuracy or remained within 1% of its previous accuracy. The "Chest" measurement is now within the desired accuracy range of 25% with a value of 24.13%. The "Waist" measurement also greatly improved, however, is still narrowly outside the desired range with an accuracy of 25.11%

Table 6.8: Results of the average accuracy of Upper Body Limbs after adjustments for clothing

Volunteer Number	***Chest***	***Upper Left Arm***	***Lower Left Arm***	***Upper Right Arm***	***Lower Right Arm***
2	27.84%	23.16%	9.84%	17.74%	13.24%
3	14.58%	10.99%	24.14%	7.33%	12.27%
6	23.39%	6.64%	15.91%	8.46%	8.63%
7	30.70%	12.34%	12.71%	12.02%	7.95%
Total Avg Error	***24.13%***	***13.28%***	***15.65%***	***11.39%***	***10.52%***

Table 6.9: Results of the average accuracy of Lower Body Limbs after adjustments for clothing

Volunteer Number	***Waist***	***Upper Left Leg***	***Lower Left Leg***	***Upper Right Leg***	***Lower Right Leg***
2	25.36%	15.32%	14.18%	13.21%	6.61%
3	20.51%	13.09%	24.62%	20.01%	10.12%
6	35.04%	20.78%	43.78%	9.58%	17.38%
7	19.53%	23.78%	22.77%	26.17%	16.17%
Total Avg Error	***25.11%***	***18.24%***	***26.34%***	***17.24%***	***12.57%***

6.1.6 Uncertainty

The uncertainty of each limb measurement in each view can be seen in Table 6.10 and Table 6.11. As mentioned in (Insert Reference), these were calculated assuming a Gaussian distribution of measured values.
Note: The values of #N/A represent values that are not available in the respective view - I.e. The left hand side of the body cannot be seen when the volunteer is orientated right and as such are not available for measurement in that view

As seen in Figure 6.1 below, all the uncertainty values calculated for each limb in the different views fell within the desired range of ¡10%. Additionally, majority of the values actually fell within the range of 0-6%.

Table 6.10: Results of the average uncertainty (U_n) of Upper Body Limbs per view

View	***Chest***	***Upper Left Arm***	***Lower Left Arm***	***Upper Right Arm***	***Lower Right Arm***
Front	1.19%	3.84%	9.37%	3.48%	5.28%
Left	2.03%	3.50%	6.82%	#N/A	#N/A
Back	1.64%	3.29%	5.41%	3.02%	4.47%
Right	0.91%	#N/A	#N/A	5.00%	5.74%
Total Avg (U_n)	***1.44%***	***3.54%***	***7.20%***	***3.83%***	***5.16%***

Table 6.11: Results of the average uncertainty (U_n) of Lower Body Limbs per view

View	***Waist***	***Upper Left Leg***	***Lower Left Leg***	***Upper Right Leg***	***Lower Right Leg***
Front	1.25%	1.26%	2.86%	3.41%	5.72%
Left	2.36%	1.34%	8.01%	#N/A	#N/A
Back	0.91%	2.42%	2.70%	1.16%	1.08%
Right	2.03%	#N/A	#N/A	4.62%	7.79%
Total Avg (U_n)	***1.64%***	***1.67%***	***4.52%***	***3.06%***	***4.86%***

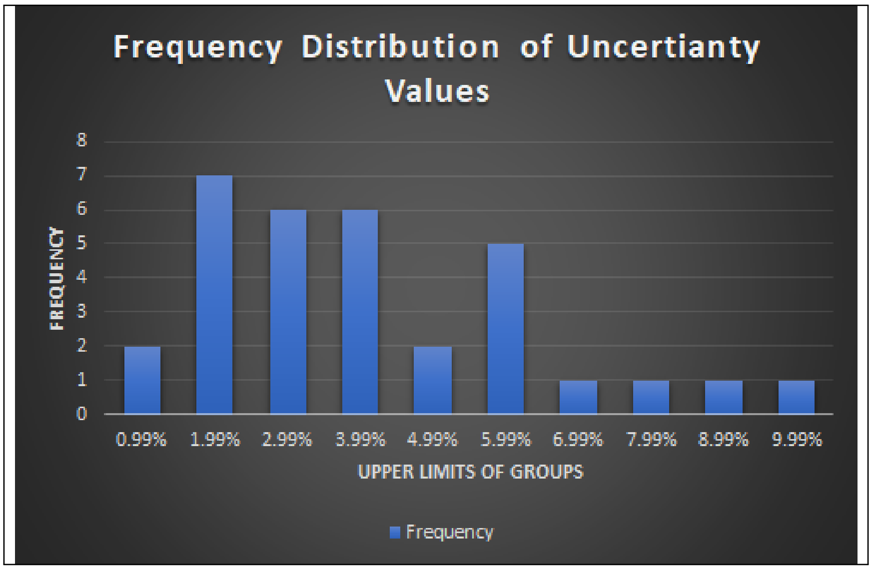

Figure 6.1: A histogram depicting the frequency distribution of the uncertainty values displayed in Table 6.10 and Table 6.11

Upon closer inspection of Table 6.10 and Table 6.11, it is clear that all the individual and average uncertainty values fell within the desired range of 10%. The most reliable reading (One with the smallest uncertainty) was the "Chest" measurement with a 1.44% uncertainty. As a group, the leg measurements seemed to be more reliable than the arm measurements as all of the average leg uncertainties fell within 5%. On the other end of the spectrum, the measurement with the greatest average uncertainty was the "Left Arm" with an uncertainty of 7.20%.

6.1.7 Other Empirical Observations

Apart from the above presented tables of results, other observations were made of the system during its use. These observations are explained in each of the following subsections:

Background Removal Error

There were instances where the Background Removal functionality of the Kinect performed with error. These errors presented themselves in two manners:

Extra Padding During early and final testing of the system, it was observed that the output background removed picture had extra padding around the detected human in

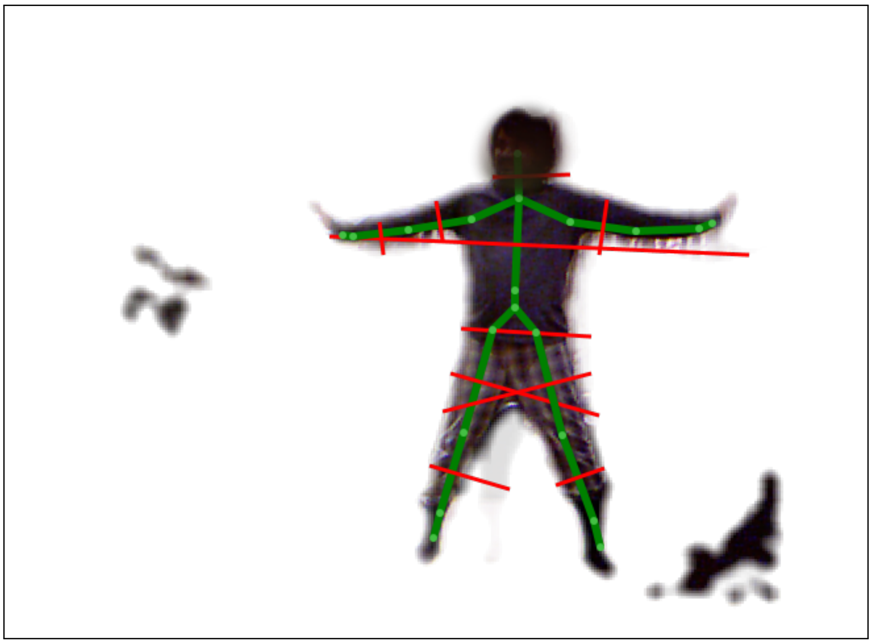

Figure 6.2: An example of failures of extremity measurements due to background removal and padding errors detected in early testing

some instances. This extra padding consisted of background pixels that should have been removed.

An example of an early test with the above error can be seen in Figure 6.2. In this image, it can be clearly seen that extra background pixels have been included in regions under the outstretched arms, on the sides of the torso and underneath the groin.

An additional caveat to the above error was also detected. It was observed that when the detected human was processed while moving, trailing pixels from the previous position would be included in the image and form part of the padding.

This was present in both early testing and final testing. In Figure 6.2, mentioned above, this can be clearly seen as the left leg has a "ghost" or "trailing" leg present. An example of a final test with trailing pixels can be seen in Figure 6.3. In this image, careful inspection of the extended hand reveals that trailing pixels are present due to movement of the detected human.

Incorrect Pixel Removal The other error present as a result of the Background Removal functionality is the incorrect pixel removal of pixels that form part of the detected human. The parts of the body that suffered the most frequently from this error are the parts at the extremes (E.g. Head, hands, "feet, etc.). Additionally, the

Figure 6.3: An example of trailing pixels detected by background removal that forms part of padding errors

view in which incorrect pixel removal from the "Head" was the most prevalent, was the "Back" view.

An example of a final test with incorrect pixel removal can be seen in Figure 6.4. Careful inspection of this image reveals that pixels that form part of the head and hands of the detected human have been incorrectly removed.

Overlap Error

It was observed that occasionally, the system failed to detect a correct extremity. As mentioned in Insert Reference, measuring extremities assumes that an outline of a limb will be against a background and thus, after the background is removed, will be clearly distinguishable. However, it was observed that in instances where an outline overlapped with another part of the body or the extra background padding mentioned in section 6.1.7 above, the outline would not be detected by the system.

A clear example can be seen in Figure 6.2. The "Chest", "Upper Right Leg", "Upper

Figure 6.4: An example of the presence of a background removal error relating to incorrect pixel removal during final testing

Left Leg" and "Lower Left Leg" in this image have been erroneously extended due to overlap errors. The "Upper Leg" measurements were extended due to overlap of the detected human's thighs, thus making their division indistinguishable. The "Chest" and the "Lower Left Leg measurement were both extended due to overlap caused by background padding. Respectively, they were caused by the padding underneath the arms and trailing pixels of the left leg.

Examples of this error during final testing can be seen in Figure 6.5 and Figure 6.6. In Figure 6.5, the overlap error is present in the "Chest" measurement as its plane of measurement intersected with the right arm, which was too low in this case. In Figure 6.6, the overlap error is present in the "Lower Right Leg" as its plane of measurement intersected with the "Lower Left Leg". The volunteer in this case was facing right for a "Right" view measurement. However, the volunteer's legs were not together and slightly ajar, thus creating an unwanted overlap.

Figure 6.5: An example of failures of extremity measurements due to background removal and padding errors during final testing

Missing Measurements

During final testing, it was observed that occasionally, certain limb measurements were not processed properly and as a result, were not available. This manifested in certain limb measurements returning a value of "0cm", in its corresponding location on the user interface, when a non-zero value was expected.

This error was observed in four individual limb readings belonging to two separate volunteers. The corresponding volunteer, view, limb details of the missing measurement are listed below, together with the figure in which it can be seen:

1. Volunteer 3 - Back View - Upper Right Arm - Figure 6.7
2. Volunteer 3 - Right View - Upper Right Arm - Figure 6.8
3. Volunteer 4 - Back View - Lower Right Arm - Figure 6.9
4. Volunteer 4 - Left View - Left Lower Arm - Figure 6.10

Figure 6.6: An example of overlap error due to orientation during final testing

Incorrect Waist Plane

The last error that was observed during final testing was the occurrence of an incorrect waist plane when taking a measurement from either the "Left" or "Right" view.

In Figure 6.11, the "Front" view of the volunteer is shown on the left side of the image and the "Right" view on the right side. It is evident that the waist plane in the "Front" view is correct as it is drawn across the hips in an almost horizontal fashion. The waist plane in all views should follow this pattern. However, the waist plane in the "Right" view is severely angled and deviates from the horizontal. As such, the measurement obtained would be incorrect and often inflated.

Additionally, the deviation from the horizontal (Or the angle fo the waist plane) varied depending on the rotation of the volunteers body, thus producing unpredictable results. An example of this changing deviation can be seen in Figure 6.12. Here, the "Left" view measurement of the same volunteer that appears in Figure 6.11 is shown. However, it is evident that the deviation of the waist plane in the "Left" and "Right" views is not consistent.

Figure 6.7: An example of a missing measurement - Volunteer 3 - Back View - Upper Right Arm

6.2 3D Modelling

6) Circumference results - Ellipse 7) Circumference results - Rectangle

6.3 User Interface Observations

9) Improved UI - trying to determine perfect pose 10) Data Set Analysis

Figure 6.8: An example of a missing measurement - Volunteer 3 - Right View - Upper Right Arm

Figure 6.9: An example of a missing measurement - Volunteer 4 - Back View - Lower Right Arm

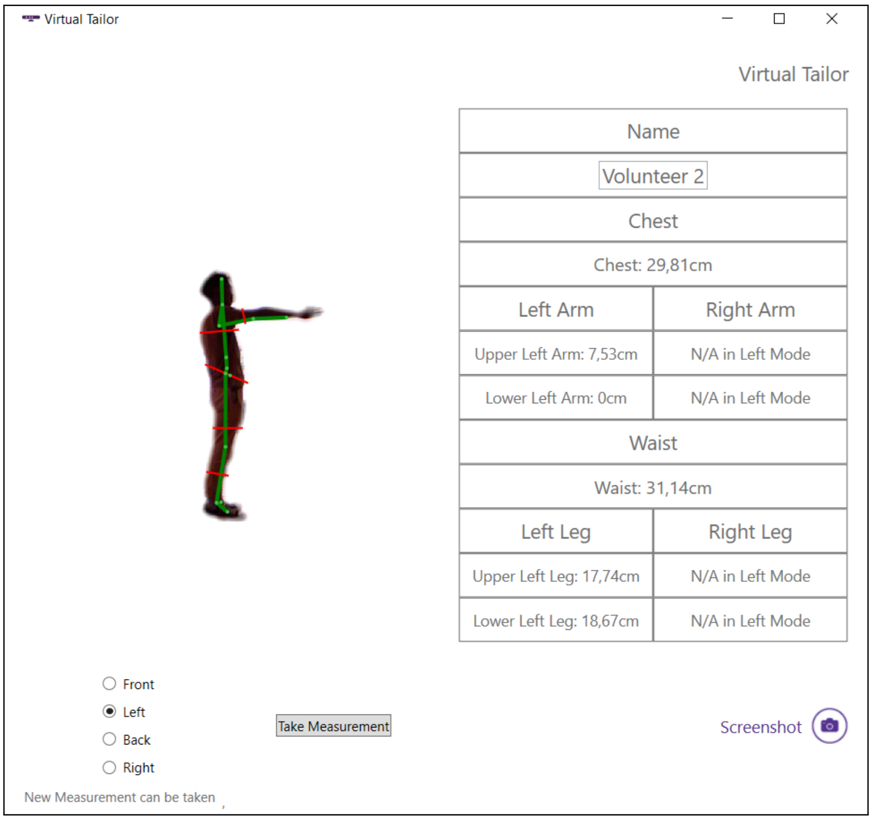

Figure 6.10: An example of a missing measurement - Volunteer 3 - Back View - Lower Left Arm

Figure 6.11: A comparison of the "Front" and "Right" view measurements volunteer 2 to illustrate the waist plane error

Figure 6.12: A comparison of the "Front" and "Right" view measurements volunteer 2 to illustrate the waist plane error

Chapter 7

Analysis

Mention data set?

The observed factors that had the greatest contribution to inaccuracy are listed below in order of impact:

1. The system not being able to accurately determine the extremities of the body.
2. The inconsistency of the plane being used to take the measurement.
3. The error or "jitter" of the tracked skeleton.

Therefore, the system performed such that it met the requirements of achieving an accuracy better than 25%, as stipulated in section 5.1.

The results obtained in Table 6.3, together with the detailed results of each volunteer available in Appendix A have yielded insights for each of the views. They are discussed in the subsequent subsections.

7.0.1 Front Performance

The "Front" view performed the best overall with an average accuracy of 20.67%. This can be attributed to the fact that the Kinect performs the best when a person faces it head on (Parallel to the image plane). This is due to the Kinect being able to fully track the skeleton of the user. As a result, a more accurate and reliable skeletal coordinate system can be used, which in turn provide more accurate planes of measure.

All joints and skeleton tracked

7.0.2 Left Performance

7.0.3 Back Performance

The "Back" view performed better than expected despite the average error of 23.11%

7.0.4 Right Performance

Front was the most accurate

Misc
Missing - Height, Skinny, Back, Skeleton Mapping 8) Empirical Insights - Trying to determine a correct measurement, length of people, skinny person, skeleton not perfectly fitting, background edges not perfect

5) Uncertainty model

Chapter 8

Discussion

Here is what the results mean and how they tie to existing literature...

Discuss the relevance of your results and how they fit into the theoretical work you described in your literature review.

Chapter 9

Conclusions

These are the conclusions from the investivation and how the investigation changes things in this field or contributes to current knowledge...

Draw suitable and intelligent conclusions from your results and subsequent discussion.

Chapter 10

Recommendations

1) Statistical Model in taking readings
2) Automatic system to remove the need for a person 3) Clothing model 4) AI for understanding body shape 5) Better modelling of 3D body parts 6) Extension to cellphone 7) Full 3D parameter modelling - Body parts, skin contours, body fat% etc. 8) Filtering skeleton joints

Use the IEEE numbered reference style for referencing your work as shown in your thesis guidelines. Please remember that the majority of your referenced work should be from journal articles, technical reports and books not online sources such as Wikipedia.

Bibliography

[1] M. S. Tsoeu and M. Braae, "Control Systems," *IEEE*, **vol. 34(3)**, pp. 123-129, 2011.

[2] J. C. Tapson, *Instrumentation*, UCT Press, Cape Town, 2010.

Appendix A

Detailed Results of Volunteers

Add any information here that you would like to have in your project but is not necessary in the main text. Remember to refer to it in the main text. Separate your appendices based on what they are for example. Equation derivations in Appendix A and code in Appendix B etc.

Table A.1: Add caption

	Chest	Waist	Upper Left Arm	Lower Left Arm	Upper Right Arm	Lower Right Arm	Upper Left Leg	Lower Left Leg	Upper Right Leg	Lower Right Leg
Front	38.92	38.27	7.97	9.28	7.09	7.27	24.72	12.55	24.38	12.02
Front	38	31	11.5	9	12	7.5	15.5	10.5	15.5	10.5
Error	2.42%	23.45%	- 30.70%	3.11%	- 40.92%	- 3.07%	59.48%	19.52%	57.29%	14.48%
Left	28.73	31.96	7.39	8.73	#N/A	#N/A	20.05	12.55	#N/A	#N/A
Left	20	20.5	11	7.5	#N/A	#N/A	14.5	11.5	#N/A	#N/A
Error	43.65%	55.90%	- 32.82%	16.40%	#N/A	#N/A	38.28%	9.13%	#N/A	#N/A
Back	80.37	34.58	8.12	8.31	7.88	7.37	22.38	12.89	23.54	11.05
Back	35	30	11	7.5	11.5	9.5	15	11.5	14.5	11.5
Error	129.63%	15.27%	- 26.18%	10.80%	- 31.48%	- 22.42%	49.20%	12.09%	62.34%	- 3.91%
Right	25.68	29.42	#N/A	#N/A	9.8	8.78	#N/A	#N/A	17.38	24.58
Right	21	22	#N/A	#N/A	10.5	9.5	#N/A	#N/A	17	11.5
Error	22.29%	33.73%	#N/A	#N/A	- 6.67%	- 7.58%	#N/A	#N/A	2.24%	113.74%

Appendix B

Addenda

B.1 Ethics Forms