Testing the tactile perception of the human finger

Eric Balfour and Chamiere Greenaway
Mentor: Prof. Kretzschmar
Harlem Children Society

Abstract

The project reported here determines the tactile sensitivity of human fingers. Tactile test surfaces of polydimethylsiloxane (PDMS) are prepared and tested. Masks made from modeling clay with the inverted surface structure are used to shape the required polymer test surfaces. The project aims at determining the optimum height and diameter of a polymer dot for tactile perception. In addition, preliminary results on the effect of dot spacing on the tactile perception of the dots are presented.

Introduction

The main goal of our project is the testing of the tactile perception of the human finger. Our project is part of a bigger effort towards the creation of a dynamic tactile tablet (DTT), which will enable blind and visually impaired people to access graphical information provided via the Internet.

The DTT is made up of three layers; a polymer layer, an electronic layer, and a touch sensitive screen. The electronic layer and the touch screen are connected to a computer. A signal to the electronic layer results in the extension of polymer pins from the polymer layer, which can be touched and sensed by the blind person. As the person touches the pins on the polymer layer, a slight pressure applied by the blind person will signal to the touch sensitive screen which area is touched. The screen then sends the coordinates of the point touched to the computer. With this information the computer can tell the person what they are touching. Further, the computer can now also send a new electronic signal to the polymer layer, e.g., change to a different display similar to a new window opening when one clicks with the mouse on a symbol on the computer screen.

In this day and age technology is rapidly changing and society has become more and more dependent on technology especially the Internet. Figure 1 shows a typical graph that can be found on the Internet. Obviously, a blind person will not be able to access the information in the graph unless a clear description of the graph is added to the webpage. Thus, they would need someone to explain to them every detail that is shown in the graph.

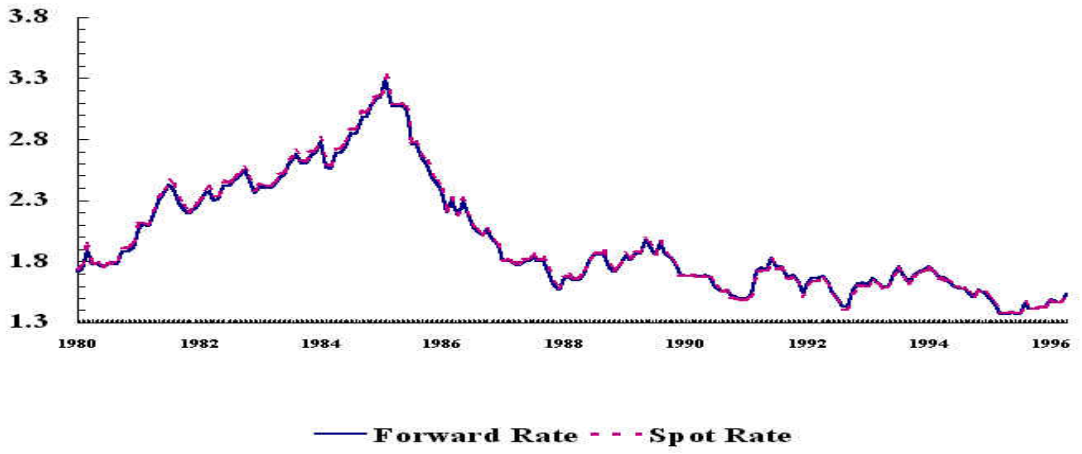

Figure 1. Exemplary graph found on the Internet. http://faculty.insead.edu/fatas/ime/exercise/ Graphs.htm).

The technology enabling blind people to access such graphical information has not yet been developed. Two of the more advanced devices used to aid blind people in accessing information are the screen reader and the note taker displayed in Figure 2 below.


www.abatim.com www.enablemart.com

Figure 2. Advanced reading devices, a) screen reader and b) note taker.

Although these are two very useful devices, they cannot help blind people to access graphical information. That is why the need for the DTT is so great.

In brief, this project determines the tactile sensitivity of human fingers. Tactile test surfaces of polydimethylsiloxane (PDMS) are prepared and tested. Masks made from modeling clay with the inverted surface structure determine the surface properties of the polymer material. The project aims at determining the optimum height and diameter of a polymer dot for tactile perception. In addition, preliminary results on the effect of spacing of dots on the tactile perception are presented.

Background

The **Tactile Sense** is how people perceive something by touching (sense of touch). In the human finger, there are touch and pressure receptors. The receptors send the information to the brain when they are activated. Then the brain sends a response or command to the muscles. Blind people have a better sense of touch than people who can see. Since blind people lost or never had the ability to see, their other four senses are dramatically enhanced.

Blind people use a system called Braille, which enables them to read with their fingers. Louis Braille created the Braille system in 1824; who was blind himself. The Braille system is made up of so called Braille cells. Each cell has six dots ⠿(Braille cell). Each dot has a diameter of about 1.3 mm. The spacing between each pair of dots is about 2.5 mm horizontally and vertically. The dot height is about 0.5 mm. The dots are made of a piezoelectric material, which expands upon the application of a voltage.

The average person can detect a dot with a diameter of 2 mm, but some people are more sensitive and can detect dots that have a diameter less than 1 mm.[ref]

The **Talking Tactile Tablet (TTT)** is made up of a tactile sheet on top of a touch sensitive screen, which is connected to a computer. When the person touches any of the features on the tactile sheet, the touch sensitive screen sends a message to the computer and in return the computer talks to the person describing what they are touching, hence the name TTT. However, unlike the DTT, the TTT is not dynamic because the computer is not able to change anything displayed to the blind person after something is touched. This is because the Tactile Sheet is pre-prepared and the features displayed are fixed and cannot be altered by the computer. In order to change anything, another tactile sheet has to be made. The DTT would enable the blind person to display new information more easily.

Experimental Set-up

Materials used:

Liquid PDMS (Dow Corning Corporation)
Modeling Clay (No. 300 Crayola Modeling Clay Non-Toxic)
Petri Dishes
Paperclips & Pencil points of different sizes
Modeling Clay Tools (Creativity Street)

Instrumentation used:

Dial Caliper
Vacuum Desiccators (Bel-Air)
Isotemp Oven (Fisher Scientific)
Scale (Denver Instrument & Ohaus)

Method:

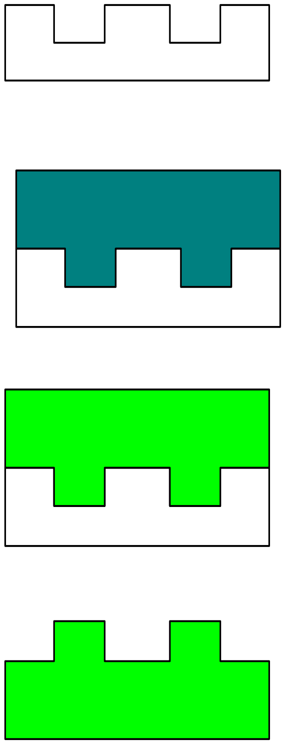

Figure 3. Schematic of mask preparation.

1) Make a mask out of the modeling clay
    - Place modeling clay in a petri dish
    - Use paper clips and other means to make dots of the same height in mask (diameter)
    - Use one paper clip to make dots of different heights in mask (height)
2) Preparation PDMS Template
    - Mix liquid PDMS (base: agent = 10:1) in a separate container
    - Pour liquid PDMS over mask
3) Curing of PDMS
    - Place the Petri dish with mask and PDMS in the vacuum desiccator
    - Evacuate the desiccator to facilitate PDMS curing (note this will lead to air bubble formation)
    - Check periodically to see if air bubbles have stopped forming
    - Place petri dish in Isotemp oven to cure for 2 – 4 hours at ~70°C
    - Remove from oven and let cool
4) Removal of PDMS template
    - Peel cured PDMS of the clay mask
    - Remove any clay residue that is left on the surface

5) Testing of the Surfaces

There are two main strategies for testing the surfaces. In the first method subjects are asked to move their finger across the surface and to say: "Dot" when they feel what they believe is a dot. In the second test method, the tester moves the subject's finger across the surface using different approaches (see results section). The person is asked to say, "Dot" when he/she feels a dot.

Results

Mask making

3 different Modeling clays were tested in this experiment:

- No. 300 Crayola Modeling Clay Non-Toxic
- Prang Modeling Clay
- Crayola Model Magic

Of the three, No. 300 Crayola Modeling Clay is best suited to carry out the experiment. It is more difficult to make a mask from Prang, because it is very sticky and the testing surface has a waxy feel to it after it is put in the oven for curing. However, the dots on the testing surface made employing the Prang clay are stiffer. The third modeling clay tested, Crayola Model Magic, is clay that hardens upon curing while the others are non-hardening clays. This is a property that would aid the experiment greatly because a mask would be able to be used more than once. Unfortunately, when the clay was tested, it was unsuccessful because the PDMS would not easily separate from the clay resulting in the destruction of the mask. It may be possible to prevent this by using a thicker PDMS layer.

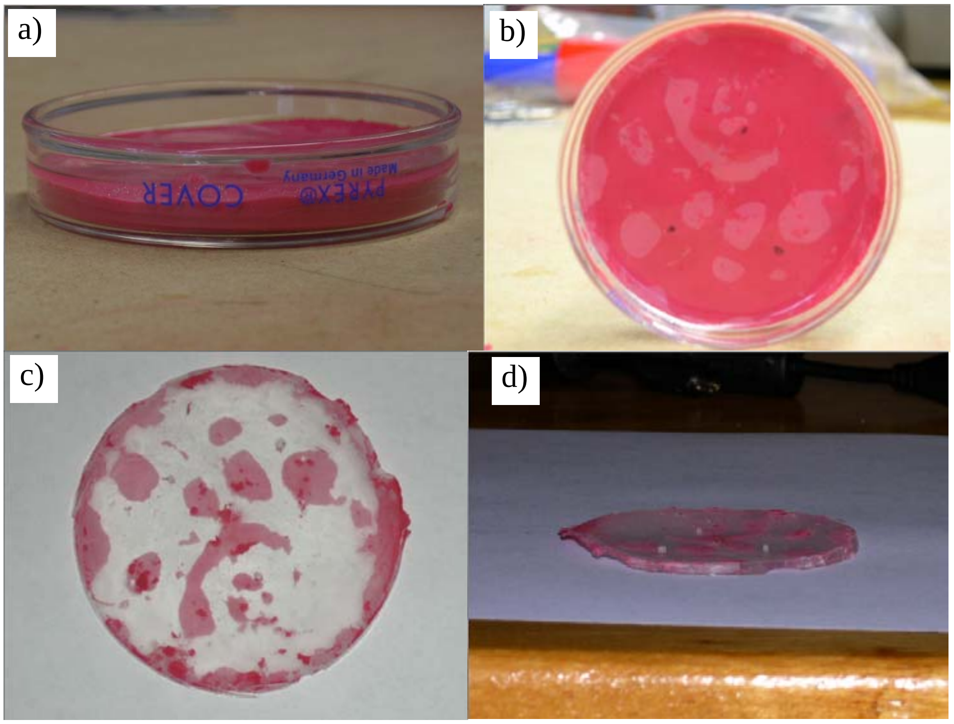

Figure 4. Images for mask-making procedure. a) PDMS/clay mask assembly, b) mask after curing, c) mask peeled off the clay, and d) side view of mask with pins.

Testing approach

The two general methods for testing the tactile perception of subjects are to guide the subjects' finger across the surface and to let the subject move their finger across the mask at his/her own will. Both methods produce similar results.

When testing the masks, different approaches are used when the tester assisted in the scanning of the surface. These methods are: (i) guiding the subjects' finger over the dots in ascending or descending order (according to size), (ii) with and without the application of pressure, (iii) dragging and tapping across the surface, and (iv) finger tip versus the flat part of the finger.

The following observations are made using the four different methods: For method (i), the results show that more dots are felt when going in ascending order than in descending order. For method (ii), the results indicate that more dots are felt without pressure. For method (iii), the results are the same because all the dots are felt for both the dragging and the tapping methods. For method (iv) the results show that more dots are felt with the tip than with the flat part of the finger.

Mask Testing Results

Height Results

Table 1. Summary of tactile testing using dots with varying heights and diameters (ACT HT = actual height, ATT HT = attempted height, and dd = dot diameter).

7/17 Y dd 1.3± 0.05mm			**7/17 B dd 1.34± 0.13mm**			**7/19 R dd 0.83± 0.04mm**			**7/19 B dd 1.04± 0.06mm**			AVG	SDV
ACT HT	ATT HT	#felt	ACT HT	ATT HT	#felt	ACT HT	ATT HT	#felt	ACT HT	ATT HT	#felt		
						0.31	.3mm	10 / 10					
						0.42	.4mm	10 / 10					
			0.49	.4mm	6 / 6								
			0.54	.5mm	5 / 6	0.52	.5mm	10 / 10				0.52	0.01
0.64	.6mm	6 / 6	0.62	.6mm	6 / 6				0.64	.3mm	8 / 10	0.63	0.01
						0.72	.6mm	10 / 10					
			0.77	.7mm	6 / 6	0.76	.7mm	10 / 10				0.75	0.03
0.8	.8mm	6 / 6	0.83	.8mm	6 / 6				0.9	.5mm	10 / 10	0.84	0.05
1	.9mm	6 / 6											
1.14	1mm	6 / 6	1.2	.9mm	6 / 6	1.13	.9mm	10 / 10	1.12	.6mm	10 / 10	1.15	0.04
			1.33	1mm	5 / 6				1.42	.7mm	10 / 10	1.38	0.06
						1.76	1mm	10 / 10					
									1.92	1mm	10 / 10		

Table 1 represents the testing surfaces (5 surfaces in total) that have a dot diameter range of 1.30 ± 0.05 mm to 0.83 ± 0.04 mm and the height range of 1.92 mm to 0.50 mm. As the table shows, all these dots are found detectable to the human finger, with some exceptions (high lighted in yellow).

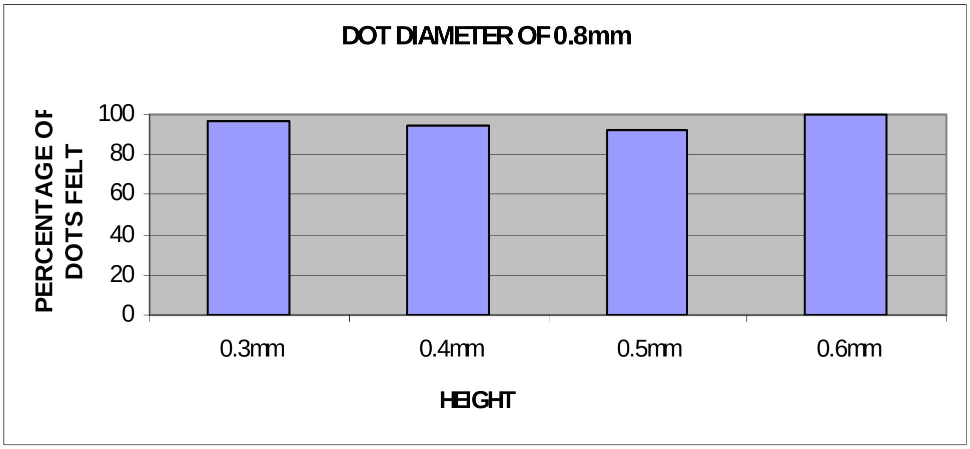

Figure 5. Graph showing the percentage of detected dots at a dot diameter of 0.80 ± 0.03 mm as a function of dot height.

The graph in Figure 5 represents the results from the mask with dots of a diameter of 0.8 ± 0.03 mm. The masks have four rows of dots. The dots of each row have a different height (0.3 mm, 0.4 mm, 0.5 mm, and 0.6 mm). All test subjects detected the dots that had the height of 0.6 mm and 97% of the subjects felt the dots with the height of 0.3 mm. The detection percentage of the 0.4 and 0.5 mm dots is 95% and 91%, respectively.

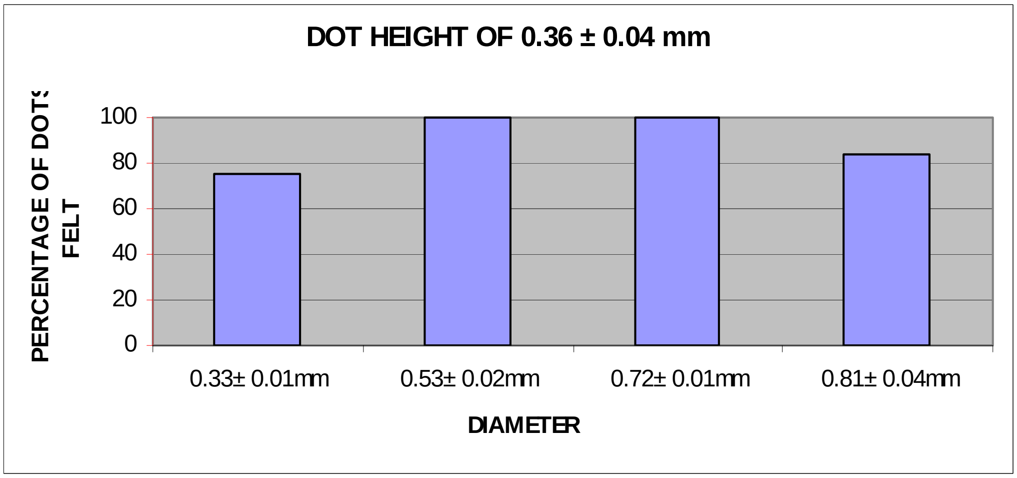

Figure 6. Graph showing the percentage of detected dots at a dot height of 0.36 ± 0.04 mm as a function of dot diameter.

This graph represents the last 4 testing surfaces that are tested for the determination of the diameter threshold at a height of 0.3 mm. Each dot has an average height of 0.36 ± 0.04 mm. The attempted height for each surface is 0.3 mm. The lowest diameter size that everyone could feel at a height of 0.36 ± 0.04 mm is 0.53 ± 0.02 mm. So, our threshold for the diameter is 0.53 ± 0.02 mm.

Diameter Results

Table 2. Summary of dots with diameter ranging from 0.17±0.03mm to1.5±0.04mm and height ranging from 0.34mm to 1.78mm

hgt / dmtr	0.17±0.03 mm	0.22±0.02 mm	0.28 mm	0.53 mm	0.68 mm	0.8±0.02 mm	1.01±0.08 mm	1.5±0.04 mm
0.34mm	***80%***							
0.41±0.02mm						100%	100%	100%
0.51±0.04mm	***10%***						100%	100%
0.65±0.02mm			52.08%	93.75%	100%	100%		
0.71mm							100%	
0.8±0.03mm	70%	83.33%						100%
0.89mm	100%							
1.03±0.04mm	67%					100%		
1.15±0.03mm						100%		100%
1.24±0.03 mm							100%	
1.36mm								100%
1.78mm							100%	

Table 2 shows the results from the first 7 testing surfaces, tested for their diameters. In the top row, there are 8 different diameters, which are tested given with their standard deviations. The first column contains the different heights tested along with their standard deviations. Inside the table are the percentages of dots felt by the test subjects. Most of the dots are detected with the exception of a few, which are highlighted in red.

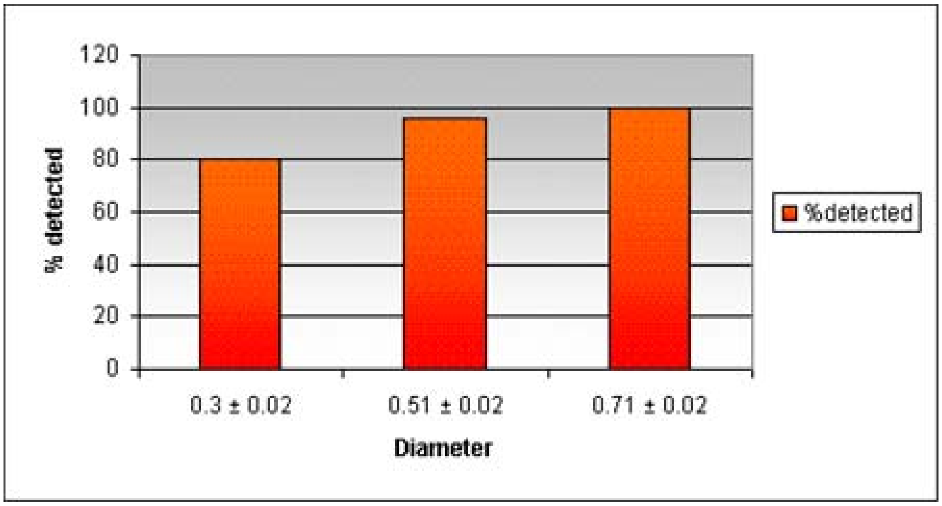

Figure 7. Summary of tested surfaces with an average dot height of 0.41 ± 0.14 mm and varying diameters.

Figure 7 contains the information gathered from the testing of the other 5 testing surfaces used for the testing of the optimum diameter. The average height of the dots tested is 0.41 ± 0.14 mm. For the 5 testing surfaces, the diameters are of 0.30 ± 0.02 mm, 0.51 ± 0.02 mm and 0.71 ± 0.02 mm. The y-axis displays the percentage of dots detected for each dot diameter size. According to this graph, the dots with the size of 0.3 ± 0.02mm are detected 80% of the time, the dots with the size of 0.51 ± 0.02mm 96% of the time and the dots with the size of 0.71 ± 0.02mm 100% of the time.

Discussion

In the following the results presented in the results section are discussed.

(i) When testing subjects with dots in ascending and descending order, more dots are felt in ascending order than in descending order. The smallest dot on the mask used to test in ascending order had a smaller height than the smallest dot on the other mask. This could have contributed to our results because when the height of a dot made of PDMS is large, the dot is not as strong as a dot with a smaller height. This could be the reason why more people missed the smallest dot on the mask used for testing descending order.

(ii) When testing the effects of pressure with which the finger of our subjects is pressed onto the mask more dots are felt without the application of pressure because when pressure is applied to a PDMS dot, the finger flattens the dot and the subject would not be able to detect it as easy as if they were to place their fingers on the dots gently.

(iii) In the test constructed to see what difference dragging and tapping makes, the result are very similar. It is believed that the reason for this is because the dots are big enough to be very detectable to the subjects so it didn’t make a difference which of the two approaches is used.

(iv) Finally, when testing the two parts of the finger, the subjects detect more dots with their finger tips than with the flat part of their finger. This allows us to conclude that for most of our subjects the finger tip is more sensitive than the flat part, which could be due to either a higher concentration of receptors or more sensitive receptors in the finger tips.

The gender of the subjects did not affect the experimental results in any way. It is not possible to tell if the age had an effect on the experimental results because we did not have a wide enough range of ages to test. Most of the subjects have very similar ages.

Table 1 shows several highlighted data points, which indicate dots that are not detected by all test subjects. One reason to why these dots are not detected, is that the testing surfaces are not completely flat which makes a detection of the dot harder.

In Figure 3 a lower “sensing” probability is observed for the 0.5 mm high dots. The rationale for this observation is the smaller number of dots (three vs. four) for the 0.5 mm high dots, i.e., the percentage of the row with the dot height of 0.5 mm will decrease faster then the other rows if only one or two subjects missed a dot. The reason for the subjects to miss dots from the row with the dot height of 0.4 mm is the presence of a large bump next to the dot, which led the subject to missing the dot.

Figure 4 shows that the dots with a diameter of 0.81 ± 0.04 mm have a lower percentage of being detected. This is caused by a dent in the testing surface. The dent was caused by air trapped at the bottom of the modeling clay, which tried to escape while the mask was in the oven leaving a bump in the mask. The testing surface is the inverted structure of the mask and the inverted structure of the bump is a dent. Two of the dots tested are next to the dent, which makes them harder to detect.

The results in Table 2 and Figure 6 are close to what one would expect with the exception of those highlighted in red. The expected results for those highlighted values would have been that the dots of 0.34 mm height and 0.16 mm diameter should have a smaller percentage than the dots of 0.51 mm height because the 0.34 mm dot is smaller and should therefore be more difficult to be detected. The fact that the opposite trend is observed, points to other factors than height and diameter to affect the tactile perception.

Conclusions

The testing of the diameter of the dots gave us a threshold of 0.5mm and the testing of the height of the dots gave us a threshold of 0.3mm. Preliminary test for the spacing of dots showed the trend that the smaller the dots, the larger the spacing required between the dots is. Future work is needed to determine the optimum dot space. Now it has to be shown experimentally that the polymer film can expand to a height of 0.3mm in a circular area with a diameter of at least 0.5mm. If the polymer film can meet these parameters, then the DTT may become reality. In the future, we will try to find the optimum parameter for the spacing of the dots.

References

National Institute of Neurological Disorders and Stroke (NINDS), Bethesda, Maryland, 20892, United States http://clinicaltrials.gov/ct/show/NCT00076700
Tom Philbin, “The 100 Greatest Inventions of All Time” pg. 138
Laurie Kelly, Clarence W De Silva, De Silva De Silva “Mechatronics An Integrated Approach” pg.579
Duane V Knudson, Craig S Morrison “Qualitative Analysis of Human Movement” pg.51

Acknowledgements

We would like to thank the people who have made this summer program possible for us.
Professor Kretzschmar
Dr. Sat Bhattacharya
The City College of New York
The Chemical Engineering Students & Staff at Steinman Hall
Mr. Nixion
Mrs.A.Sassine
Our mothers
MSKCC
Harlem Children Society