DEPARTMENT OF COMPUTER SCIENCE
THE UNIVERSITY OF HONG KONG

COMP4801 Final Year Project 2016-2017
VR Technology in Self-defined Clothing
Individual Final Report

Supervisor
Dr. C.K. Chui

Student
TANG Chun Keung 3035122924

16th April 2017
Abstract

Since the rise of online shopping, it has brought enormous impacts to the traditional retailers. However, issues emerge with significant number of returns, especially in online apparel stores. The reasons of return are mainly the unfit problem and wrong style problem. This project tries to demonstrate a feasible way to solve these problems. It aims to implement a virtual shop which brings some more elements from actual shops to the online shops by virtualizing the real fitting room through the use of VR technology. Together with the virtual fitting room, the users will also be virtualized. A 3D avatar will be created for each user with the personal body measurements obtained by analyzing the user’s front and side view images. In addition, user profiles are constructed for users for further improving online shopping experience.

The deliverable of the project is a prototype system consisting two ends: the frontend and backend. The frontend contains an iOS app implementing the virtual fitting room; and the backend contains a set of scripts to support the functionalities of the frontend part. The focus of this report is the details on implementing the backend part in the system.
Acknowledgement

Our team is extremely grateful to Dr. C.K. Chui for providing continuous support and insightful guidance in helping the team to foreseeing the future practice of online shopping in fashion industry and realizing the use of advanced technologies which can truly solve real-life problems.

Our team also thanks Dr. K.P. Chan, course coordinator for COMP4801/CSIS0801, for structuring the course and enabling students in getting resources from the Department of Computer Science.
# Table of Contents

1 Introduction .......................................................................................................................... 5  
   1.1 Background .................................................................................................................. 5  
   1.2 Objectives .................................................................................................................. 5  

2 Literature Review ................................................................................................................. 7  

3 Project Overview .................................................................................................................. 8  
   3.1 System Architecture ..................................................................................................... 8  
   3.2 Contribution ................................................................................................................ 9  
   3.3 Development Methodology .......................................................................................... 9  
   3.4 Deliverables ................................................................................................................ 10  

4 Implementation .................................................................................................................... 11  
   4.1 Technical Tools Used ................................................................................................. 11  
   4.2 Implementation Details ............................................................................................... 12  
      4.2.1 Web Server ........................................................................................................... 12  
      4.2.2 Database .............................................................................................................. 12  
      4.2.3 Body Measurement Program ............................................................................. 13  

5 Conclusion ........................................................................................................................... 23  

5 References ............................................................................................................................ 24
1 Introduction
1.1 Background

Since the rise of online shopping, more people choose online shopping instead of traditional retail shopping in buying clothes. Statistics published by Nielsen in 2016 have shown that over eighty percent of Hong Kong people shopped online and more than fifty percent of customers bought clothing online [1]. However, there is a growing problem that many online shoppers are not satisfied with the actual products they received. The reason for this is that they did not actually have not tried on the purchased clothes in fitting rooms [2].

The most significant difference between traditional shopping and online shopping is the shopping experience. In current online apparel shopping practice, the online shoppers simply browse the products displaying on the online shop websites and pick the products they are interested in. Before checkout, they have to choose what size they would like to buy. In this whole process, including choosing products and size, online shoppers have to make their decisions with imaginations. They do not have the real products on hand to decide whether the products are suitable to them.

Since virtual reality (VR) can offer users an illusion of behaving like in the real world, our team has decided to utilize this technology to bring some more elements in the actual shops to online shops by implementing virtual fitting room using the technology. In addition, computer vision techniques are also used in this project for assisting the shoppers in buying clothes online by analyzing their body shape to provide the body measurements for reference.

1.2 Objectives

The goal of this project is to develop a prototype in mobile environment (an iOS mobile device and a VR headset) to demonstrate the next generation of online apparel shops. Unlike traditional online shops, the prototype does not just publish the products online, but also virtualize the shoppers and the fitting room in actual shops when shoppers shopping online.

The project aims to demonstrate a feasible way to further improve online shopping experience and raise shoppers’ satisfaction. Online shoppers no longer purchase the wrong style or unfit clothing and retailers have to suffer a significant number of returns and the costs for such returns.

There are three main objectives in this project, they are:

(1) Body measurement

The prototype aims to develop a body measurement program to perform non-contact body measurement process and provide shoppers with a set of reference body measurements, which assists them in purchasing ready-to-wear apparel.
(2) User profile

Based on the measurements from the body measurement program, the prototype aims to construct a user profile for each shopper. The measurements in the profile are used to create personal avatars for shoppers. Also, the shoppers can make use the profile to determine whether which size of the clothes is suitable for them.

(3) Virtual fitting room

The prototype aims to virtualize the shoppers and the real fitting room, and provide them with virtual environment as if they are in actual fitting by wearing a VR headset. A 3D avatar will be created for each shopper and different kind of clothing can be put on to the avatar.
2 Literature Review

After an extensive background research, some related works available on the market were found, which aims to assist online shoppers in determining the size or style to purchase. However, there appears to be no single solution can solve all the problems encountered in online shopping. Below are a list of some existing solutions:

(1) MTailor[3]

It is a mobile app which features all-in-one purchasing experience for ordering well-fitted tailor made male formal wear with customized style selections. In particular, there is a mandatory in-app video recording process to capture the users' body shape for calculating the users' body measurement.

However, the app never shows the users their real body measurements measured from the video that the users might not be confident with the wear they are ordering. In addition, it cannot offer an experience of virtual trial of the clothing.

(2) Fitnect[4]

It is a software which makes use of augmented reality and computer vision technology to implement a 3D fitting room in user homes or real retail stores. Users can use simple hand gesture to interact with the software. It allows users to browse thousands of various clothes and accessories, and then virtually try on them immediately, giving the chance to preview products without trying them on physically.

However, the hardware requirements of the system are high, especially the graphical compute capability (nVidia GTX 650,660 or later required). Also, it requires user to have a motion sensor for detecting purpose, and only supports few common models on the market, for example, Microsoft Kinect and Asus XTION LIVE.

(3) Joy of Clothes[5]

It is an online personal stylist. Before customers make any purchase, they can create their own model by selecting the body shape, skin color, hair style, features on the face, and etc. also, it provides measurement guide for customer. Then the customer can use the own created model for previewing of the selected clothes available on the website. However, there are many manual settings on creating the model.
3 Project Overview

3.1 System Architecture

Server-client architecture is adopted in this project and the system contains 3 components at 2 ends, see figure 1:

(1) Frontend

The iOS app acts as the user interface of the system to the users. There are some functionalities in the app, including registration, browsing of clothing and virtual fitting.

(2) Backend

The web server contains the several scripts programmed to respond to the requests sent from the app. It contains the basic registration and authorization process; and access of user profile data. Also, the body measurement program also resides in the hosting server and is to be called once requested from the app.

Database storage is a relational database to store the necessary data and information for the system to run. It includes the personal data of the user in the registration process and the measurements returned from the body measurement program.

![Server-client architecture of the prototype system](image)
3.2 Contribution

<table>
<thead>
<tr>
<th>Name</th>
<th>Role</th>
</tr>
</thead>
<tbody>
<tr>
<td>HO Ka Miu</td>
<td>• Frontend development</td>
</tr>
<tr>
<td>TANG Chun Keung</td>
<td>• Backend development</td>
</tr>
</tbody>
</table>

3.3 Development Methodology

It is believed that adopting the prototype development based method can facilitate us to achieve the aims of clearly demonstrating a feasible way to solve the insufficiencies in current online shops. Developing a prototype can give clear idea about the functional process in a system under resource limitation. Time is a crucial and limiting factor for this project as the project team has to strictly adhere to the 8 months limitation for FYP grading purposes. In addition, the prototype development would also be beneficial in the project future development in terms of user requirement gathering and analysis as there is currently lack of industrial standard requirement documents.
3.4 Deliverables

The project aims to develop a prototype system to achieve the goals and objectives stated in the section 1.2.

The body measurement program in the prototype system should be able to process two 2D images of a user (the front and side view) to perform a non-contact body measurement calculations which the measurements are used in the other modules inside the app. Figure 2 shows the requirements of the two images in the body pose. When shooting the user from the frontal view, the user’s legs are required to apart from each other for shoulder width and the arms are open on both sides of the body. When photographing, users are requested to stand in front of a plain color background, and wear plain color spandex or shirtless. The color of the background and wearing should not be in gray and should be in contrast.

The iOS app in the system should be able to construct personal 3D avatars using the figures accordingly to the measurements in the user profiles returned from the measurement program. Moreover, different kinds of clothing are provided to the users to browse and try with the created 3D avatar. Last but not least, VR environment is provided to the users when user put the phone into a VR headset.

![Figure 2. Pose requirements for the 2 images](image-url)
4 Implementation

This section only provides details of the development and implementation of the backend part in the prototype system.

4.1 Technical Tools Used

(1) Languages

C# is used as the implementation language in implementing the web services and defining the formal agreement between the web service and the iOS app.

C++ is used as the implementation language in implementing the body measurement program. As OpenCV library is the main image processing library in the program and the library is mainly written in C++, using C++ in our implementation would bring better performance compared with using other languages.

(2) Libraries

- OpenCV 3.1
  - an open source computer vision and machine learning software library

- MySQL Connector
  - Connector for MySQL

(3) Environment

- Windows Internet Information Services (IIS) 6.2

(4) Development IDE

- Windows Visual Studio 2015
4.2 Implementation Details

4.2.1 Web Server

The Windows Internet Information Services (IIS) web server is hosted at a server running with Windows Server 2012 R2 under the Computer Science Department. The web server supports and accepts HTTP requests from the frontend app. The required Windows Communication Foundation (WCF) RESTful API web services written in C# are published to the IIS web server which support the functionalities in the frontend app. Requests are sent to the server API and the data is exchanged as JSON object.

Below is a list of services providing:
- Registration
- Authorization
- Uploading of images for body measurement program
- Access of user profile

4.2.2 Database

Database is setup to support the storing the user profiles in the project. The weight is in unit of kilogram and the other measurements of users are in unit of centimeter. Below is the database schema:

```sql
CREATE TABLE user
(user_id INT NOT NULL AUTO_INCREMENT,
 first_name varchar(20) NOT NULL,
 last_name varchar(20) NOT NULL,
 gender varchar(1) NOT NULL,
 phone_number varchar(20),
 email varchar(50) NOT NULL UNIQUE,
 password varchar(20) NOT NULL,
 PRIMARY KEY user_id (user_id, email));

CREATE TABLE user_measurement
(user_id INT NOT NULL,
 height int NOT NULL,
 weight double,
 neck double,
 shoulder double ,
 chest double,
 waist double,
 low_hips double,
 sleeve double,
 upper_body_length double,
 lower_body_length double,
 front_img varchar(20),
 side_img varchar(20),
 background_img varchar(20)
 PRIMARY KEY (user_id));
```
4.2.3 Body Measurement Program

The body measurement program is one of the main modules in the prototype system. It outputs the measurements that are used by the frontend app to construct personal avatars for users in the virtual fitting room and suggest which size of clothes the users should choose.

The flow of the program is first to perform image processing procedure to obtain the silhouette of the user. With the silhouette, body part landmark localization is then performed to locate different parts in the body. After that a set of interested points are be extracted. Finally, estimation formulas are executed to calculate the measurements.

(1) Image Processing
There are numerous background noises existing together with the interested object in the 2D images. To get rid of them, a series of image preprocessing has to be done before the body part landmark localization.

(a) Image Preprocessing
   (i) Shadow Removal
Shadows in the images are the most troublesome factor contributing to the inaccurate measurements in the program. It is because if the shadows exist in the following calculations, the outcome would be greatly affected. Therefore they have to be removed. The method adopted to remove them is to reset the brightness value in the 2D images. The images to be processed are firstly converted from BGR mode (blue, green and red) to HSB mode (hue, saturation, brightness) The B value is then reset to 100% hence the shadows and the lighting information are greatly removed. The results of removal is shown in figure 3.

*Figure 3. The original image before removal: (a) & (b) The result after removal: (c) & (d)*
(ii) Normalization
This step aims to increase the contrast the foreground (the user body) and the background (the things other than the user body) and facilitate the following steps. The process to be taken is to convert the image which the B value is maximized to grayscale mode. Figure 4 shows the result after normalization step.

![Figure 4. The results after normalization](image)

(b) Edge Detection
Although the shadows and the lighting information are removed, there still are noises in the images. Therefore there is additional denoising step to further remove the noises. The algorithm adopted is the Gaussian Blurring. There are several denoising algorithms in the OpenCV library. The reason of choosing this algorithm instead of the others is that the results returned from this algorithm are reasonable reliable and the operation speed is fast. Although there are another algorithm in the library (Non-local Means algorithm) which is able to obtain more favor results, but the time to be taken of it is impractical.

Gaussian Blurring algorithm recalculates pixel value for each value, and each pixel’s new value is set to a weighted average of that pixel’s neighborhood pixels. Figure 5 shows the result of the algorithm, although there will be lost of detail in the images and the images are blurred, the edges between the subject (the user) and the background in (b) are clearer than in (a).
After that, canny edge detector in the OpenCV library is invoked to detect edges on the blurred result above. The concept behind is to set two thresholding values to determine whether a pixel is on the edges by comparing its intensity gradient value. Figure 6 helps to illustrate the idea. The two thresholding values in the illustration are called the maxVal and the minVal. For the pixels which the intensity gradient values are greater than the maxVal (line A in figure 6), they are on the edges. On the other hand, for the pixels which the intensity gradient values are lower than the maxVal, they are not on the edges. For those the values are between the maxVal and the minVal, the test for them to determine if they are on the edges is whether they are connected to the pixels on the edges. If they are, they are then on the edge, otherwise, they are not. The line C in figure 6 is on the edge as it is connecting with A, while B is not as it is not connecting with any edges. The thresholding values preset in the program are 250 and 750 empirically. Figure 7 is the result of edge detection.
Figure 7. The result of canny edge detection
(c) **Silhouette Extraction**
By the Canny detector in the library, the overall shape of the user body is drawn. To extract the human body silhouette interested, there still are some processes to be performed.

(i) **Dilation**
As there exist numerous gap between the edges detected (see examples on figure 8), there is a need to fill the gap to obtain one single human silhouette. Dilation is therefore performed to add extra layers of pixels on the edges detected. Generally speaking, this process enlarges and exaggerates the pixels hence the gaps are closed. Figure 9 shows the result of dilation.

![Figure 8. Gaps between the edges detected (circled in red)](image1)

![Figure 9. The result of dilation](image2)
(ii) Floodfill
This process fills the ‘holes’ inside the outermost borders and prepares intermediate images for the next step. See the result of this process in figure 10.

![Figure 10. The result of floodfill](image)

(iii) Erosion
At the last step, erosion is performed to compensate the previous dilation step to strip out the outermost layers of pixels on the edges. See the results from below figure 11.

![Figure 11. (a)&(b): the result of floodfill; (c)&(d): using (a)&(b) as the masks in the original images accordingly](image)
After the image processing step, clear body silhouettes can be extracted from the images. Each silhouette is represented by a vector of points containing x and y value on 2D plane originated at the top-left corner of the image. The points in the vector is in anticlockwise order, starting with points with minimal x and y value. With the silhouettes, several phases of locating body part landmark can be performed.

The localization work is only performed on the front silhouette as there is no landmark can be located on the side silhouette. The work is divided in two phases. The first phase is to locate the extremum points on the front silhouette; and the second phase is to locate different body parts based on extremum points located or by iterating over the body height.

(a) Basic extremum points[7]

There are five extremum points on the silhouette with required pose (see figure 12: e1-e5). Below is the list of them and the method of locating them:

- Top point on the head (e1):
  Locate the point with the minimum y value

- Leftmost and rightmost points on the hands (e2, e5):
  Locate the points with the minimum and maximum x value

- Bottom points on the feet (e3, e4):
  Locate the points with the maximum y value on each side of the body divided by a center line. The center line is defined by averaging the x values in the vector of points.

Figure 12. The five extremum points on the silhouette (e1-e5)
(b) Kollmann decimal standard[8]

Kollmann decimal standard is a concept of dividing the height of human body into 10 equal segments and each of those is subdivided into 10 subunits. It indicates that different body parts are commonly located within respectively particular segments. The standard is used to estimate certain body parts in the program.

![Kollmann decimal standard](image)

Figure 13. Kollmann decimal standard

(c) Localization of the body parts

The different body parts are located by different methods in the program:

- **Neck:**
  The neck girth is defined as the minimum horizontal circumference around the body at neck level. Therefore, the neck level in the Kollmann decimal standard is from the 10th subunits to 20th subunits. The interested neck level is scanned from this range, searching for the level with the narrowest part.

- **Shoulder:**
  Shoulder is identified by locating the two shoulder points with the farthest perpendicular distance from the line drawing from the left/right neck point to the leftmost/rightmost point on hand from the points in the range between the left/right neck point and the leftmost/rightmost point on hand.
- **Chest:**
  Chest localization in the program is by estimation. The level is located by searching for the two points with minimum y value from the range the leftmost/rightmost point on hand and the left/right bottom point on feet.

- **Waist:**
  The waist girth is defined as the minimum horizontal circumference around the body at waist level. The waist level in the Kollmann decimal standard is from the 40th subunits to 50th subunits. Therefore, the interested waist level is scanned from this range, searching for the level with the narrowest part.

- **Crotch:**
  The crotch level is located by searching for the point with minimum y value from the points in the range between the left bottom point and the right bottom point.

- **Hip:**
  The hip girth is defined as the minimum horizontal circumference around the body at hip height. The hip level is searching for the widest part from the waist level to the crotch level.

After the different body part levels on the front silhouette are located, the corresponding levels on the side silhouette are then located by calculating the ratio.
(3) Body Measurement

(a) Reference Ratio
To calculate the body measurements, a reference ratio is needed. The ratio is calculated from the user height input by the user and the number of pixels occupied from the highest point to the lowest point in the front image. The formula is given as following:

$$Reference\ Ratio = \frac{user\ input\ height\ (centimeter)}{user\ height\ in\ the\ image\ (measured\ in\ number\ of\ pixels)}$$

This gives approximate centimeters per every pixel in the images. Hence, the body measurements can computed by counting number of the pixels in the images.

(b) Measuring
There are two type of body measurements: 2D and 3D measurements.

(i) 2D measurement
The 2D measurement means the linear measurements, for example, the height, arm length and shoulder. The calculations for them is to count the number of the pixel from their start and end point, and then multiple by the reference ratio.

(ii) 3D measurement
The 3D measurement means the spatial measurements, for example, the neck, chest and waist. The measurements for them are calculated by estimations. The measurements are calculated by estimating the approximate number of pixel of the circumference multiplied by the reference ratio. The shape of the 3D measurements are estimated as the shape of ellipse and the formula to estimate the circumference is given as following:

$$Circumference = \pi \cdot \left[ \frac{3}{2} (a + b) - \sqrt{a \cdot b} \right], \text{ where } a \text{ and } b \text{ are the radius of ellipse}$$
5 Conclusion

To conclude, the project is to try demonstrate a feasible way for improving online shoppers’ experience. The project tries to implement a virtual shop, which is standing out from the traditional online shops that just publish their products online. The project virtualizes the fitting room and the shoppers through using VR technology and computer vision technologies on 2D images.

For the body measurement program, several tests using different samples were performed after the completion of implementation. The results were expectedly differ from the actual measurements of the samples’ measurements. However, the results were reliable to be within ±10% at the 90% confidence level. It reveals that the measurements are still of considerable referential value for shoppers when they are purchasing ready-to-wear clothing. Undoubtedly, researching on other effective and efficient image processing algorithms would be the main future works in terms of body measurement function in the system.
6 References