Spring 2017

Mosquito popper: a multiplayer online game for 3D human body scan data segmentation

Zachary Nolte
University of Iowa

Recommended Citation
Nolte, Zachary. "Mosquito popper: a multiplayer online game for 3D human body scan data segmentation." MS (Master of Science) thesis, University of Iowa, 2017.
https://doi.org/10.17077/etd.pmcjyoy5

Follow this and additional works at: https://ir.uiowa.edu/etd
Part of the Industrial Engineering Commons

Mosquito Popper: A Multiplayer Online Game for 3D Human Body Scan Data Segmentation

by

Zachary Nolte

A thesis submitted in partial fulfillment

of the requirements for the Master of Science

Degree in Industrial Engineering

in the Graduate College of

The University of Iowa

May 2017

Thesis Supervisor: Assistant Professor Stepehen Baek

Graduate College
The University of Iowa
Iowa City, Iowa

CERTIFICATE OF APPROVAL

MASTER'S THESIS

This is to certify that the Master's thesis of

Zachary James Nolte

has been approved by the Examining Committee for the thesis requirement for the Master of Science degree in Industrial Engineering at the May 2017 graduation.

Thesis Committee: ______________________________
Stephen Baek, Thesis Supervisor

____
Amaury Lendasse

____
Xuan Song

ACKNOWLEDGEMENTS

The author would like to acknowledge Dr. Baek for lending his invaluable expertise in the field and providing the digital human model databases essential to this project. This research was additionally aided by the efforts of my co-workers in the IDEA Lab, namely Maxwell Riley for his technical assistance. The author would also like to acknowledge Paul Yon and Timothy Dougherty for their technical contributions to the overall project as well as the participants and players of Mosquito Popper.

ABSTRACT

Game with a purpose (GWAP) is a concept that aims to utilize the hours spent in the world playing video games by everyday people to yield valuable data. The main objective of this research is to prove the feasibility of using the concept of GWAP for the segmentation and labeling of massive amount of 3D human body scan data. The rationale behind using GWAP as a method for mesh segmentation and labeling is that the current methods use expensive, time consuming computational algorithms to accomplish this task. Furthermore, the computer algorithms are not as detailed and specific as what natural human ability can achieve in segmentation tasks. The method presented in this paper overcomes the shortcomings of computer algorithms by introducing the concept of GWAP for human model segmentation. The actual process of segmenting and labeling the mesh becomes a form of entertainment rather than a tedious process, from which segmentation data is produced as a bi-product. In addition, the natural capabilities of the human visual processing systems are harnessed to identify and label various parts of the 3D human body shape, which in turn gives more details and specificity in segmentation. The effectiveness of the proposed game play mechanism is proven by experiments conducted in this study.

PUBLIC ABSTRACT

Games with a purpose (GWAP) is a concept that aims to utilize the hours spent in the world playing video games by everyday people to yield valuable data. The main objective of this research is to prove the feasibility of using the concept of GWAP for the segmentation and labeling of massive amount of 3D human body scan data. Accurate segmentation and labeling of 3D human body scan data is of paramount importance in many areas of research, such as human tracking, digital human modeling and anthropometric analysis, and etc. Such a task is extremely expensive as it requires lots of tedious, time-consuming hand labor. There are a number of computational methods for automatically segmenting and labeling a 3D model, but the computers are still a way less reliable than the human capability in terms of accuracy, amount of detail, and robustness. To solve this problem and make geometry labeling and segmentation easier and less demanding, we created a multiplayer online game called "*Mosquito Popper*". The purpose of this game is to re-channel the efforts and the hours spent by game players to the collection of segmentation and labeling data through gameplay. By crowdsourcing, it is possible to yield massive amounts of segmented mesh data while at the same time accurately label the 3D human body mesh segments. The advantage this approach offers is that it will help overcoming the problem of tedious and time consuming work that previous computational approaches ran into. While playing the game, the players will effectively be providing geometry labeling and mesh segmentation data through the mechanics of the game. Furthermore, by collecting this data directly from the players this way, we are using the natural 3D segmentation and image identification capability that humans already possess. Finally, we ultimately want to create a data repository full of already segmented and labeled 3D human body scan data that is easy to navigate and use for future research.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1: INTRODUCTION

Games with a purpose (GWAP) is a concept that aims to utilize the hours spent in the world playing video games by everyday people to yield valuable data. The main objective of this research is to prove the feasibility of using the concept of GWAP for the segmentation and labeling of massive amount of 3D human body scan data. Accurate segmentation and labeling of 3D human body scan data is of paramount importance in many areas of research, such as human tracking [6], digital human modeling and anthropometric analysis [4],[14],[18], and etc. Such a task is extremely expensive as it requires lots of tedious, time-consuming hand labor. There are a number of computational methods for automatically segmenting and labeling a 3D model (e.g. [7], ,[13],[16]), but the computers are still a way less reliable than the human capability in terms of accuracy, amount of detail, and robustness.

The number of 3D models being uploaded to the web continues to increase every day, forming gigantic repositories of 3D geometry information. In recent history, many databases have emerged that contain full 3D scans of human body shapes such as the Size Korea [11] and CEASAR [15] projects. It is important that geometry processing tools be constructed and start harnessing the massive amount of information and data that is available to us regarding the geometry of various 3D shapes.

1.1 Games With a Purpose

GWAP is a concept that strives utilize the hours spent playing video games by everyday people in a constructive and progressive manner. Every week, billions of hours are spent playing video games around the world. In America, 59% of people play video games, which comes out to about 150 million gamers. In 2013, each American gamer played roughly 330 hours per year, that's about 130 million human-hours per day. To put it into perspective, 7 million human-hours were put into building the Empire State Building. That means that using the human-hours spent on video games, we could build almost 19 Empire State Buildings every day. Most people play these games because they provide individuals with happiness, entertainment, and maybe even some skillsets. GWAP looks to provide people with an entertaining game that someone will play because it is simply entertaining to do so, but also yields scientific data through gameplay in an attempt to solve some greater problem, giving these human-hours purpose beyond entertainment.

1.2 Mesh Segmentation and Labeling

Technically speaking, the task of segmenting and labeling 3D human body scan data can be described as follows. A 3D model is composed from a mesh, or a set of triangles that make up the surface of a model. Segmenting a mesh is performed by forming smaller groups, or sub-meshes, with their own separate identities contained within the overall mesh. For example, consider figure 1, the entire shape of the head is considered the "mesh", while the eyes, ears, and nose would be considered "sub-meshes" of the head, or overall "mesh". The segmentation problem is hard to solve because in the eyes of the computer, a 3D mesh is just a set of scattered points and isn't ordered or organized into a format that they can make sense of on their own. Therefore, complex computer algorithms or other methods, such as our own, must be used to segment and label a 3D mesh.

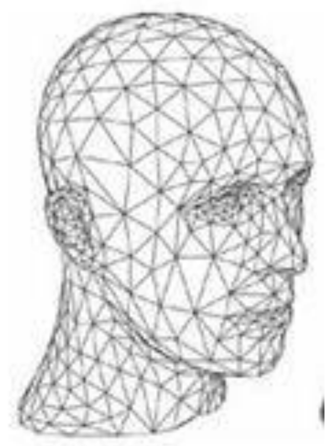

Figure 1: Example mesh of a human head (google images)

1.3 Objectives

To solve this problem and make geometry labeling and segmentation easier and less demanding, we created a multiplayer online game called "*Mosquito Popper*". The purpose of this game is to re-channel the efforts and the hours spent by game players to the collection of segmentation and labeling data through gameplay and investigate the feasibility of using the concept of GWAP as a method to perform such a task. By crowdsourcing, it is possible to yield massive amounts of segmented mesh data while at the same time accurately label the 3D human body mesh segments. The advantage this approach offers is that it will help overcoming the problem of tedious and time consuming work that previous computational approaches ran into. While playing the game, the players will effectively be providing geometry labeling and mesh segmentation data through the mechanics of the game. This makes the process of the tedious work and time spent more enjoyable and overall less laborious by utilizing the hours spent by people around the world playing games. Furthermore, by collecting this data directly from the players this way, we are using the natural 3D segmentation and image identification capability that humans already possess. Finally, we ultimately want to create a data repository full of already segmented and labeled 3D human body scan data that is easy to navigate and use for future research.

1.4 Contributions

A significant portion of this thesis was written as a submission to the international CAD '17 conference as *Mosquito Popper: A Multiplayer Online Game for 3D Body Scan Data Segmentation*.

CHAPTER 2: RELATED WORKS

2.1 Games with a Purpose

In general, the main objective of GWAP is to accomplish a certain task by re-channeling the efforts devoted by game players. In particular, GWAP is beneficial for the tasks in which humans perform significantly better than computer algorithms, such as labeling, recognition, and segmentation. One of the early works on GWAP is the ESP game [1]. Please see figure 2 for an example image of the ESP game.

Figure 2: A sample image of the ESP game [1]

In this game, the players share an image, but this is the only common information they share. The goal of the game is for the players to come up with the same name or label for the image without communicating with each other and obtain a match. This concept in which randomly paired players try to achieve the same output is called the *output-agreement* mechanism. Through this game, it is possible to reliably label images and to help solve the problem of image recognition. As demonstrated by the ESP game, data accumulated through the time spent playing games can be used in a variety of practical applications.

Other examples of GWAP are Peekaboom [3] and Phetch [2]. Peekaboom locates individual objects contained within images and produces labels for them. Please see figure 3 for an example image from Peekaboom.

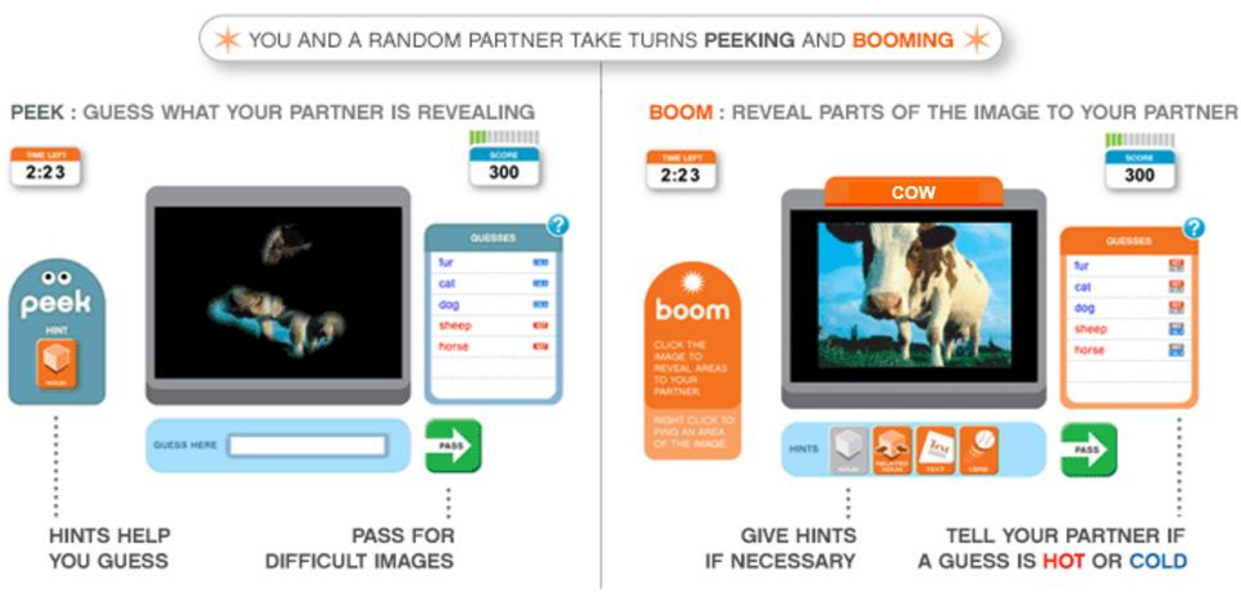

Figure 3: An example image from Peekaboom showing both player's perspectives [3]

One player reveals small pieces of a larger image to another player little by little. While the player revealing the image is trying to get the other player to guess a specific word, the smaller pieces are being labeled by the guessing player. By revealing pieces of a larger image little by little, it helps the computer identify where in the image the objects being referred to are. Furthermore, it helps determine the way in which the object of interest appears. For example, does "chair" refer to an actual chair in the image, or the text "chair"?

Another example, Phetch, annotates images with descriptive paragraphs with the intent of creating proper labels for images. Instead of relying on a web page author to create proper labels for each image on a website, the game has a player describe an image to a few other players, the seekers. Please see figure 4 for an example image of the Phetch interface.

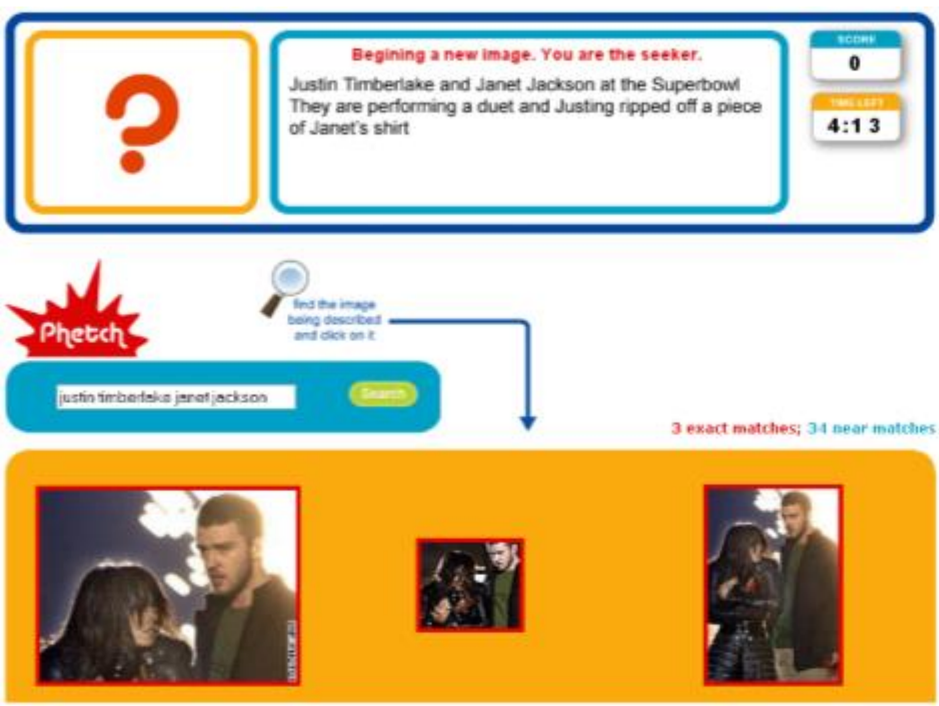

Figure 4: An example image of the Phetch interface from the seeker's perspective [2]

The seeker's jobs are to web search for an image based on the text description provided by the describing player. The description provided by the describer is valuable data and becomes the text labels for the images being described. The advantage of this method is that it allows images that may contain more than one object or label within the whole image to be labeled appropriately. For example, take an image that is half woman, half man. An image like this has two substantially different images that actually share the same ESP labels, "man" and "woman". By implementing the methodology proposed by Phetch, these images will appropriately be labeled as "half woman, half man". See figure 5 for an example of these types of images.

Figure 5: Example images with discrepancies or combinations that Phetch can overcome [2]

For more details, a comprehensive summary of previous work and games that have already been developed are contained in [12].

2.2 Mesh Segmentation and Labeling

Precise segmentation and labeling of a 3D model is one of the fundamental problems of computer-aided design. For the segmentation tasks, typically, one aims to design a computational algorithm that finds a perceptually sound partition of a geometry. For example, Liu *et al*. [13] mapped a surface geometry to the spectral domain and conducted k-means clustering to achieve the segmentation of a mesh model. Please see figure 6.

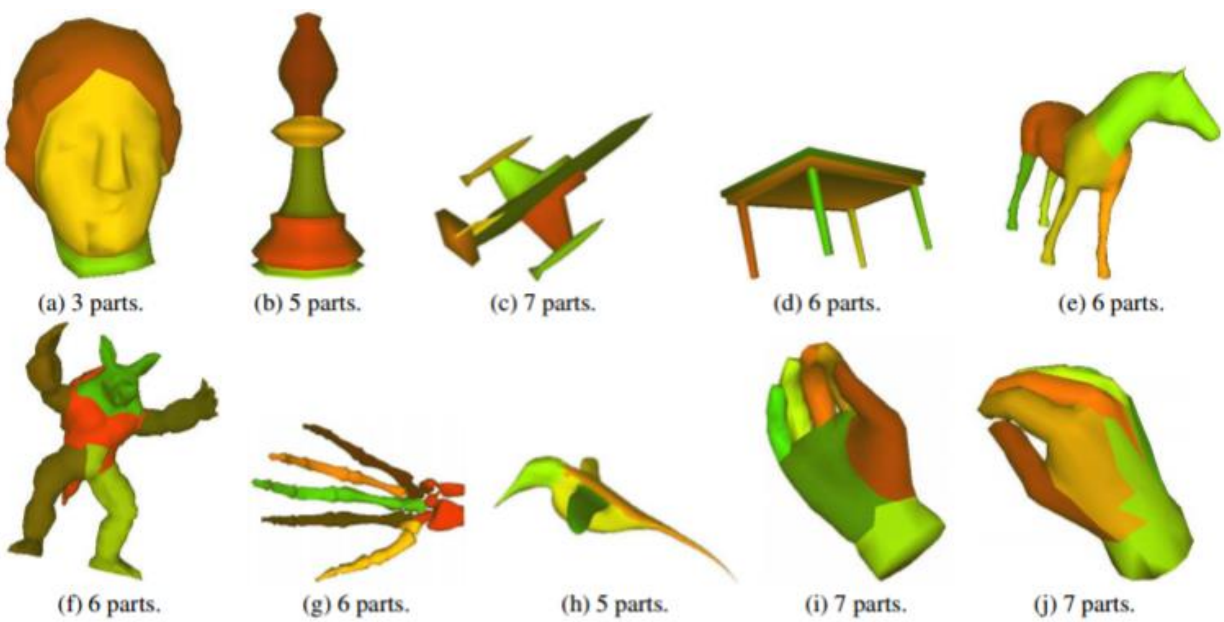

Figure 6: Results from Liu et al. showing successful segmentation using spectral clustering [13]

Kalogerakis *et al*. [9] exploited the data-driven approach for the segmentation task. They formulated the task as a supervised learning problem in which they learned the objective function assessing the consistency between faces. Please see figure 7.

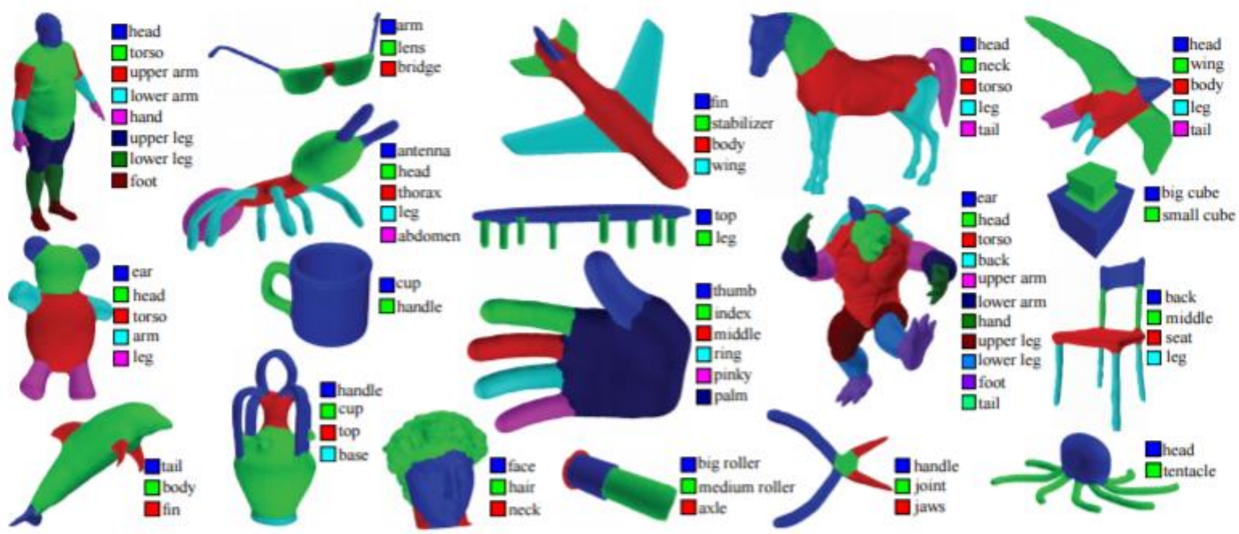

Figure 7: Results from applying the algorithm and supervised learning problem to various meshes in [9]

Glovinskiy *et al*. [7] used a graph-based formulation to achieve consistent segmentation result across an entire set of models. They constructed a graph representing the similarity between faces, not just within the same mesh, but also across different meshes, and clustered the graph to achieve a consistent segmentation of multiple models of the same class. Please see figure 8.

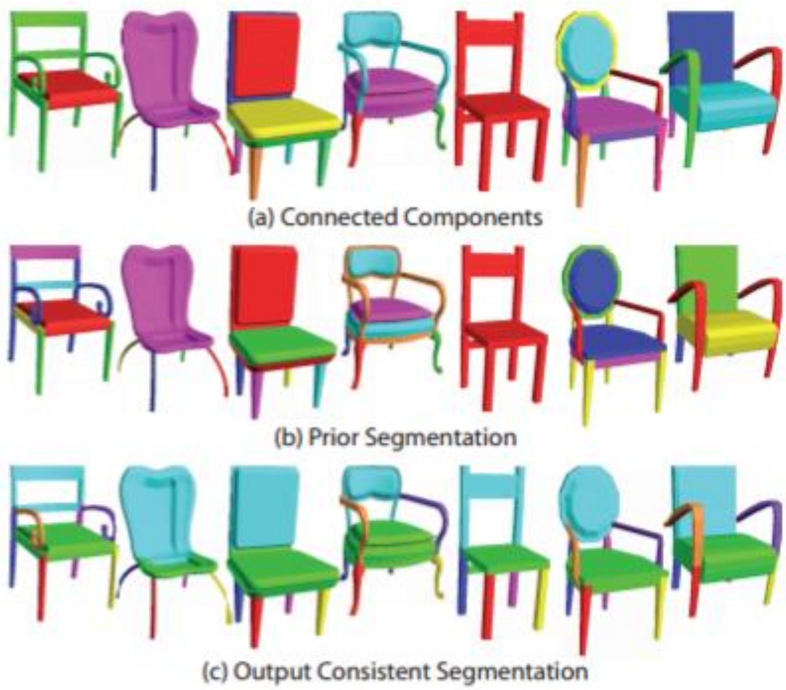

Figure 8: Showing the process of connecting similarities between mesh faces and final segmentation results of [7]

More recently, Harik *et al*. [8] defined a local shape signature based on the heat diffusion characteristics on a surface, and used the signature for assessing the likeliness of different faces belonging to the same segment. Please see figure 9.

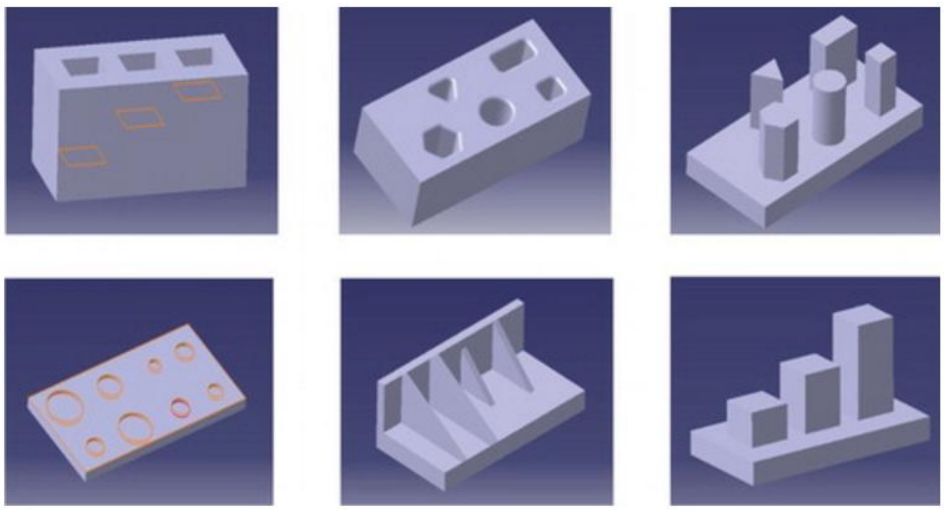

Figure 9: Results from [8] demonstrating segmentation based on heat diffusion characteristics

Just about a month ago, Baek *et al*. [5] presented a novel method for improving similarity metrics for segmentation tasks. This was performed using geodesic curvature flow, or geometric flow that minimizes arc lengths of level set contours. Please see figure 10.

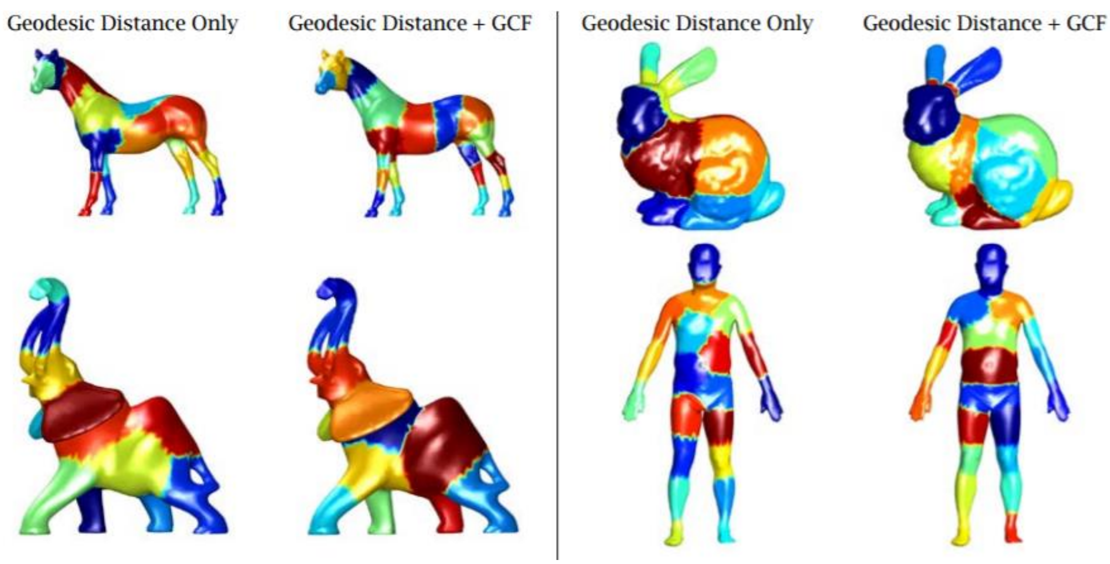

Figure 10: Results from Baek *et al.* showing successful segmentation using geodesic curve method [5]

For a more comprehensive review of a number of relevant works, see e.g., [16].

Although such computational approaches perform fairly well, they are still far behind the capability of humans. Even though a significant breakthrough has been made recently based on data-driven techniques, such as deep learning, and convolutional neural network [10], we still need an effective method for the segmentation and labeling tasks since those methods require a large volume of training examples as an input.

CHAPTER 3: GAME DESIGN AND IMPLEMENTATION

3.1 Main Objectives of the Game

As previously stated, the main objectives of this game are to re-channel the efforts and time spent by game players to the collection of segmentation and labeling data through game play and investigate the feasibility of using the concept of GWAP as a method to perform such a task. To achieve this, it was our goal to create a game that was entertaining and relatively simple, but most importantly, collected a large amount of useful data as it was played. Another objective that was important was easy accessibility to the game. For this reason, we used a web player build for the game and it is posted in several locations on the web. Through the completion of these objectives, we believe that it is possible to utilize the concept of crowdsourcing to yield massive amounts of segmented 3D human body mesh data with accurate labels for each segment.

3.2 Design of Game Play

Using the terms of [12], the game mechanism we selected was the *problem inversion function computation*, in which a player must perform a computation based on some partial input to yield a result. Our mechanism in particular works by giving one of the two players access to all of the information while the other only has some. Based on this scheme, one player is assigned as a *describer*, and the other, a *guesser* in Mosquito Popper. Initially, a randomly-selected human model from a 3D whole body scan database is loaded in as well as a mosquito model. The human model is visible to the both players, but the mosquito model is rendered only on the screen of the describer. As the game begins, the mosquito randomly picks and flies to a vertex on the mesh of the human model starts sucking blood. The goal of the both players is to locate and smash the mosquito before it gets its fill and flies away. The guesser can smash the mosquito by mouse-clicking on the skin surface, but cannot see the mosquito and thus can only *guess* its location based on the information provided by the describer. On the other hand, the describer can see the mosquito on the screen but is not allowed to smash the mosquito. Therefore, the describer must communicate its location to the guesser through the use of a simple chat system implemented in the game. The describer may use proper and indicative words they see fit to describe the particular location. The guesser must click on the human model where they think the mosquito is based on the communication from the describer, ultimately trying to click on the mosquito and pop it. The guesser can click on the model as many times as they would like in order to find the mosquito. The both players earn points only if the guesser successfully “pops” the mosquito, and a new mosquito is spawned for the next game; however, the players achieve no points when the guesser fails to pop mosquito before the blood gauge displayed on the corner fills up and the mosquito flies away to a different location to start sucking blood again. Since the players share the common objective, they have a good motivation to cooperate well together. This stream of events continues until the main game clock runs out. Screenshots of gameplay can be seen in figures 11, 12 and 13. In figure 11, a visual depiction of the game flow can seen to illustrate the progression of the game. In figure 12, the 3D human model is the white humanoid figure in the center of the image, the chat box is in the lower left corner of the image with the yellow text, the blood gauge and game timer are in the top right corner of the image. The rest of the scene, such as the checkerboard patterns, window art, and counters, is entirely cosmetic and is intended to provide a more fun, immersive experience for the players.

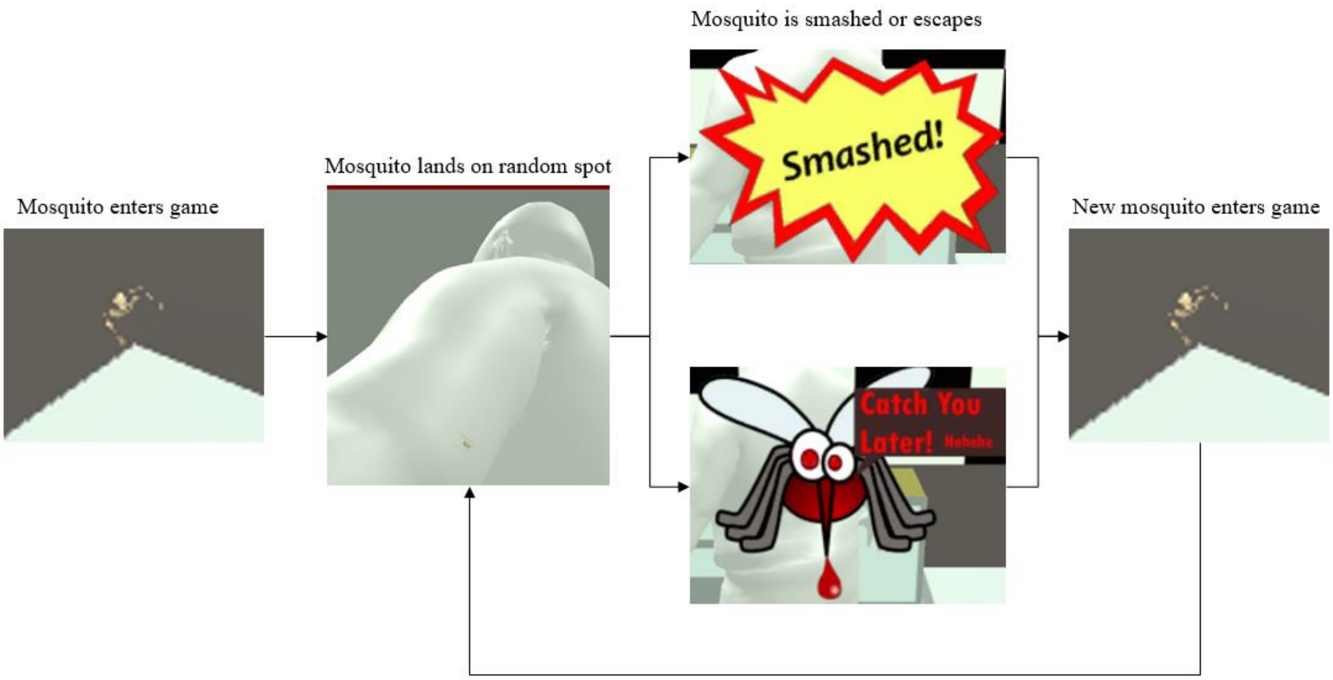

Figure 11: A visual depiction of game flow, this cycle continues until the game timer runs out

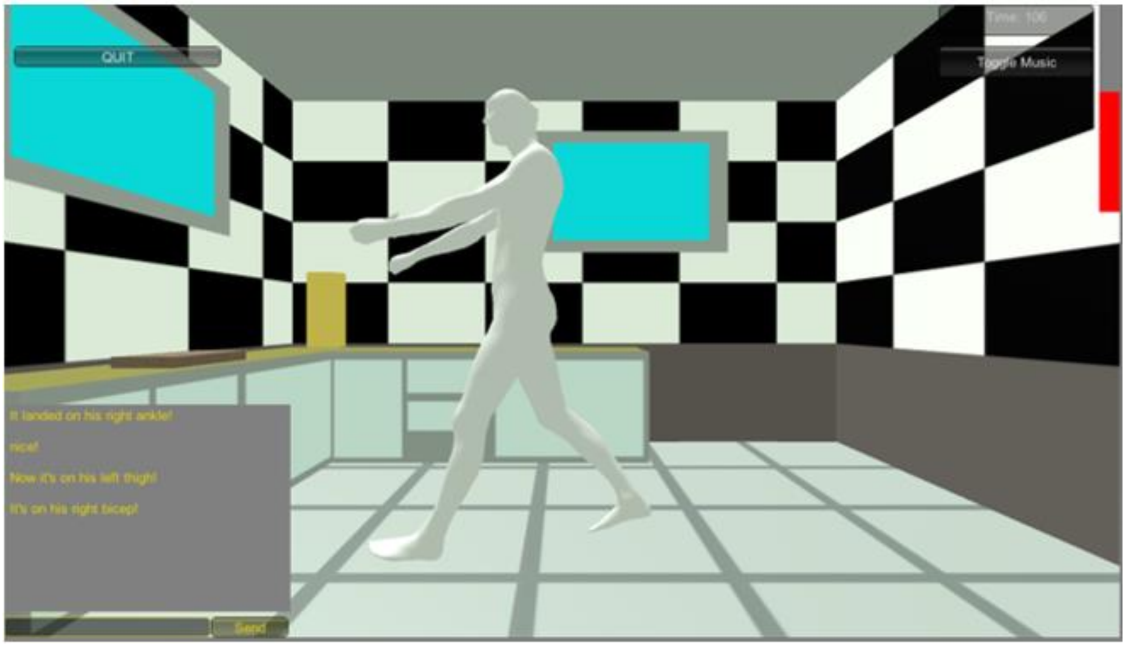

Figure 12: A screenshot of Mosquito Popper from the guesser's perspective.

Figure 13: A screenshot of Mosquito Popper from the describer's perspective

3.3 Implementation

3.3.1 Unity 3D

In our work, a multiplayer game named *Mosquito Popper* was developed using the Unity 3D software engine, version 5.3.5f1 [17]. As none of the authors had any prior experience using the Unity 3D software, a significant amount of time was spent on learning the system, toolkits, and language.

In general, the steps of implementation were as follows. The first step in implementing the game was to design the environment that it would take place in. This included developing the artwork and the digital structures within the game to give the environment life. We used photoshop and free images from the internet to accomplish this. The next step was loading in the assets necessary for our game, such as the human 3D model, the mosquito 3D model, and chat functionality. The 3D human models were supplied from previous research works and the 3D mosquito model was obtained from a free 3D model website. After this was complete, a significant portion of time was spent on having everything in the scene to interact correctly and be networked with one another as well as with the players within the game. This involved assigning each individual piece in the scene with components such as network identities, network transforms, and scripts that successfully communicated with the other objects in the scene. Next, post-processing and data collection code was implemented along with a separate, self-hosted online server to receive the data once it was sent. Finally, game features, menus and other user interface objects were added as final touches to the game, please see figure 14. *Mosquito Popper* was then built in a web player format that is supported by the Unity 3D software and posted online on our website, www.mosquitopopper.com, as well as other various locations on the web.

Figure 14: A screenshot of Mosquito Popper's main menu

3.3.2 Website and Server

As previously stated, to implement our game in a format that the public could have access to and play we developed a website in html, www.mosquitopopper.com. This website contains information about the developers, a survey for the player base to fill out, a short description about our research, but most importantly, the website houses our game.

To collect data, a server was established to function as a data repository that the game could send its information logs to. The server that collected the data was hosted on a raspberry pi. Python was used to create the actual web server that runs on the pi board. To achieve successful connections, we first needed to allow the web to reach the raspberry pi. This required that the IP address of the pi board to always be known. Therefore, a port was opened on the router and a 3rd party service called *NoIp* was used to keep track of the pi's current IP address. Since the raspberry pi was hosted on a personal internet connection and connected to a router it was typically not able to get requests without first making a connection to the web. This was due to a few reasons.

First, an internet subscriber is usually allocated 1 dynamic IP address. To allow more then one device to use that IP address, a router uses a NAT table to convert each request from inside the subscriber's network to one overall request that uses the current IP address. Second, it is to protect users from malicious attacks from the web. To get around the issue of the strict NAT, port forwarding was implemented. Port forwarding is simply telling the router that if it gets a request on a certain port to let that request go through. That allowed the pi to get requests from the outside without the pi making the initial connection.

Second, we needed to solve the issue of a static IP address. The issue here is that without notice, an internet service provider can change the router's IP address, this presents a huge problem for our server. Without being able to always know our exact IP address it can break our connection at any moment. To solve this, a service called NoIp.com was used. This service gives an IP address that will be static. To achieve this, *NoIp* has software that was installed on the pi. When the internet service provider updates the IP address of the router, the software detects that change and sends that information back to Noip and they record this change. In essence, *NoIp* is a DNS server that converts the static *NoIp* address a user has to the current IP address of whatever network the software is running on.

Finally, when a connection is received it is parsed and validated. After validation occurs the data is saved to a folder the is labeled with the current date. A Cron job was setup on the pi to run every hour. A Cron job is just code that is run on schedule. For example, a Cron job can be setup to run every 1 min and have it upload a tweet of a picture of a cat. This technique was used to run a script, wrote in python, that would look for new data. If new data was detected then that data would be uploaded to a drop-box so that we could access our data from anywhere. If no new data was detected, nothing would happen. The drop-box script was from Drop-Box Uploader. Please see figure 15 for a visual depiction of information flow.

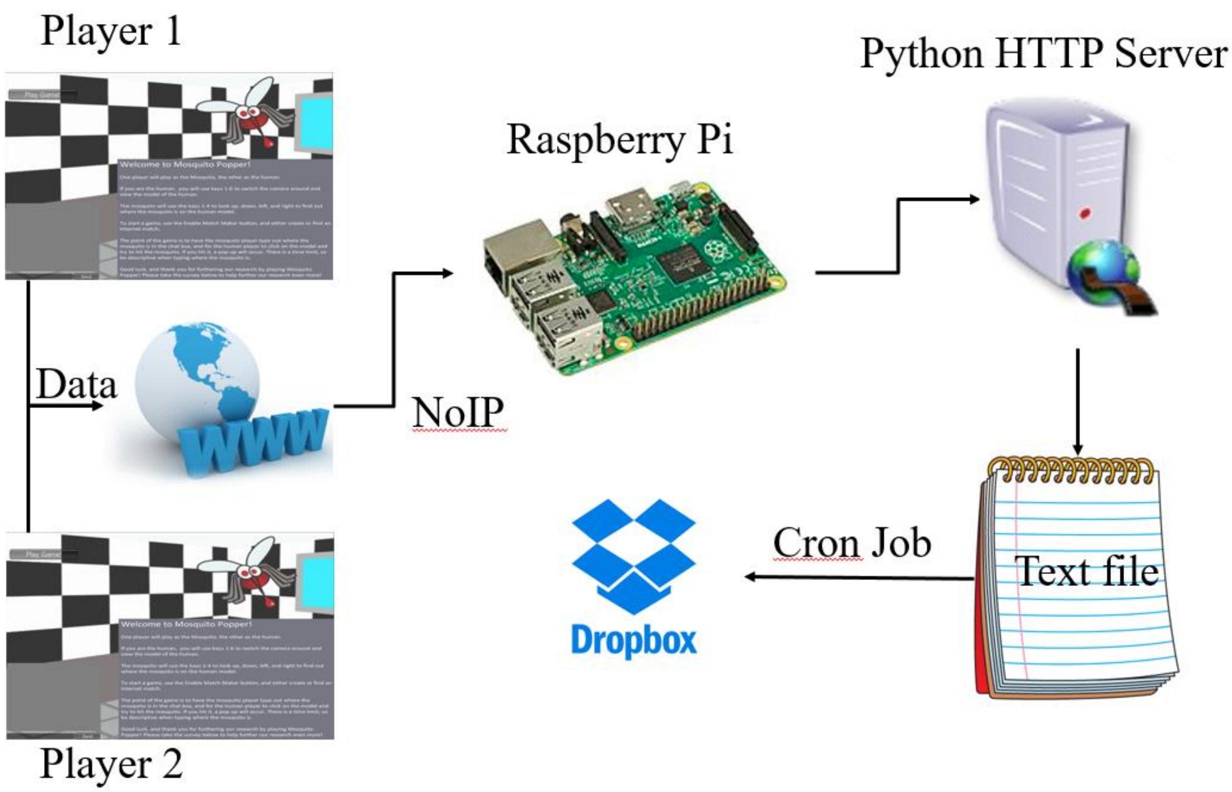

Figure 15: A visual depiction of information flow from the game to our data repository

CHAPTER 4: MESH SEGMENTATION AND LABELING

4.1 Problem Statement

As previously stated, accurate segmentation and labeling of 3D human body scan data is extremely expensive as it requires a lot of tedious, time-consuming hand labor. Despite the computational methods available for automatically performing this task, computers are far less reliable than the human capability in terms of accuracy, level of detail, and robustness. The main idea of our experiment is to observe if it is possible to use an online game and outsource the labor to the public. By framing the task as a game, it becomes an object of entertainment, rather than work. Also, at the same time, we are harnessing the natural capabilities of the human image processing systems to identify and label various parts of the 3D human body shape rather than rely on computational algorithms to perform the task automatically.

4.2 Methods

4.2.1 Model Acquisition

For this experiment, the 3D human model we used was acquired from Dr. Stephen Baek's 3D body scan data repository. No modifications were performed on the model.

4.2.2 Data Collection

In the background, during gameplay, the game log data is extracted and collected. The information extracted from the game play is (a) the xyz coordinates of the points clicked by the guesser and (b) the chat elements provided by the describer. As the game is played, these data are added to arrays in real-time at the client computer. Once the game is completed, a word parsing algorithm is then run to extract the useful pieces of information out of the chat message log. This is performed by taking each element within the chat message array and comparing it to a *dictionary* of words pre-defined. This dictionary contains the words of interest, including adjectives/prefixes such as “fore-,” “right,” and “upper”, and the names of the body parts such as “leg,” “pelvis,” and “arm.” Therefore, if the describer communicated, “It’s on the right upper arm!” the output from the algorithm would be, “right upper arm”, eliminating the unnecessary and less useful pieces of information. The dictionary was created to include the vast majority of words that could be used to describe the human body, its function being something to compare the describer’s input to, therefore allowing the users to communicate however they wished with no restrictions. The xyz coordinate values and the corresponding chat words are then sent to an online server. The stream of information is then processed on the server-side and stored to a database. The results presented in this paper are, hence, created from the data collected on the server. A visual depiction of the data collection process can be seen in figure 16.

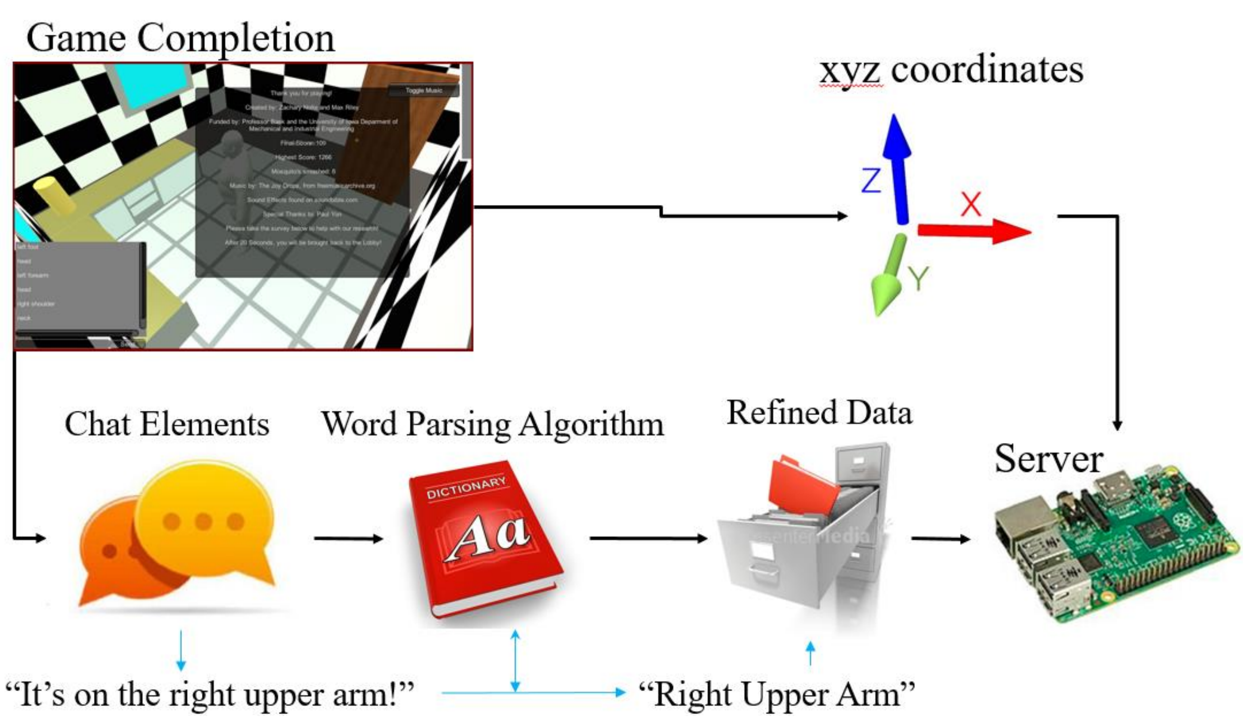

Figure 16: A visual depiction of the data collection process before data is sent to the server

4.2.3 Segmentation and Labeling

The segmentation and labeling of the mesh occurs naturally through the gameplay of Mosquito Popper; the segmentation aspect takes place as the guesser is clicking on the mesh of the 3D human model and, the labeling aspect takes place as the describer is communicating the location of the mosquito. The data is only saved and paired together if the players successfully pop the mosquito by working together. Please see figure 17 for a visual representation of this process.

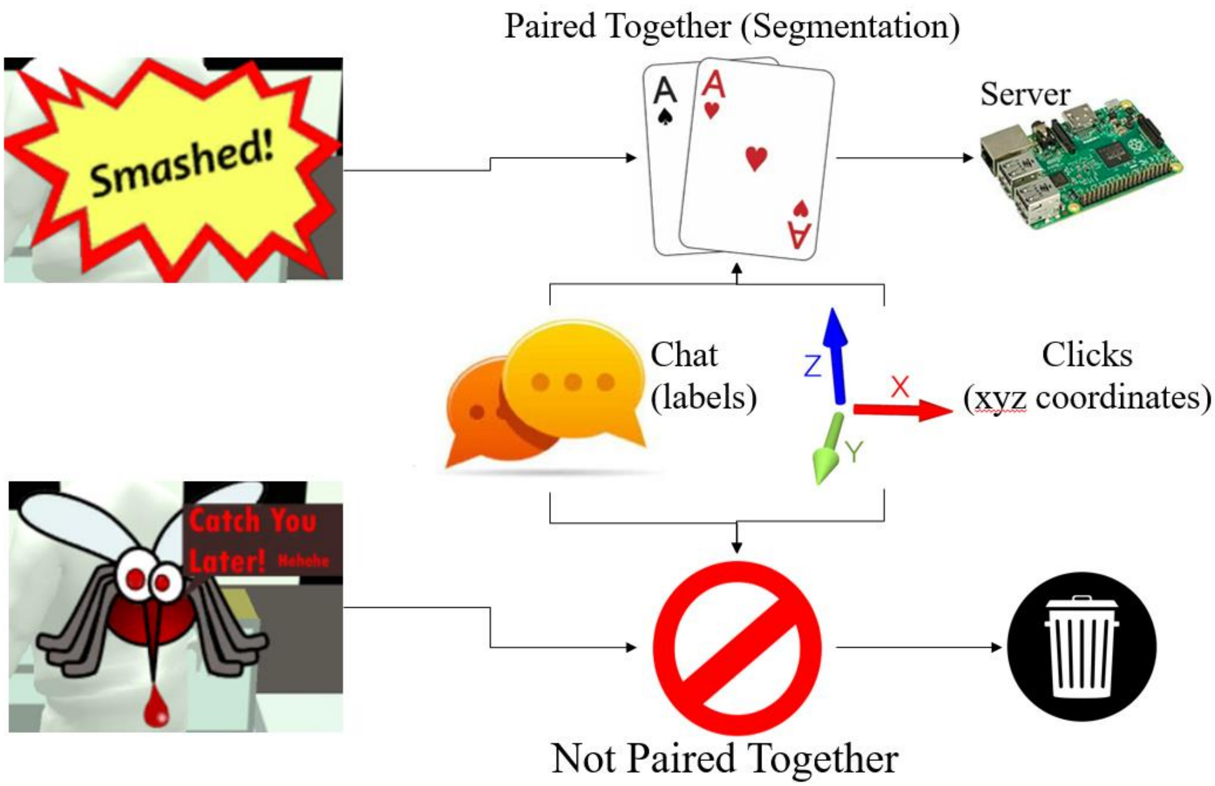

Figure 17: A flowchart of the general process is shown. If players are successful, data is saved. If players are not successful, this bad data becomes waste.

Computationally, each of the faces in the 3D mesh has bins for counting frequencies of vocabularies being mentioned by the describer, and the bins are updated according to the click history of the guesser. The similarity between the faces are calculated based on the bin counts in a similar sense to the well-known *bag of words* technique. Based on this metric, similar facets are clustered together to form a *segment*, and the bins are merged to determine the semantic label of the segment.

4.3 Experimental Design

Our experiments for the gameplay of Mosquito Popper included multiple trials using a single human 3D model. The trials were all conducted using the same group of 4 subjects. The only information the participants were given was the objective of the game. Each participant was urged to do their best to work with their partners to accomplish the task. Each pair of subjects played Mosquito Popper for an hour or two per trial, there were 6 trials performed by each pair. Based on the initial data we collected, some adjustments to the game were made. For example, we included more potential labels and added additional filtering to remove unwanted text from labels to increase utility and usability.

Another experiment was conducted using the same human 3D model. The purpose of this experiment was to have subjects segment a 3D human model by "painting" it with different colors. The results of this experiment are used as some grounds of comparison for Mosquito Popper as well as other computational methods. In this manual segmentation experiment, the trials were conducted using a different set of 4 subjects than the Mosquito Popper experiment. The only information the participants were given was that they needed to divide the human body up into different parts that made sense to them. Each participant was urged to follow their intuition and be as detailed as they wanted to be. The data that was collected from this experiment was made into figures and used to evaluate intuitiveness.

4.4 Results and Discussion

4.4.1 Mosquito Popper Experiment

Results of our experiment are displayed in figure 18. Each of the dots annotates a clicked point on the surface by the smasher and the different colors represent different labels. Despite of the small number of trials during the experiment, the result still shows a promising outcome in terms of the accuracy and the level of details. One interesting result observed in figure 18 is the accurate, complete segmentation of the knee and elbow areas on the 3D human model. This is of notable importance because these areas on the body have minimal geometric landmarks that distinguish them from the overall structure of the leg and arm respectively. For this reason, the current computational algorithm approaches to this task have significant problems segmenting these portions of the 3D human body shape. Furthermore, we published our game on a website www.mosquitopopper.com, as well as other locations online and are collecting large amounts of data from this online game. The results displayed in this work include the data obtained through the implementation of this website and are not necessarily restricted to only the results of our experiment. We expect to achieve high quality segmentation results for the human models in our database as we accumulate more hours of game play.

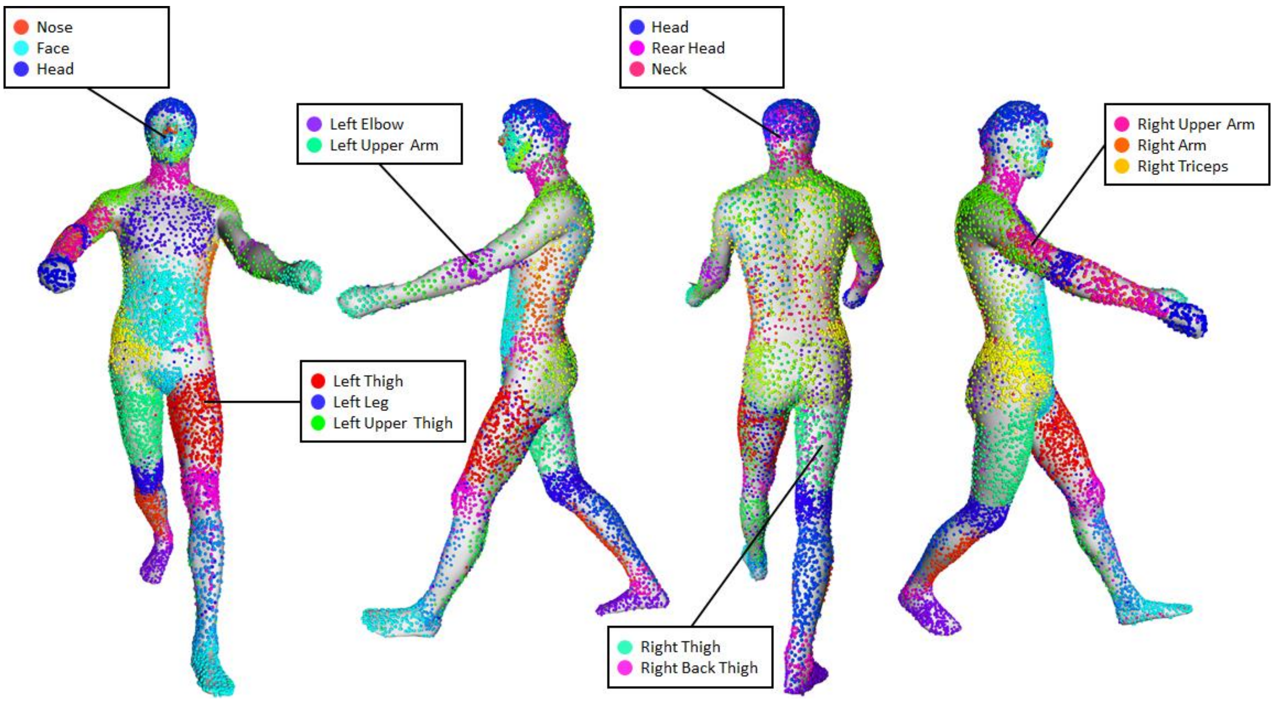

Figure 18: Segmentation and labeling result from the experiment. Each of the dots on the human model represents a point of click by the guessing player, and the color denotes the label. Several examples of labeling per facet is also given in the text box.

4.4.2 Manual Segmentation Experiment

Results from our experiment are shown in figures 19, 20, 21, and 22. Each location on the 3D human model with a different color than its neighbor represents a different segment. The results of this experiment are an indication of how humans intuitively segment human body shape based on perception. One interesting thing to note here is that despite the fact each participant of the experiment was given the same exact 3D model, the results of the segmentation performed are drastically different in level of detail between the subjects. For example, comparing Subject C to Subject D in figures 21 and 22, Subject C's segmentation is far more detailed than that of Subject D. As previously stated, the purpose of this experiment was conducted to achieve a grounds of comparison to evaluate intuitiveness and specificity of natural human perception against Mosquito Popper and other computational methods.

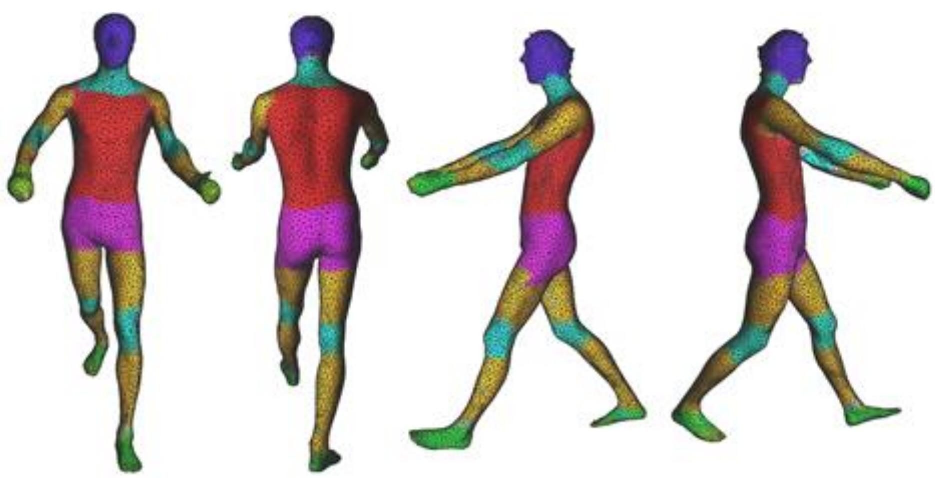

Figure 19: Subject A experiment results

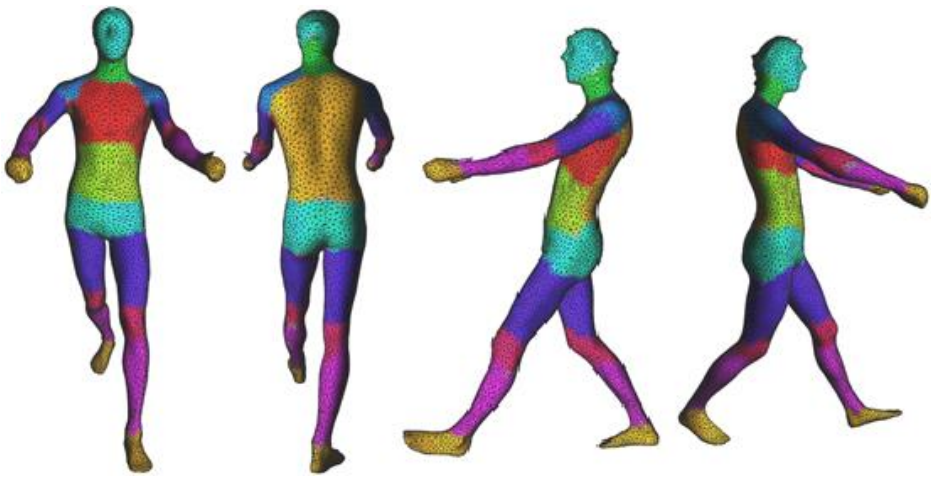

Figure 20: Subject B experiment results

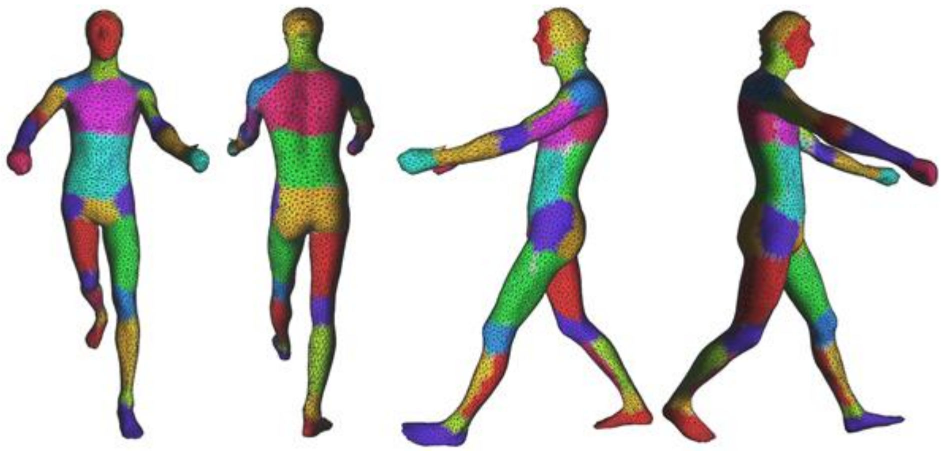

Figure 21: Subject C experiment results

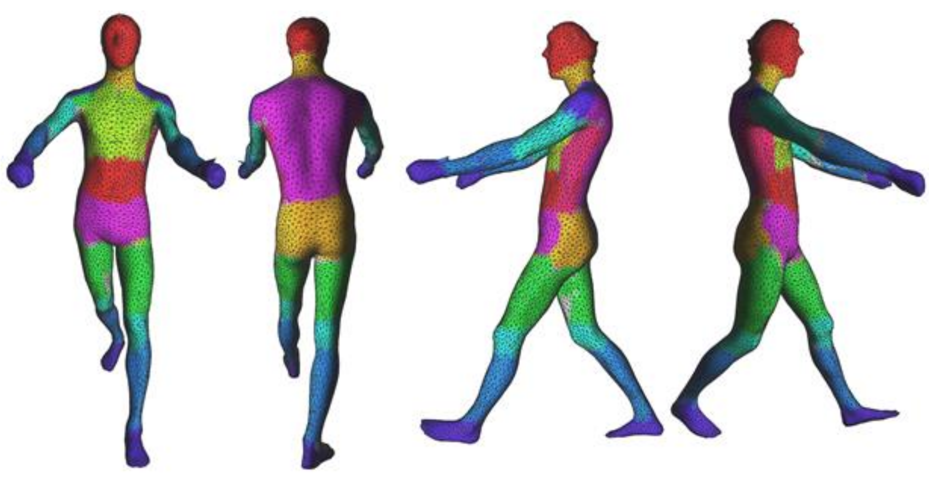

Figure 22: Subject D experiment results

4.4.3 Analysis

The analysis of this thesis will be evaluating both the intuitiveness and specificity of the results produced by Mosquito Popper. These values will be compared with and against both computational methods performed by other related works, as well as the manual segmentation experiments performed for this research. The computational methods used for comparison are the papers written by Kalogerakis *et al*. [9], and Baek *et al.* [5]

The value of specificity is evaluated by simply counting the number of unique, perceptually observed segments that a given method produces for a 3D human model. Please see table 1 for the comparison between Mosquito popper, the manually labeled experiments, and the computational methods.

Table 1: Specificity comparison between Mosquito Popper, computational methods, and manual segmentation experiment results

	Mosquito Popper	**Kalogerakis *et al. [9]***	**Baek *et al. [5]***	**Manual Subj. A**	**Manual Subj. B**	**Manual Subj. C**	**Manual Subj. D**
Specificity (Segments)	40	14	20	20	23	34	23

It is clear from the results displayed in table 1 that Mosquito Popper is more specific than the other evaluated works using this method of evaluation. However, one interesting thing to note is that the number of segments produced by the computational methods are on average more similar to that of the manual segmentation experiments (intuitive human-performed segmentation) than Mosquito Popper is. This is most likely due to the fact that Mosquito Popper is a culmination of communication based on human perception collected over time while the computational methods are based on training sets and algorithms. This culmination allows for

Mosquito Popper to collect many different labels, some of which may even belong to the same segment of the 3D human body shape. For example, if evaluating based on raw output, Mosquito Popper actually produces 79 unique segments. However, it is not possible to actually observe 79 segments based on the graphical output of Mosquito Popper.

The value of intuitiveness is evaluated by comparing a given method against the results of the manual segmentation method performed for this research. To achieve a value for intuitiveness, a scoring system is used. For a given method to obtain a point, it must contain an equal or higher resolution for a given segment than any one of the manually segmented experiments (our measure of intuitive human-performed segmentation). Therefore, each method can earn up to a maximum of 4 possible points for each of its segments. Please see figure 23 for a histogram showing the distribution of points for Mosquito Popper, Kalogerakis *et al.* [9], and Baek *et al.* [5].

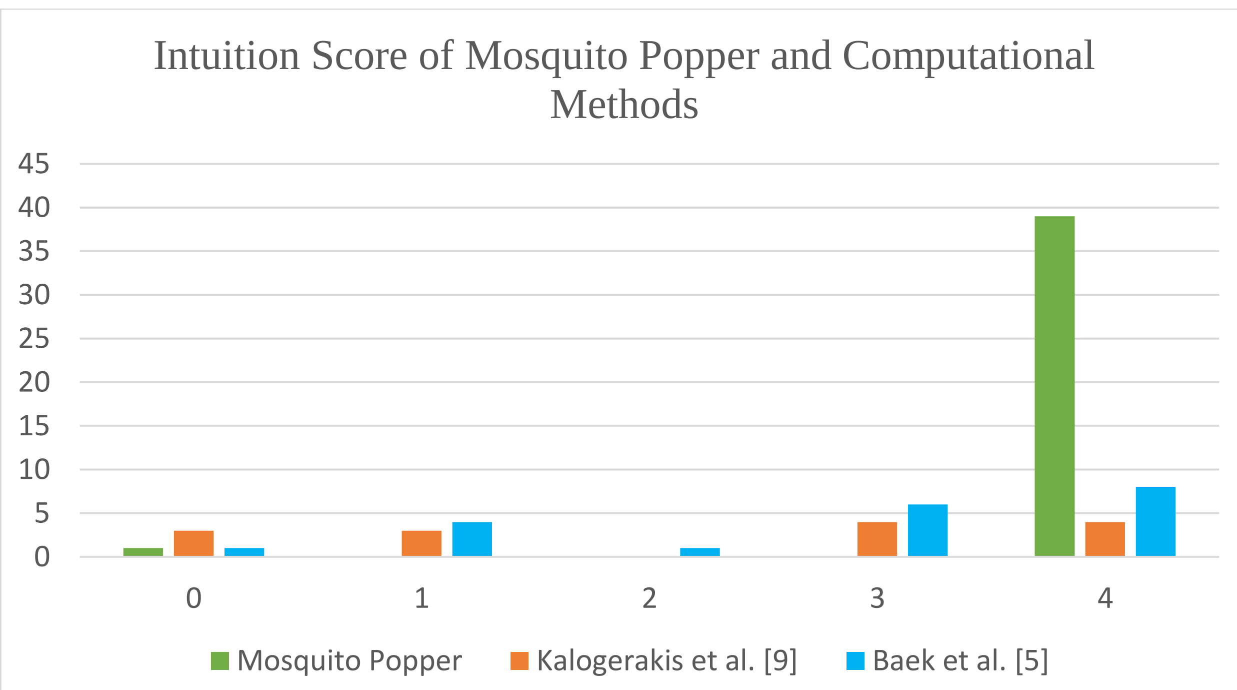

Figure 23: Histogram displaying the intuition scores of Mosquito Popper and the chosen computational methods

Table 2: Table displaying the percentage of points to total segments earned by each method

	% 0's	% 1's	% 2's	% 3's	% 4's
Mosquito Popper	2.5	0	0	0	97.5
Kalogerakis *et al.*	21.4	21.4	0	28.6	28.6
Baek *et al.*	5	20	5	30	40

It is clear from the results shown in figure 23 and table 2 that Mosquito Popper is more intuitive than the other evaluated works using this method of evaluation. Table 2 was created with the purpose of keeping the evaluation fair between methods as each method does not have the same number of segments. However, by using a percentage based method of comparison, it is possible to negate the difference in specificity an evaluate only intuition. Although creating a percentage based comparison helps to create an even grounds for comparison, it is worthy to note that it is more likely for a method to score higher for intuition if it has a higher number of segments. For this reason, it is possible that Mosquito Popper scored higher in intuition due to its increased number of segments. However, this does not discredit the evaluation as humans have a naturally detailed perception of the human body shape. In other words, humans intuitively perceive the human body in many segments, therefore a method should score higher for intuitiveness with the more segments it can produce.

4.5 Data Repository and Future Research

As more and more data is collected, it becomes imperative that there is a way to effectively store, navigate, and analyze this data for future research. To address this, a program was written in python that allows a user to query data from the data repository created by Mosquito Popper. This program works by reading in user defined keywords and returning all the related pieces of data, such as the mesh faces and xyz coordinates, that contain the keyword as one of its labels. This program will allow future researchers to make use of the data generated by Mosquito Popper and hopefully yield some interesting and useful insights.

4.6 Summary

In this experimental study, we proposed a method of segmenting and labeling human body scan data with an online game. In the background, during gameplay, game log data is extracted and collected. The information extracted from the game play is (a) the xyz coordinates of the points clicked by the guessing player and (b) the chat elements provided by the describing player. The segmentation and labeling of the mesh occurs naturally through the gameplay of Mosquito Popper; the segmentation aspect takes place as the guesser is clicking on the mesh of the 3D human model and, the labeling aspect takes place as the describer is communicating the location of the mosquito. Our experiments included multiple trials using a single human 3D model. The trials were all conducted using the same group of four subjects. Each pair of subjects performed six trials, each trial lasted between one and two hours. Our experiment and analysis showed that the proposed game play mechanism was effective for such a task, despite of a small number of hours of game play during the experiment.

CHAPTER 5: CONCLUSION

To reiterate, the objectives of this research were to re-channel the efforts and the hours spent by game players to the collection of segmentation and labeling data through gameplay and investigate the feasibility of using the concept of GWAP as a method to perform such a task.

The hopes in the beginning of this project were to utilize crowdsourcing to collect a mass amount of data. However, utilizing crowdsourcing was unsuccessful. Unfortunately, there were not a significant number of players that played the game through our website as there was originally hoped to be. We believe this to be a result of the difficulty associated with the successful advertisement of a product and perhaps related to the overall rudimentary polish of the game. Although crowdsourcing was unsuccessful, the results from our conducted experiment were actually quite detailed and complete, despite the smaller number of hours of gameplay. From these results, it is reasonable to assume that should crowdsourcing be successfully implemented for a task such as the one presented in this research, the results would be incredibly saturated and rich.

Finally, our results indicate that implementing the concept of GWAP for the task of mesh segmentation and labeling is in fact a feasible method for the completion of such a task. Furthermore, our results indicate that using the concept of GWAP and utilizing the natural 3D segmentation and image identification capability of humans for this task may actually outperform related computational methods that strive to achieve the same results.

This research will be continued with the goal of creating a more finely polished product in hopes to one day successfully utilize crowdsourcing as a method to obtain massive amounts of mesh segmentation and label data.

REFERENCES

[1] Ahn, L.; Dabbish, L.: Labeling images with a computer game, Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI'04), 2004, 319-326. https://doi.org/10.1145/985692.985733.

[2] Ahn, L.; Ginosar, S.; Kedia, M.; Liu, R.; Blum, M.: Improving accessibility of the web with a computer game, Proceedings of the SIGGCHI Conference on Human Factors in Computing Systems (CHI'06), 2006, 79-82. https://doi.org/10.1145/1124772.1124785.

[3] Ahn, L.; Liu, R.; Blum, M.: Peekaboom: a game for locating objects in images, Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI'06), 2006, 56-64. https://doi.org/10.1145/1124772.1124782.

[4] Baek, S.; Lee, K.: Parametric human body shape modeling framework for human-centered product design, Computer-Aided Design, 44(1), 2012, 56-67. https://doi.org/10.1016/j.cad.2010.12.006.

[5] Baek, S., Sun, Z., & Harik, R. (2017). Mesh Segmentation via Geodesic Curvature Flow. In Proceedings of International Conference on Computer-Aided Design (CAD'17). To appear.

[6] Bălan, A.; Sigal, L.; Black, M.; Davis, J.; Haussecker, H.: Detailed human shape and pose from images, IEEE Conference on Computer Vision and Pattern Recognition (CVPR), 2007, 1-8. https://doi.org/10.1109/CVPR.2007.383340.

[7] Golovinskiy A.; Funkhouser, T.: Consistent segmentation of 3D models, Computers and Graphics, 33(3), 2009, 262-269. https://doi.org/10.1016/j.cag.2009.03.010.

[8] Harik, R.; Shi, Y.; Baek, S.: Shape Terra: mechanical feature recognition based on a persistent heat signature, Computer-Aided Design & Applications, 14(2), 2017, 206-218. https://doi.org/10.1080/16864360.2016.1223433.

[9] Kalogerakis, E.; Hertzmann, A.; Singh, K.: Learning 3D mesh segmentation and labeling, ACM Trans. Graphics, 29(4), 2010, Article No. 102. https://doi.org/10.1145/1778765.1778839.

[10] Krizhevsky, A.; Sutskever, I.; Hinton, G.E.: ImageNet classification with deep convolutional neural networks, Proceedings of Advances in Neural Information Processing Systems, 2012.

[11] Kyu, C.: Implementation and Analysis of Size Korea Projects Using 3D Body Scanning Systems, Proceedings from the 3rd International Conference on 3D Body Scanning Technologies, 257-260 2012. https://doi.org/10.15221/12.257

[12] Law, E.; Ahn, L.: Synthesis Lectures on Artificial Intelligence & Machine Learning: Human Computation. Morgan & Claypool Publishers, San Rafael, CA, 2011.

[13] Liu, R.; Zhang, H.: Segmentation of 3D meshes through spectral clustering, Proceedings of the 12th Pacific Conference on Computer Graphics and Applications (PG'04), 2004, 290-305. https://doi.org/10.1109/PCCGA.2004.1348360.

[14] Reed, M.; Hu, J.: Rupp, J.: Statistical analysis of body shapes for parametric human body modeling, In Proceedings of the IRCOBI Conference on Impact Biomechanics Modelling, 2013.

[15] Robinette, K.; Daanen, H.; Paquet, E.: The CEASAR project: a 3-D surface anthropometry survey, Proceedings from the second international conference on 3-D Digital Imaging and Modeling, 1999. https://doi.org/10.1109/IM.1999.805368

[16] Theologou, P.; Pratikakis, I.; Theoharis, T.: A comprehensive overview of methodologies and performance evaluation frameworks in 3D mesh segmentation, Computer Vision and Image Understanding, 135, 2015, 49-82. https://doi:10.1016/j.cviu.2014.12.008.

[17] Unity 3D, https://unity3d.com/, Unity Software.

[18] Wang, C.: Parameterization and parametric design of mannequins, Computer-Aided Design, 37(1), 2005, 83-98. https://doi.org/10.1016/j.cad.2004.05.001.