Project PAALM: Phalangeal Angle Approximation through the Leap Motion Controller

Michael L. Rivera
mrivera.lee@gmail.com
University of Pennsylvania

Dr. Norman I. Badler
badler@seas.upenn.edu
University of Pennsylvania

Aline Normoyle
alinen@seas.upenn.edu
University of Pennsylvania

ABSTRACT

A significant problem in computer graphics has been the realistic animation of the human hand. The dexterity and flexibility of the hand make it difficult to accurately capture information about complex gestures. Current approaches are expensive, restrict movement of the hand, confine the user to a capture region, or cannot capture hand motion data in real time.

We propose an accurate and inexpensive method for approximating phalangeal joint angles of the hand using the Leap Motion Controller. Our method provides an application programming interface for the approximation and visualization of the phalangeal joint angle data for use with the Leap Motion Controller.

Project Blog: http://projectpaalm.mikeriv.com/

1. INTRODUCTION

Our hands are very dexterous and versatile. They are the principal mechanism we use to interface with the physical world. In computer graphics, the realistic animation of the human hand has been a fundamental problem [ZCX12]. Detailed and subtle finger motions and hand movements help bring characters to life but are often difficult to capture. A great deal of research has been devoted to better describing the hand and its complexities. Imaged-based, glove-based, and marker-based techniques have been developed to obtain descriptive data regarding hands movements and gestures. These methods, however, are expensive, restrict the motion of the hand, confine the user to a space, or cannot be accomplished in real time.

We propose an effective method for approximating phalangeal joint angles of the hand that is portable, unrestrictive and cost-effective. Our approach utilizes a new and unexplored technology called the Leap Motion Controller that is roughly the size of a flash drive and tracks individual finger movements to $1/100^{th}$ of a millimeter [LEA]. Our approach implements an application programming interface for approximating and visualizing the phalangeal joint angles of the hand.

Contributions.

Our main contributions are as follows:

- An accurate, portable, cost-effective, and freehand method of obtaining phalangeal joint angles using an unexplored technology.
- An application programming interface (API) for obtaining and visualizing the phalangeal joint angle data using the Leap Motion Controller.

1.1 Design Goals

The target audience of this project is the computer graphics and animation industry. We aim to provide an effective approach to approximating phalangeal joint angles of the hand. Our approach differs from current offerings because it is unrestrictive, requiring no sensors to be attached to the hand, and is inexpensive. While our main focus is in the computer graphics and animation industry, we do not discount the applicability of our approach to additional fields. The detection of phalangeal joint angles is useful in many other fields such as Human Computer Interaction (HCI) for the development of Natural User Interfaces (NUI), and robotics for the simulation of human gestures through mechanical means.

1.2 Proposed Features and Functionality

Our method will achieve the following functionality:

- Approximate phalangeal joint angles using the Leap Motion Controller.
- Visualize the approximated phalangeal joint angle data.

2. RELATED WORK

The problem of hand motion recognition is ubiquitous making it a considerable research focus for many fields like computer graphics. A number of systems have been developed to detect and obtain descriptive data about hand gestures.

2.1 Marker-based Systems

Marker-based motion capture systems are a popular means of obtaining hand motion data. The standard approach requires attaching approximately 30 retro-reflective markers to the hand and tracking them over time [VIC]. The temporal data is then used to reconstruct a 3D representation of the hand and its motions.

Recent advancements in hand motion capture have made it possible to achieve descriptive hand motion data with a reduction in the number of markers [HRM*12]. Though even with such advancements, marker-based approaches still pose significant problems in hand motion detection. Gestures featuring self-occlusion (fingers overlapping one another) are difficult to detect using the system. Automatic marker tracking is not effective in maintaining the markers over time. Thus, the process of tracking markers is then a tedious one, requiring manual labeling that is both time-consuming and error prone [ZCX12].

2.2 Glove-based Systems

Glove-based systems such as the CyberGlove [CYB] provide a useful method of obtaining hand gesture data that is free from issues that arise when fingers occlude each other. The motions recorded using the system, however, are often noisy and fail to capture delicate articulations with high precision [ZCX12]. Likewise, the system restricts the natural motion of the hand, making capturing realistic gestures a more complex task. The advantage of using the Leap Motion Controller for our approach is that it permits the hand to move freely and naturally.

2.3 Image-based Systems

Computer vision has offered a promising alternative to data gloves and other worn mechanisms for detecting hand motions [EBN*07]. Image-based systems have allowed for some natural hand movements to be detected and offer a less expensive approach to marker-based systems. Typically, the process analyzes a series of image frames to reconstruct the gesture of a hand and project it to a hand model through inverse kinematics.

A recent device called *Digits* has been developed that uses a wrist-worn gloveless sensor to detect 3D hand gestures [KHI*12]. The sensor features two infrared illumination schemes that are used to produce a hand model through inverse kinematics. The wrist-worn device avoids the need for any embedded sensors in the environment and permits the hand to move freely as well as the user to move about without being confined to a capturing region.

Computer vision techniques do have limitations in obtaining hand motion data. The process is computationally intensive. Systems using inverse kinematics for the fingers and the rotation of the palm are solved by numerical iteration [LK93]. Better results are obtained by running numerous iterations. Some processes also pose limitations by only providing support for a small range of hand actions under restrictive conditions. Thus real time detection can only be accomplished if there already exists a vocabulary of recognized gestures. Additionally, computer vision techniques do not fair well under conditions that create self-occlusion, namely fingers overlapping or blocking the view of each other with respect to the camera.

2.4 Joint Systems

A recent innovation has been combining marker-based and image-based systems to provide higher fidelity hand motion data [ZCX12]. These systems are capable of accurately detecting hand motions even in cases of self-occlusion. The markers are used as reference when rebuilding hand motion data using an RGB-depth camera such as the Microsoft Kinect. These systems are robust and do not significantly restrict hand movements as the markers are small. The shortcoming of this system is that it currently cannot produce results in real time and requires a user to be confined to a particular space.

2.5 The Leap Motion Controller

The Leap Motion Controller offers a cost-effective, fast and precise means of capturing live hand motion data. In addition, the small size of the device makes it easily portable. In our implementation, we leverage these features to provide real time data about articulated phalangeal joint angles on the hand.

3. PROJECT PROPOSAL

The goal of this project is to produce a method for approximating the phalangeal angles of the hand using the unrestrictive Leap Motion Controller.

3.1 Anticipated Approach

Our approach can be divided into three phases:

1. Understand and Prototype

The Leap Motion Controller is a new technology that is still in a developer-testing phase. There are currently no frameworks or libraries for handling data that the device receives except for the SDK provided by Leap Motion. Achieving phalangeal angle approximation will require a full understanding of the device's capabilities and the software development kit.

We will build a prototype in either C++ or Javascript with a visualization component that will demonstrate a simple approximation method for phalangeal joint angles. We will isolate a single finger, and use its position and speed to estimate the resulting joint angles at the end of a movement. As a simplification measure, we will first approach the problem by averaging the angle of motion over all joint angles of the finger.

2. Develop an Approximation Method

Using the prototype as a foundation, we will extend our approximation method to multiple fingers and the thumb. This will require experimenting with techniques for capturing useful data such as altering the position of the Leap Motion Controller and/or using multiple devices concurrently. We will begin to incorporate more data into our approximation method such as the palm position relative to the fingers, the palm's normal plane, the palm's curvature and finger positions relative to other fingers.

3. Refinement and Testing

With the approximation method outlined and working for the fingers on the hand, we will begin testing the accuracy of the method and refining the algorithm in place. If time permits, we will apply the approximation method as an Autodesk Maya Plugin that will support the real time animation of a rigged human hand model.

3.2 Target Platforms

- *Software:* Leap Motion SDK, WebGL (Javascript), OpenGL (C++), Autodesk Maya.
- *Hardware:* Leap Motion Controller.

3.3 Evaluation Criteria

Evaluation of our method will be based on whether phalangeal joint angles on the hand can be reasonably approximated and visualized using the Leap Motion Controller. If our approach accomplishes this task in a more efficient and user-friendly manner than current approaches such as motion capture systems, the project will be considered successful.

4. RESEARCH TIMELINE

Project Milestone Report (Alpha Version)

- Completed all background reading and have an understanding of the anatomical structure of the hand.
- Proposed methods of approach for developing an API for estimating phalangeal joint angles.
- Prototype demonstrating potentiality of estimating joint angles.

Project Final Deliverables

- An API for approximating hand joint angles in real-time.
- A visualization mechanism for displaying phalangeal joint angles.
- Documentation on how to use the API with the Leap Motion Controller.

Project Future Tasks

- Extend the approximation method and API to estimate phalangeal joint angles for two hands simultaneously.
- Implement an Autodesk Maya plugin to use the phalangeal joint angle estimation in real-time to animate a rigged character hand model.
- Use the API and approximated joint angle information to develop better gesture-recognition methods for use in Natural User Interfaces and in the detection and translation of American Sign Language.

5. Method

To be completed as the project progresses.

6. RESULTS

To be completed as the project progresses.

7. CONCLUSIONS and FUTURE WORK

To be completed as the project progresses.

APPENDIX

A. Optional Appendix

To be completed as the project progresses.

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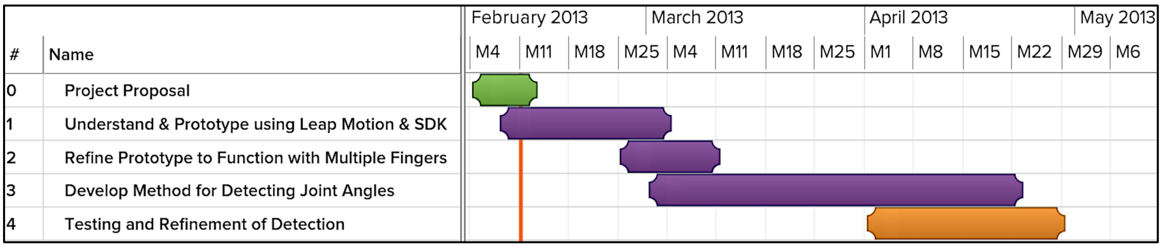

Figure 1: *Research Timeline*