Chiron: Interpreting signals from Capacitive Patterns and Inertial Sensors for intuitive Shape Modeling.

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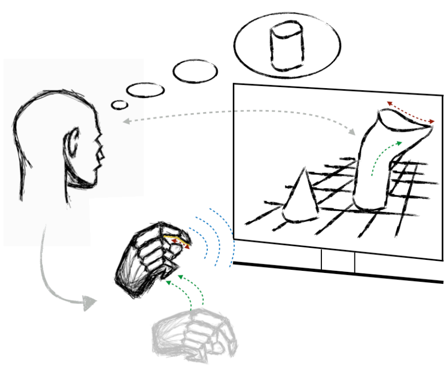

Figure 1. Concept Overview.

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Abstract

In this paper we introduce *Chiron* (abbr. *Chironomia*[1]): A wearable device for the hand that reads the digital and analogous signals from capacitive sensor patterns and orientation sensors, to interpret user-intent. Here, we explore two cases – (a) an unconventional and low-cost method for intuitive shape modeling and control, (b) ergonomically designing these patterns from conductive ink, for reading localized finger interactions (swiping or pinching). We also exploit *Chiron's* thumb-based interaction mechanism and discuss future novel applications.

Author Keywords

Finger Ergonomics; Gestural Interaction; Capacitive Sensors; Wearable Computing; Cognitive Load.

ACM Classification Keywords

H.5.2. [Information interfaces and presentation]: User Interfaces – Input devices and strategies; Interactions styles; Graphical User Interface; User centered design.

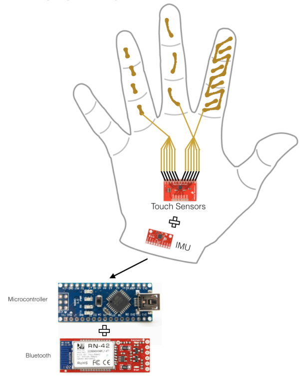
Introduction

In human communication*, "hand gestures add 'dynamic dimension' to verbal exchanges. They are integrated on*

[1] The art of using gesticulations or hand gestures to good effect in traditional rhetoric

(a) User Interaction

(b) Capacitive Sensors



(c) Hardware Overview

Figure 2. Chiron's System.

actionable, cognitive and ultimately biological levels" (*pg. 3*) [2]. This explains the involuntary response from the human body - that when we speak, we gesticulate more often than intended. The motivation here is to emulate gesticulation on a digital platform effectively. Recent advances in the depth sensing technology (such as Leap Motion, SoftKinetic, Microsoft Kinect)[2], have encouraged the use of vision-based algorithms for hand pose and finger tracking. However, they have two disadvantages: (a) fatigue caused due to confined workspaces, (b) robustness against occlusions. Similar issues can be stated for devices like Microsoft Research's Digits [13], which describes the technology of gesture emulation in a compact depth sensor-based hardware system. Gaming gloves have also been developed to emulate controllers by the Mattel & Peregrine[3] but failed to create an impact in market. Mechdyne's Pinch Glove[4] attempted to capture the essence of hand gestures based on bending of the fingers. Thalmic Labs' Myo[5] band is an introductory product used for giving gesture commands by interpreting the EMG signals from the arm.

Our approach is to develop Chiron as an input device that reads signals in real-time. Using low-cost conductive ink and off-the-shelf electronic components, we explore a map between user intent and intuitive shape modeling via touch interactions and hand movements (Figure 1). We attempt to synergistically couple the touch-based interactions via the capacitive patterns with hand orientations from the inertial sensors. We use these signals to formulate the user's hand posture at any instance. Then our algorithm reports changes when the user's hand posture is altered. We map these changes to actions that are associated to develop 3D shape models in an interactive application built using Unity3D game engine[6].

[2] https://www.leapmotion.com; http://www.softkinetic.com; http://www.microsoft.com/en-us/kinectforwindows/

[3] http://en.wikipedia.org/wiki/Power_Glove ; http://theperegrine.com

[4] http://www.mechdyne.com/touch-and-gesture.aspx

[5] https://www.thalmic.com/en/myo/

Related work.

Capacitive sensor technology has also evolved during the past several years. Techniques have been developed to recognize complex configurations of the human hands using Swept Frequency Capacitive Sensing [11]. Similar methods were used to measure the impendence of the human for distinguishing multiple users [3]. Patterns of capacitive sensors were implemented to create an innovative ear-based interaction system [16]. Sensors have been augmented into gloves for interaction purposes [4,7-10]. However, few have tried to exploit the sensor patterns to derive metaphorical meaning for shape modeling.

Gesture-based interaction methods have been used to control virtual entities. Colors have been used with nearest-neighbor approach to track hands at interactive rate, demonstrating an inexpensive system [1]. Work at MIT Media Labs [14] showcases the use of Vicon systems[7] to develop tangible interaction with the virtual entities via gestures. Microsoft Kinect has been used to provide an interface for developing pottery-based models [15]. They require camera setups confining the user to be in front of the camera. A system for creating

[6] http://unity3d.com

[7] http://www.vicon.com/System/Bonita

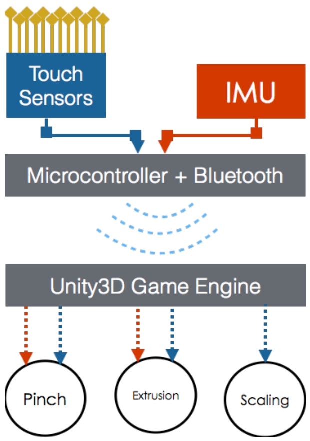


Figure 3. Pipeline Overview.

(a) Slider Based Pattern.

(b) Menu Driven Pattern.

Figure 4. Sensor Patterns

organic 3D shapes in a semi-immersive virtual environment using tangible tools and hand [17] uses stereo display device and a low functionality glove system. In 1987, a sensor-based glove was developed for simple pick and place manipulation of 3D Shape models in a CAD environment [6].

CHIRON – The Prototype

Design Rationale

Chiron implements a naked thumb-based interaction mechanism. Based on finger ergonomics, patterns are laid on three fingers: (1)Forefinger (2)Middle Finger & (3)Ring Finger (Figure 2b, 2c). Since the usage of forefinger is most comprehensive, due to its available area for the thumb, we use it to provide a slider-based output. The middle and ring finger are used for menu driven outputs. These menus were allocated based on the ergonomic accessibility of the thumb to those areas.

Hardware

The device comprises of the Arduino Nano microcontroller, MPR 121 Multiplexer, MPU 6050 IMU and a BlueSMiRF Bluetooth[8] (Figure 3), which the user can wear on his hand. The locations of these components are defined to provide ergonomic comfort without compromising any intuitive feedback (Figure 2c). The IMU device's algorithm outputs 6 values – the acceleration in the three axis and the Euler angles. These values are interpreted to define the dynamic pose of the user's hand at any instance. The communication between the IMU and the microcontroller is based on the i2c serial protocol that performs measurement and signal analysis.

Sensor Pattern

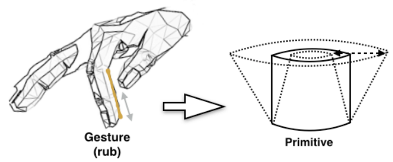
We implement a sensor pattern to get feedback from the user. These signals are interpreted as shape modeling operations using a pre-defined mapping (such as rubbing of the index finger implies scaling of the cross-section). Going with the current trend of sketch-able electronics, conductive ink[9] was used to make capacitive sensor patterns. Two types of patterns were fabricated based on the functionalities: pattern for (1) slider-based recognition (2) ergonomic menus on fingers (Figure 2b,4). The slider-based pattern is constructed of 5 pins, defining the resolution of slider-activity. It is designed in a two-column matrix (Figure 4a). The algorithm understands the position of the finger based on which pins are active. The menu driven sensors are simple touch points, which are ergonomically placed based on the finger's usage area (Figure 4b). The MPR121 Capacitive Touch Sensor, which is a multiplexer to sense touch events, uses a total of 12 electrodes whose capacitance increases when a finger touches it.

Software

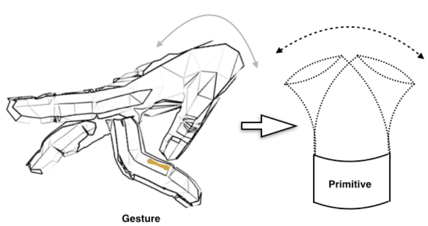
The software of the system has three modules (a) Microcontroller program, (b) Mapping and (c) Shape Modeling. The latter two, because of their dependency, are implemented within the Unity3D application. Analogous values from the IMU and digital states of the pin, is being read by the micro-controller and sent to the modeling application. In the modeling application, the change in these imported values is associated to

[8] http://arduino.cc/en/Main/arduinoBoardNano ; https://www.sparkfun.com/products/9695 ; https://www.sparkfun.com/products/11028 ; https://www.sparkfun.com/products/10269

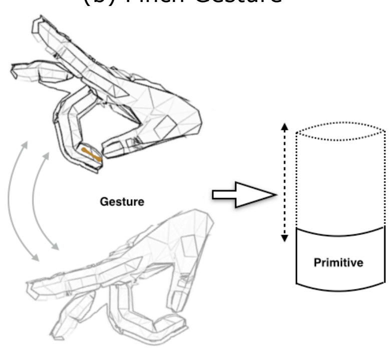
[9] http://www.bareconductive.com



(a) Scaling Gesture



(b) Pinch Gesture



(c) Extrusion Gesture

Figure 5. Gestures

modeling functionalities (such as movement of hand implies extrusion). Based on a mesh algorithm, these shape-modeling functions are performed. By interpreting these changes in value, user intent is mapped to modeling tools.

Usage Scenario.

Chiron recognizes the following actions –

1. Slider action to increment the value.
2. Spatial movement of the hand.
3. Orientation of the hand pose.
4. States of the menu driven electrodes.

For shape modeling, these actions are mapped to the following operations: (1) Primitive Selection, (2) Scaling, (3) Extrusion and (4) Pinch.

Primitive Selection

Since the task of selecting a primitive to extrude has a lower significance, the ring finger was used to house the menu-driven pattern for this task. It consists of 4 capacitive electrodes, which detects the touch state and associates each electrode to a primitive shape. The user via their thumb can reach out to these electrodes and select the appropriate primitive (Figure 6b). A smooth interaction is achieved, since the area of contact for the thumb is comparatively greater on the finger, making it extremely easy for the user to understand and use.

Scaling

Scaling of the cross-section area is best emulated in a slider mechanism for which the forefinger was used. Based on the slider action, the user can scale up or down the exposed cross-section area (Figure 5a).

Extrusion

The very top electrode in the middle finger is for activating the extrusion state. The user has to keep the state of this electrode active by maintaining a contact. By moving their arm in the air the object will extrude (Figure 5c). To map it in an intuitive manner, we extracted the acceleration value in the z- direction of the IMU to play as the variable responsible for the depth of extrusion. Thus the user experiences that they picked up the primitive and extruded it in air. Hence a pinch and elongate metaphor was achieved.

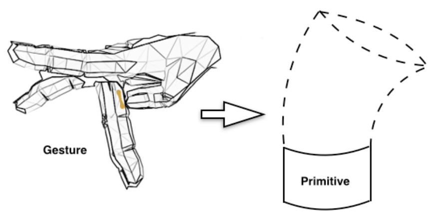
Pinch

Based on usage preferences, pinch command comes after extrusion. The second electrode's activity is associated with this aspect. After keeping the state active, the user can change the angle of the exposed cross-section by changing the orientation of their hand as sensed by the IMU (Figure 5b). The user thus experiences a 'grab and rotate' action while performing this operation. Activating the last electrode in the middle finger completes the current modeling event (Figure 5a).

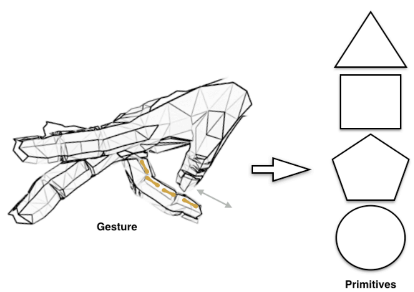
Implications.

Cognitive Load

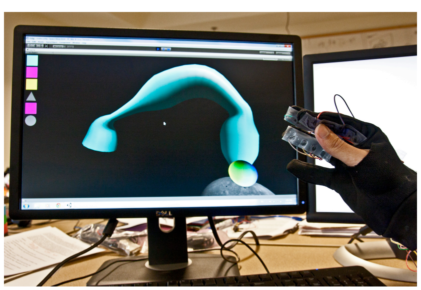
In a heavy menu driven application; the user develops a 'split attention effect' [18]: dividing their attention between the task and the control mechanism. By leveraging proprioception and tactility of the hardware coupled with a visual mechanism to educate the user of functionalities (Figure 7), we hypothesize that the user will be more immersed in the task rather than dividing a greater attention for the control mechanism.



(a) Completion Gesture



(b) Primitive Selection



(c) Gesture Interaction

Figure 6. Gestures

We predict the learning time to be short provided the user develops a "muscle" memory that maps the gestures to the shape. Based on kinesthetic learning and dexterity of the user, the muscle memory may help us maximize the Germane Cognitive Load [18]. The future user study will account for verification of these claims.

Generality
We are working to develop an input device that reads localized finger interactions. The pattern of the sensors provides us with a higher resolution of gesture detection. The easy 'customizability' (because of conductive ink), empowers this device for prototyping concepts and quick mapping. By developing suitable mapping algorithms, the system can be used to derive various applications centralizing the user's intent.

Evaluations
The device presently is made for right-handed people, as the dynamics of a southpaw is still to be studied. Also it is a completely sensor-based electronic system, which implies that chances of signal noises to interfere with regular data are always high. This may cause annoyance and dissatisfaction to the users. The future work on Chiron will address the issues regarding the hand size variation, noise interferences and unintended interactions by developing filters.

Potential Improvements and Future Work
The most immediate work is to improve the hardware for comfort, aesthetics and resolution. A Polydimethylsiloxane (PDMS)- Indium Tin Oxide (ITO) based flexible transparent circuit pattern is being considered to replace the fabric-conductive ink system.

Here we discussed Chiron for shape modeling. Other applications that are being worked upon are:

- *Augmented Reality (AR) Glasses:* Hardware integration of Chiron with AR Glasses (Google, Epson etc) for hands free interaction.

- *Actuated Systems:* Controlling system based on Electro-Active Polymer actuators for tangible interactions.

Presently, a different synergistic integration between the capacitive sensors patterns and inertial measurement unit is being prototyped for easy shape modeling. This may provide us with a deeper insight towards this ideology of intuitive on-the-fly shape modeling.

Conclusions
In this paper we introduced Chiron and its mechanism of interpreting the capacitive sensors & orientation sensor to develop an intuitive mapping for modeling. The device, which the user can wear, follows a thumb-based interaction mechanism and the modeling operations are appropriately mapped. A flow cycle initiating from the point where the user perceives a shape, to creating what they perceived is implemented. We thereby seek to gather new insights towards how human hand gestures could be derived from signals coming out of a pattern of sensors and mapping the associated actions to user intent.

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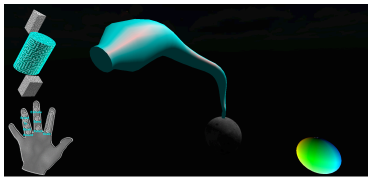
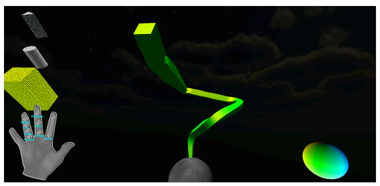
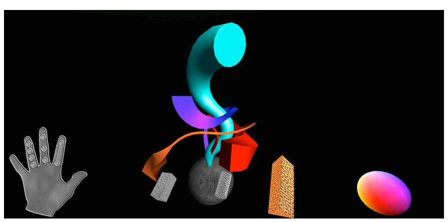


(a) Cylinder (Swept)



(b) Cube (Swept)

(c) Prism (Swept)



(d) Running application.

Figure 7. Screenshots of Application

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