Purpose

Plots and models are limited and constrained because it is difficult to visualize 3D on a 2D monitor.

Through visualization, one can develop a deeper understanding of the information and grasp the important details faster.
Project Overview

A 3D RGB LED matrix display controlled wirelessly by a mobile application and hand gestures read by a smart glove

Key Features:

- Input math function from mobile application connected via Bluetooth
- Display figure on 16x16x16 LED matrix
- Control figure with hand gestures sent through smart glove connected via Bluetooth
The Team

Ryan Chau
CAD, Distance Sensor

Eric Hsieh
LED Driver, Gesture Logic

Anna Koh
Cube Assembly, PCB

Sachen Sampath
Mobile App, Bluetooth

Christine Wan
IMU, Smart Glove
LEDs

- 5mm PL9823
- Individually addressable LEDs
- 4 leads:
  - Data input
  - Data output
  - Voltage input (VDD)
  - Ground input (GND)
Tri-State Buffer

- 74LS125 contains 4 tri-state buffers within a chip
- For directing control to multiple LED data-lines and reduce load to MCU
Custom PCB: Tri-State Buffer

- Opens input and output pins for tri-state buffer
- 4 layer, 2 inch x 2 inch
Microcontroller

- STM32L412RBT6
- Used on two custom PCBs that expose the pins on the MCU
  - One for the smart glove
  - One for controlling the cube
Custom PCB: LED Cube

- Receives input and drives LED matrix with a STM32
- 4 layer, 2 inch x 2 inch
Custom PCB: Smart Glove

- Reads glove sensors and determines hand gesture with a STM32
- 4 layer, 2 inch x 2 inch
Bluetooth Module

- BGM220-EK4314A
- For Bluetooth communication with matrix and smart glove
Inertial Measurement Unit (IMU)

- Adafruit BNO055 Absolute Orientation Sensor
- For rotation and shift gesture
Distance Sensor

- VL6180x: Time-of-Flight Distance Sensor
- For zoom in and out gesture
Force Sensitive Resistor (FSR)

- FSR03CE package
- Serve as buttons to determine which gesture
LED Cube Construction

LED Matrix

Metal Sheet

Power Supply

Circuits

LED strips
LED Cube Construction

LED bending jig

LED strip assembly

Tower base
LED Cube Construction

Power supplies beneath the matrix

LED matrix driver circuit
Smart Glove Construction

- FSRs
- PCB
- Bluetooth Module
- Distance Sensor
- IMUs
Smart Glove Gesture Recognition

Diagram:

- **Idle**
  - Transition to **Waitz** with condition $S_2 \& x \in R_1$
  - Transition to **Waitzo** with condition $S_2 \& x \in R_3$

- **Waitz**
  - Transition to **Waitz** with condition $S_2 \& x \in R_2$
  - Transition to **Waitzo** with condition $S_2 \& x \in R_3$

- **Waitzo**
  - Transition to **Waitz** with condition $S_2 \& x \in R_2$
  - Transition to **Waitzo** with condition $S_2 \& x \in R_3$

- **Waitz**
  - Transition to **Waitz** with condition $S_2 \& x \in R_2$
  - Transition to **Waitzo** with condition $S_2 \& x \in R_3$

- **Waitzo**
  - Transition to **Waitz** with condition $S_2 \& x \in R_2$
  - Transition to **Waitzo** with condition $S_2 \& x \in R_3$

- **Donez**
  - Transition to **Waitz** with condition $S_2 \& x \in R_3$
  - Transition to **Donez** with condition $S_2 \& x \in R_3$

- **Waitz**
  - Transition to **Waitz** with condition $S_2 \& x \in R_2$
  - Transition to **Waitzo** with condition $S_2 \& x \in R_3$

- **Waitzo**
  - Transition to **Waitz** with condition $S_2 \& x \in R_2$
  - Transition to **Waitzo** with condition $S_2 \& x \in R_3$

- **Donez**
  - Transition to **Waitz** with condition $S_2 \& x \in R_2$
  - Transition to **Waitzo** with condition $S_2 \& x \in R_3$

- **SR**
  - Transition to **SR** with condition $i_j = e_j, j \in x, y, z$
  - Transition to **SR** with condition $c_j = e_j - i_j, j \in x, y, z$
  - Transition to **SR** with condition $S_R \& c_i = \max(c_x, c_y, c_z)$
Smart Glove Gesture Recognition: Rotate

- Rotate every 10 degrees change
- 3 directions: row, pitch and yaw

Graph:
- From Idle to $S_R$
- From $S_R$ to $Wait_R$
- From $Wait_R$ to $Turn_i$

Mathematical expressions:
- $i_j = e_j | j \in x, y, z$
- $c_j = e_j - i_j | j \in x, y, z$
- $S_R \& c_i = \max(c_x, c_y, c_z)$
Smart Glove Gesture Recognition: Zoom

Idle

$S_Z & x \in R_1$

Wait$_{zi}$

$S_Z & x \in R_2$

Wait$_{zo}$

$S_Z & x \in R_1$

$S_Z & x \in R_3$

$S_Z & x \in R_2$

$S_Z & x \in R_3$

×2

÷2

×4

÷4

R1

R2

R3
Smart Glove Gesture Recognition: Shift

Idle

Wait_{Si}

Done_{Si}

\text{Shift}_{Si} \& \text{Gesture 1}

\text{Shift}_{Si} \& \text{Gesture 2}

\text{Shift}_{Si} \& \text{Not Gesture 2}
Smart Glove Gesture Recognition: Shift

- Up Gesture: 75°
- Down Gesture: 75°
- Left Gesture: 70°
- Right Gesture: 110°
- Back Gesture: 110°
- Front Gesture: 50°
Bluetooth Module Firmware

Diagram showing the flow of data handling and connections for Bluetooth module firmware.
Mobile Application: Math Logic

- Function provided by user
- Algorithm iterates through x and y values within the chosen resolution
- Root finding algorithm evaluates the function at each (x, y)
- Round z value to nearest pixel
Mobile Application: Data

- Users can choose color scheme
- Byte array is mapped to format for LED Matrix Driver
- Byte array can be compressed 2x
Mobile Application: Handshake with LED Cube
LED Matrix Driver: PL9823 LED Control

Signal

VDD

GND

E.g.:

Blue(0x0000FF)  Red(0xFF0000)  Green(0x00FF00)

Signal

 DMA buffer

L = 27, H = 100
LED Matrix Driver: Data Flow and Timing

**LED data**

<table>
<thead>
<tr>
<th>Channel</th>
<th>Value</th>
<th>Color LUT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ch 1</td>
<td>1</td>
<td>0x000000</td>
</tr>
<tr>
<td>Ch 2</td>
<td>F</td>
<td>0xFF0000</td>
</tr>
<tr>
<td>Ch 3</td>
<td>6</td>
<td>0x1254A8</td>
</tr>
<tr>
<td>Ch 4</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Buffer 1**

- ADR1: 100
- ADR2: 27
- ADR3: 100

**Buffer 2**

- ADR4: 27

**DMA**

- T_{set} ≈ 1ms
- T_{wait} ≈ 12ms
- T_{stage} ≈ 25ms
- T_{Display} ≈ 100ms

**Stages**

- 4 stage
- 4 channel
- 256 LED
- 4096 LEDs

**Notes**

- T_{set} + T_{wait}
- S.S. (Standby State)
LED Matrix Driver: Tri-State Buffer Control of Matrix

OUT1

\[ S_1 O_1 \]

\[ S_2 O_1 \]

\[ S_3 O_1 \]

\[ S_4 O_1 \]

OUT2

OUT3

OUT4

\[ S_4 O_4 \] \[ S_3 O_4 \] \[ S_4 O_3 \] \[ S_3 O_3 \]

\[ S_1 O_4 \] \[ S_2 O_4 \] \[ S_1 O_3 \] \[ S_2 O_3 \]

\[ S_4 O_1 \] \[ S_3 O_1 \] \[ S_4 O_2 \] \[ S_3 O_2 \]

\[ S_1 O_1 \] \[ S_2 O_1 \] \[ S_1 O_2 \] \[ S_2 O_2 \]
Gesture Response Time

\[ T_{Total} = T_1 + T_T + T_E + T_2 + T_D + T_{Display} \]

<table>
<thead>
<tr>
<th>gesture</th>
<th>Preset shapes</th>
<th>User-defined equations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rotate</td>
<td>260 ms</td>
<td>260 ms</td>
</tr>
<tr>
<td>Shift / Zoom</td>
<td>260 ms</td>
<td>350 ms ~ 1 s</td>
</tr>
</tbody>
</table>
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   Venkat Krishnan, Jimmy Kraemer, Alex Lai

Cube Assembly Help:

   Christopher Wimmel, Adam Yu, Simon Yu, Michael Cheng

Malt Whiskey
Questions?
## Power Consumption for 0xFFFFFFFF

<table>
<thead>
<tr>
<th></th>
<th>1 PL9823 LED</th>
<th>4096 PL9823 LEDs</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Current</td>
<td>Power</td>
</tr>
<tr>
<td>0% brightness</td>
<td>~ 8 mA</td>
<td>~ 0.04 W</td>
</tr>
<tr>
<td>30% brightness</td>
<td>~ 18 mA</td>
<td>~ 0.09 W</td>
</tr>
<tr>
<td>50% brightness</td>
<td>~ 27 mA</td>
<td>~ 0.135 W</td>
</tr>
<tr>
<td>100% brightness</td>
<td>~ 53 mA</td>
<td>~ 0.265 W</td>
</tr>
</tbody>
</table>
LED Matrix Driver: Buffer Optimization

One DMA buffer present

Two DMA buffer present
Brightness Control Detail

Total data size: 2049 bytes

128 bytes per tower
Choose of MicroController - STM32L412RBT6

- STM32 low-power series
- 40 KB RAM
  - DMA buffers for LED transfer takes up 12KB memory each.
- 2 ADCs