**Camera-based Visible Light Communications with LED Matrices (MWH1-16)**

**Students:** TSE Yiu Leung  
WONG Chun Loi  
YU Wai Tung  

**Supervisor:** Prof. Wai Ho, MOW

### Introduction

In the past few decades, wireless data transmission has become essential to human society. However, the data carrier we have been using, RF wave, has insufficient bandwidth and data rate for modern applications. Our project proposes an alternative, VLC, which has wider bandwidth, faster speed and higher noise immunity.

### Objectives

- Control LED matrices to transmit signal
- Develop a user-friendly VLC system with mobile application
- Promote energy efficient data transmission

### Methodology

At this stage of the project, we need to make a simple VLC system that transmit data by a programmed LED matrix, receive the encoded data using a mobile phone camera, decode and retrieve information using Matlab software.

### Design

**Encoding stage:**

- Every row implements 31 bits with 2-3 cycles displayed on the matrix.
- Insert maximum length sequence for synchronization.
- Insert training sequence for sampling purpose.

**Decoding stage:**

- Image binarization
- Extract LED matrix from binarized image
- Calculate sampling position with training sequence and maximum length sequence phase
- Retrieve information

### Technical Challenges

- Camera alignment
- Background light interference
- Lost bits between LED bulbs
- Synchronization of LED matrices and phone camera

### Components

<table>
<thead>
<tr>
<th>Components</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arduino Software (IDE) 1.6.12</td>
<td>Program the microcontroller</td>
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<tr>
<td>Arduino Uno R3</td>
<td>Control LED matrices</td>
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<tr>
<td>LED matrix</td>
<td>Display data</td>
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<tr>
<td>Smart phone CMOS camera</td>
<td>Capture data from LED matrices</td>
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<tr>
<td>Matlab R2015b</td>
<td>Decode and retrieve information</td>
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</table>

### Preliminary Results

**Encoded bit sequences:**

- 0000011111
- 1010101110
- 1010101010
- 33 bits training sequence
- 33 bits maximum sequence
- 12001101100
- 12001101111

**Decoded bit sequences:**

- Angle shift = 0°  
  BER = 0.0025
- Angle shift = 1°  
  BER = 0.053
- Angle shift = 2°  
  BER = 0.06
- Angle shift = 3°  
  BER = 0.3925

### Conclusion

We are able to control the LED matrix as we expected. The communication between the phone camera and the LED matrix is successful. We can decode data and retrieve information using Matlab.

The bit error rate for greater than 2-degree’s angle shift is increased explosively. Therefore, the angle shift should not exceed 2 degree when capturing images of LED matrix.

Further works about error correction can be applied to enhance the tolerance of angle shift and the successful rate of transmitting all data bits.