ChromaCam: Demodulating Colored Light with a High-End Smartphone

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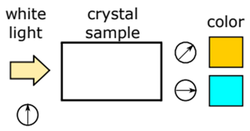
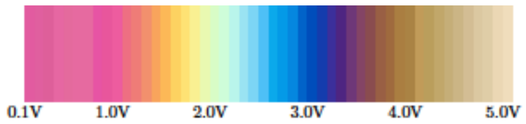
1. Background

Using the refractive property of liquid crystals, it is possible to create colors from white light, just like what ishappening in LCD displays.



By applying a voltage over a liquid crystal cell, the color can be changed. Depending on the voltage different colors are produced.

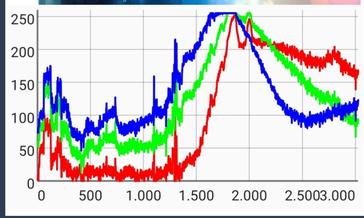


The colors can be received with a phone camera. These phone camera's work by exposing every line of the camera separately. If the source light gets updated quickly it creates the rolling shutter effect.

2. Transmitter

To achieve the highest possible bit rate, the transmitter must switch as fast as possible.

If a voltage is applied to the liquid crystals, the three color channels change at different speeds.



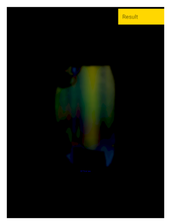
For sending data, the voltages are used were a single channel changes the fastest.

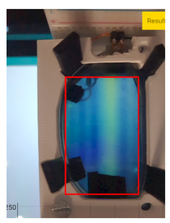
3. Workings of ChromaCam

Research Question
How to demodulate the optical signal transmitted by a liquid crystal with a high-end smartphone camera

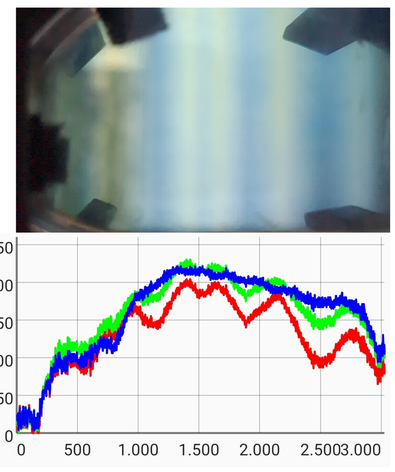
Transmitter Detection
Two pictures are taken, one with high and one with low shutter speed.

The location of the transmitter is at the difference of these pictures.
An OTSU filter can be applied to find the place with the brightest pixels.



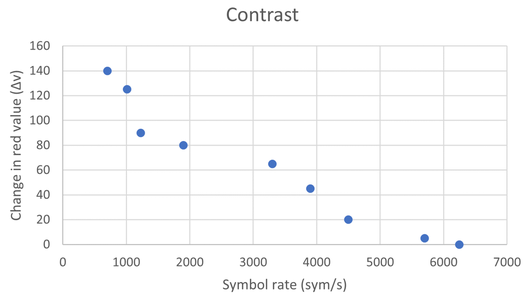


Demodulating Data
With the location of the transmitter known, the red green and blue values of the columns can be summed up, and the data can be decoded.



4. Results

There is a limit of how fast the liquid crystals can update. To find this limit the contrast between the zero and one symbol is measured for the red channel at different speeds.



Another important factor is the width of the transition. This dictates how many transitions can fit onto one frame.

Last factor is the speed of the demodulation. This is from a known position of the transmitter the time to find the rising and falling edges.

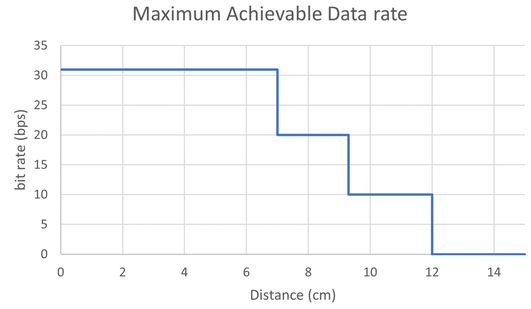
95ms

Using tracking algorithms when the position of the transmitter is known, removes the need for applying the difference everytime, this is usefull as it was found that every calibration frame adds a considerable amount of time.

+45ms

5. Conclusion

From these results we find that at a symbol rate of 3000 symbols per second, a maximum bit rate of 31 bps was found at a max distance of seven centimeters. Three bits fit into a single packet at that distance. The maximum distance data could be decoded was at twelve centimeters with a bit rate of ten bits per second.



Even these low data rates show that the algorithm proposed called ChromaCam is viable.

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References

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