TETRIS: Smartphone-to-Smartphone Screen-Based Visible Light Communication

REU fellows: Matthew C. Stafford[1], Adriana E. Rogers[2], Charles J. Carver[3], Shela Y. Wu[4]
Faculty Mentors: Drs. N. Sertac Artan[5] and Ziqian Dong[5]
Affiliation: [1] University of Buffalo, [2] Lewis & Clark College, [3] Fordham University, [4] New York University, [5] School of Engineering and Computing Science, NYIT
Emails: mcstaffo@buffalo.edu, rogers.adriana@gmail.com, ccarver1@fordham.edu, shela.wu@nyu.edu, nartan@nyit.edu, ziqian.dong@nyit.edu

ABSTRACT

With the extensive use of smartphones, technology improving secure communication between smartphones is a growing field of research. As a form of Visible Light Communication, a color video barcode system creates a smartphone-to-smartphone communication channel. This color video barcode system, essentially an evolved form of QR codes, provides a secure alternative to WiFi, Bluetooth, and Near-field communication. Recent improvements in smartphone screen resolution and camera capabilities allow for data transmission with larger amounts of information. We investigate if these hardware changes will allow for improvements to be made in data transmission over a screen-to-camera color barcode link. Our system, TEtra-TRansmISsion (TETRIS), achieves a communication throughput of 311.22 kbps with 90% accuracy with a 4-color scheme.

BACKGROUND

Visible Light Communication
- line of sight security [1]
- minimal interference
- unregulated

Near-Field Communication (NFC)
- 10 cm range [2]

[2]

Wifi & Bluetooth
- long range
- security drawbacks

Barcodes & Quick Response (QR) Codes

NYIT REU 2017

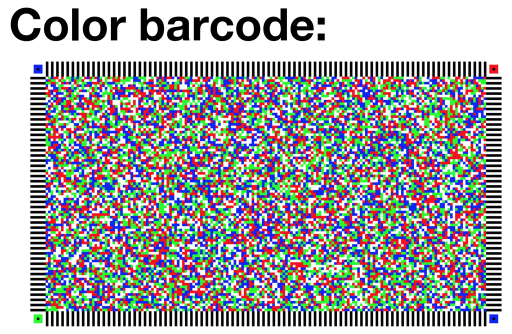
EXPERIMENTAL SET-UP

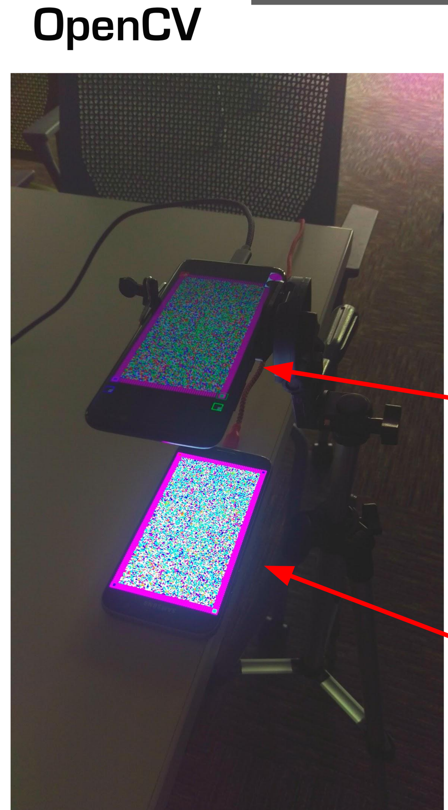
Decoding color barcode using:

OpenCV

Android Studio

Color barcode:

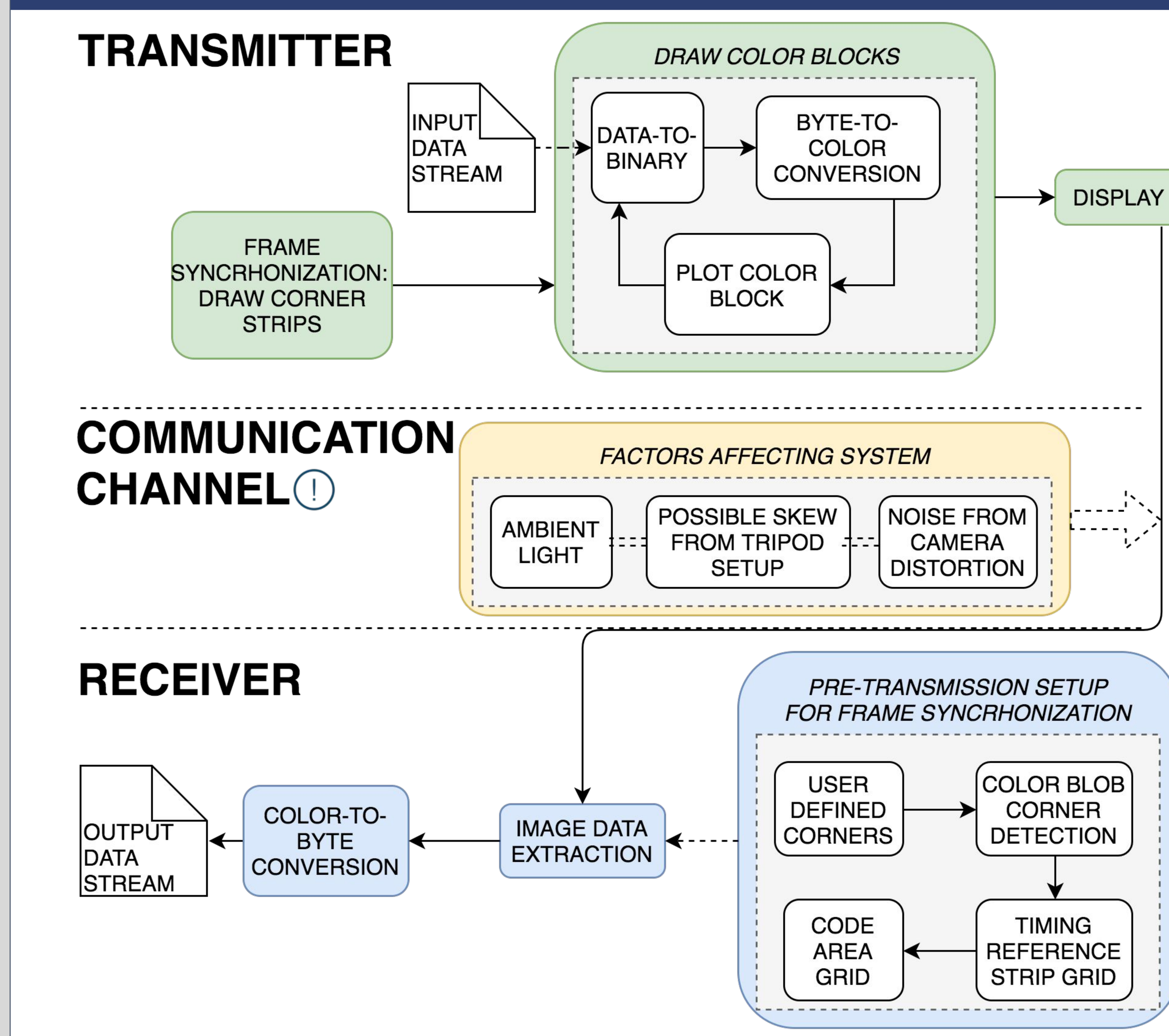




Receiver:
- Samsung Galaxy S8
- 12-megapixel camera
- On tripod 15 cm above transmitter

Transmitter:
- Samsung Galaxy S7
- 2560 x 1440 resolution screen

SYSTEM OVERVIEW



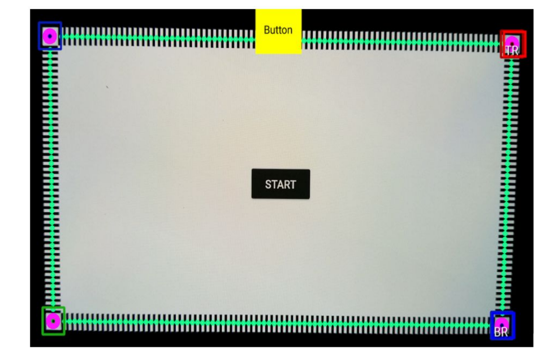


Fig. 1: Graphical user interface to drag corners

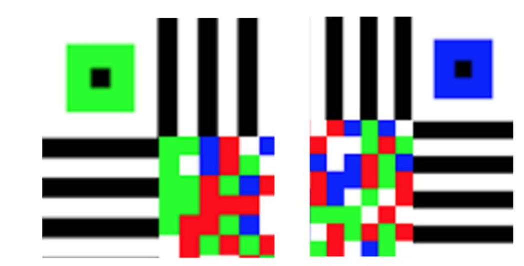


Fig. 2: Close-up of our top left and right corners and timing strips

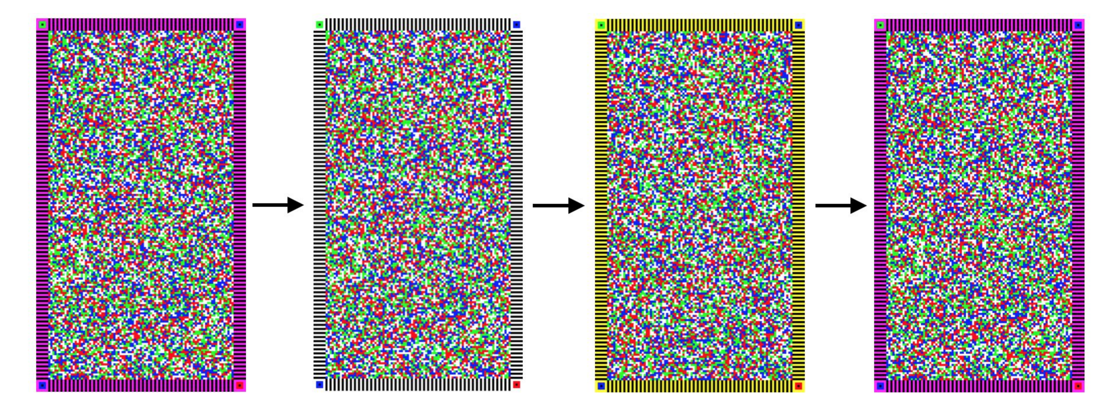


Fig. 3: Example of 4 frames being sent
Pink signals beginning and end, white and yellow alternate

RESULTS

Table I: Outline of TETRIS's preliminary and best results

TETRIS's preliminary result:	24 x 24 pixel block size	4 Hz (frames per second)	2 bits (4 colors: red, green, blue, white)	36.096 (kilobits per second)	Error rate: 2% of transmission
TETRIS's best result:	14 x 14 pixel block size	10 Hz (frames per second	2 bits (4 colors: red, green, blue, white)	311.22 kbps (kilobits per second)	Error rate: 10% of transmission

Table II: Comparison between TETRIS and related works

Transmission Method	Block size (pixels)	Resolution	Throughput (kbps)	Supported with adaptive blur-awareness	Supported with feedback channel
TETRIS	14 x 14	2560 x 1440	311.22	✗	✗
COBRA [3]	6 x 6	800 x 480	225	✓	✗
RainBar [4]	11 x 11	1920 x 1080	956	✓	✓
SoftLight [5]	variable	1920 x 1080	317	✓	✓

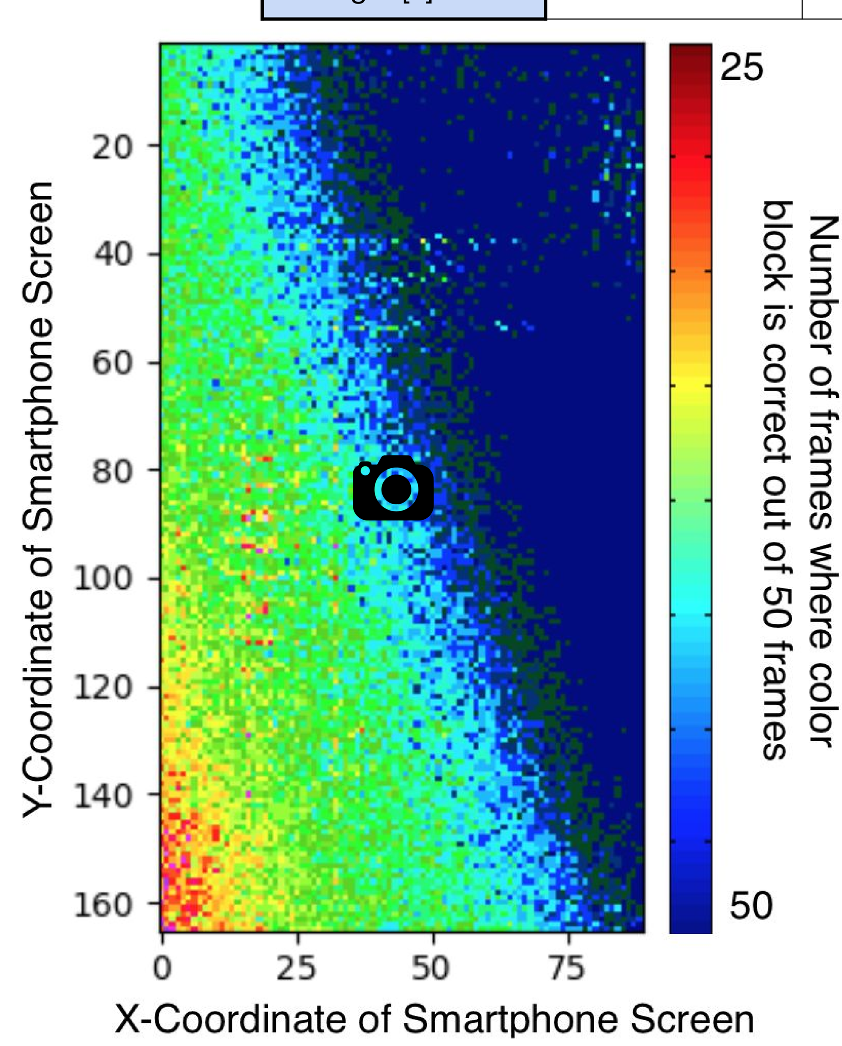


Fig. 6: Error heat map of smartphone screen
Camera is located above (45, 85) at a height of 15 cm.

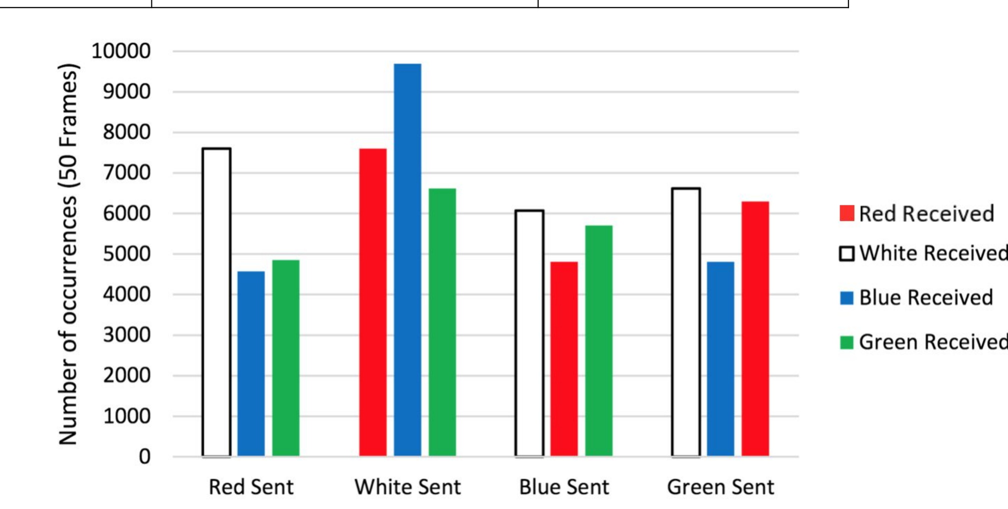


Fig. 4: Distribution of incorrect colors detections over 50 frames

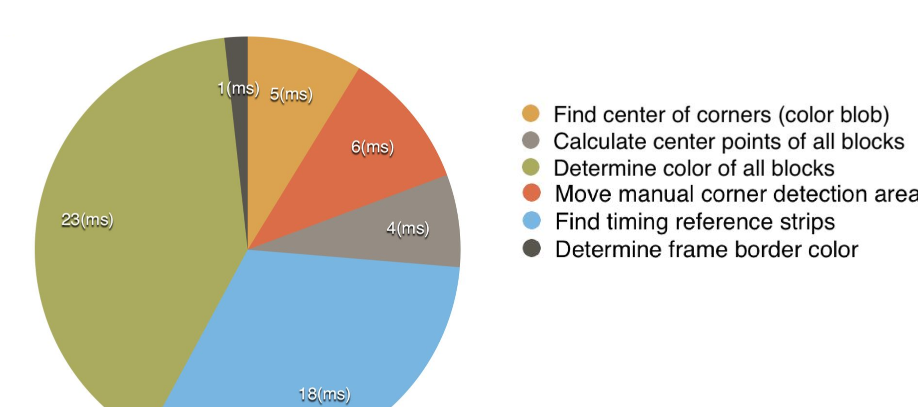


Fig. 5: Computational time of each processing component

*Found using Android Studio on Galaxy S7

DISCUSSIONS

Reasons for bit error:
- Receiver takes images before transmitter screen has refreshed, creating what we see in the heat map
- Ambient light may have impacted testing

Focus on finding computational sweetspot between:
- Number of colors used
- Frame rate of video
- Color block size
- Maintaining accuracy

CONCLUSIONS

With improvements in smartphone screen and camera resolution, we improve our ability to transmit more code blocks in a densely packed grid, and ultimately improve the potential for secure smartphone-to-smartphone color barcode communication. In testing our hypothesis, we focused on how we could optimize results by altering the frame rate, size of color blocks, and number of colors, while maintaining an acceptable level of accuracy. We successfully implemented a screen-to-camera link using a high resolution smartphone and camera with a connection throughput of 311.22 kbps. We allow for future work to improve the accuracy and throughput of our smartphone-to-smartphone communication system.

FUTURE WORK

- Implement a feedback channel between transmitter and receiver to retake inaccurate image
- Improve usability in various levels of ambient light
- Test usability over various distances between transmitter and receiver
- Attempt an 8-color scheme using mid-point RGB values
- Implement usability without a tripod using continuous corner detection

REFERENCES

[1] C. Rohner, S. Raza, D. Puccinelli and T. Voigt. "Security in visible communication: Novel challenges and opportunities," in *Sensors & Transducers* 192. 2015.
[2] "NFC or EMV, Which is More Secure?" Best of Category Reviews. Accessed July 28, 2017. https://bestofcategoryreviews.com/nfc-or-emv-which-is-more-secure.
[3] T. Hao, R. Zhou, and G. Xing, "COBRA: Color barcode streaming for smartphone systems," in Proc. 10th Int. Conf. MobiSys, New York, NY, USA, June 2012, pp. 85–98.
[4] Q. Wang, M. Zhou, K. Ren, T. Lei, J. Li, and Z. Wang. "Rain bar: Robust application-driven visual communication using color barcodes," in *2015 IEEE 35th Int. Conf. Distributed Computing Systems (ICDCS)*, June 2015, pp. 537-546.
[5] W. Du, J.C. Liando, and M. Li. "Softlight: Adaptive visible light communication over screen-camera links," in *35th Annu. IEEE Int. Conf. Computer Communications (INFOCOM)*, April 2016, pp. 1-9.

ACKNOWLEDGEMENT

This research was supported by the National Science Foundation (NSF) Research Experiences for Undergraduates (REU) program. We would like to thank all of the mentors and research fellows at the New York Institute of Technology who have provided their helpful insight and expertise that greatly assisted with our research. We want to extend our thanks to the helpful graduate students, Mahmoud Saleh and Gopi Prasad, for their constant help over the program's duration.

This project is funded by National Science Foundation Grant No. CNS-1559652 and New York Institute of Technology.