Visual communication via the Becton Café LED display
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Overview:
While barcodes are used on any merchandise you could find in any store, QR codes have increasingly become popular for advertisers as a simple form of communication. As more people own smartphones and new wearable technology like Google Glass with scanner apps, we can imagine many more ways users can interact with their environment through the use of visual communication. While QR codes have experienced mild success, they are only effective when the entire code is captured and is at an acceptable resolution. Therefore, we must improve the coding scheme and the decoding software on the smartphone to make it more flexible for all situations. Some situations that could disrupt proper reading of the code are: taking a picture of the code from the side (geometric distortion), variable distances, large contrasts in brightness, and blurriness. The ultimate goal is to design a code that can be used in any of these challenging situations.

It is also possible that too many codes could actually be annoying for a person who is just trying to find the information he needs. One way to do this is through steganography, which is the method of encoding hidden messages so that apart from the sender and the intended recipient, no one suspects the existence of the message. This method, originally a form of security through obscurity, could be leveraged so that a billboard that looks unassuming to the human eye could be transformed into an interactive experience after processing the image of the billboard using a smartphone.

Project description:
For this project, we will use the wall and ceiling LED displays in Becton Café to display smartphone-readable code. This display is ideal for developing more robust codes since it is a challenging, yet common, use case. We will create a code that is flexible enough to be used on any surface of the LED display, and simultaneously create an Android app that can read the display at various qualities (different angles, brightness, and clarity). If time allows, we will improve the code by using steganographic techniques to make the content interesting even for people who do not have smartphones.

The Becton Café uses over 23,000 LED lights to achieve a display that nearly covers one wall and wraps across the ceiling. The display is covered with several glass panes that act as diffusers to allow viewers to see a more cohesive image. This kind of LED display is used in many large screens, such as the ones seen in Times Square. The LED display acts as a canvas for programmable art, and it is able to display custom images and video. Each light is individually programmable, and can be controlled using a piece of software called Pharos, which provides a drag and drop
interface to display images and create slideshows. The computer controlling the
display also has the capability to connect with external sensors, which will allow for
an interactive environment with the display. Pharos allows conditionals and
scripting, which can be used, along with sensors, to display different visual codes
depending on environmental factors such as brightness. Pharos also allows users to
simulate the whole project before going onsite, which will allow for easy testing and
minimal disruption to the café.

For the design stage of the project, there will be two components: designing the
encoding scheme for visual communication and making the decoding algorithm.
These will be done concurrently so we can iteratively test each design. One method
of testing is to design both the encoder and the decoder offline by taking pictures of
the visual code on the display, saving it on the computer, and using a desktop
version of the decoder to process the picture.

Previous Research:

Before starting this project, we must understand the challenges facing visual
communication research in the past. This project has been inspired by the efficiency
of QR (Quick Response) codes as well as the problems associated with it. A QR code
is a matrix barcode that allows fast readability and greater storage capacity
compared to UPC barcodes. It is arranged in a square grid on a white background,
and can be scanned using software and processed using Reed-Solomon error
correction.

While QR codes have proven to be effective in a variety of situations, it faces
problems, such as when the modules are distorted, when the image is blurry, and
when the code is situated in different spatial arrangements. Several methods have
been developed to deal with these issues. COBRA (COlor Barcode stReaming for
smArtphones) encodes information into 2D color barcodes and is designed to deal
with significant image blur and also allows real-time barcode stream decoding.
Another LCD-camera communication system is PixNet, which generalizes OFDM
(Orthogonal frequency-division multiplexing) to address issues such as perspective
distortion and blur. All of the techniques mentioned above will be studied to provide
a developmental basis for this project when looking at other challenges such as
discontinuous geometric distortion given the shape of the Becton display and the
potential blurriness its diffusing glass may cause.

As we progress through the project, we may want to make our code scalable across
frames. Professor Wenjun Hu has also done research on the challenges facing
smartphone-based visual communication, tackling the challenges that stem from the
differences in frame rate between the transmitting display and the receiving device
due to camera capability, lighting conditions, and other system factors. If the
transmitting frame rate is too high, the receiving device may not be able to decode
the images because its camera cannot receive all of the frames since its frame rate is
too low. While it is possible to simply reduce the effective screen frame rate to
ensure a decodable frame every other frame, this does not take advantage of the full capabilities of the transmitter. LightSync is therefore developed to use in-frame color tracking to decode imperfect frames and a linear erasure code across frames to recover lost frames. This provides a solution to inefficiency and allows more than double the data to be send compared to the earlier codec scheme.

Checkpoints:

- Understand previous research on visual communication
- Determine the challenges QR codes face by testing it with many use cases (scanning from different angles, resolutions, brightness)
- Evaluate if the current QR design, along with ideas of our own ongoing scalable design, can meet the challenges
- Test design in different use cases and refine
- If time allows, use steganography to hide the code within graphics.

Timeline:

Week 1: Background reading
Week 2: Set up experiment, setting up code environment, simple test experiment
Weeks 3-5*: Design a code and desktop program that can be used to decode for a variety of displays
Weeks 6-8*: Port the desktop program onto a smartphone to be used for field experiments
Week 9: Draft results
Week 10: Summarize results and presentation

* These weeks can be divided into iterations of separate, smaller projects. For example: designing a code, building a decoder app, improving functionality on the app, etc.