# Storage Coordination System

## EECS 452: Digital Signal Processing Design Lab - Fall 2011

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## Motivation & Objectives

Warehouse storage is in need of a more efficient and less expensive organization system to properly locate and move containers. To simulate this storage coordination we set out to:

(1) **Develop an image processing algorithm to locate items, using a Sony bullet camera and Altera FPGA board**

(2) **Develop a control system to move the robot cart across a simulation mat, using a pre-constructed cart and Altera FPGA board**

(3) **Develop a Serial Peripheral Interface Bus (SPI) to allow the robot cart movement to be controlled by real-time image processing**

The big picture: a full –scale warehouse storage space.
http://www.wlcindia.in/images/Warehouse.jpg

## Methods

A full-scale warehouse system is beyond the scope of the course. We developed a small-scale design that utilizes one camera, one robot cart, and the Altera FPGA board to locate various color circles (i.e. storage containers) on a test mat.

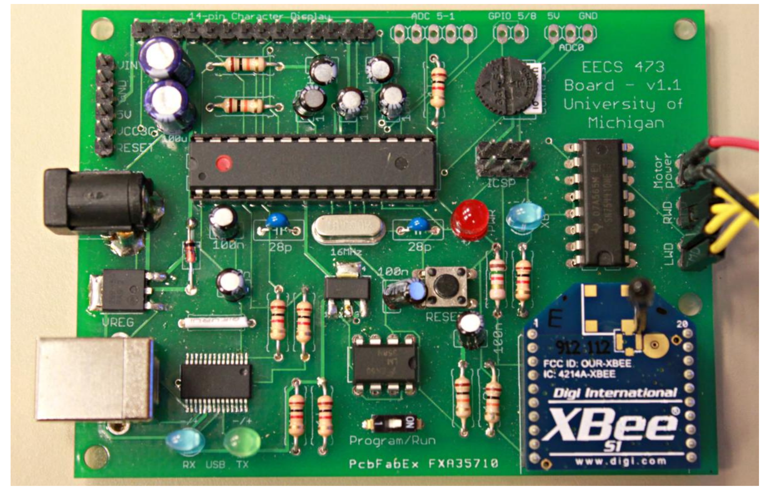
We completed our design by:

- **Simulating color segmentation in MATLAB with a single snapshot image**
- **Adapting our color recognition algorithm to Altera TV Box Demonstration sample codes**
- **Analyzing features of RGB and HSV color spaces and converting between the two**
- **Calibrating real-time video images to determine the proper colors of the simulation mat and test circles**
- **Simulating the robot cart control system in the Arduino coding environment**
- **Transcoding our robot cart algorithm to the Verilog language of the Altera FPGA board**

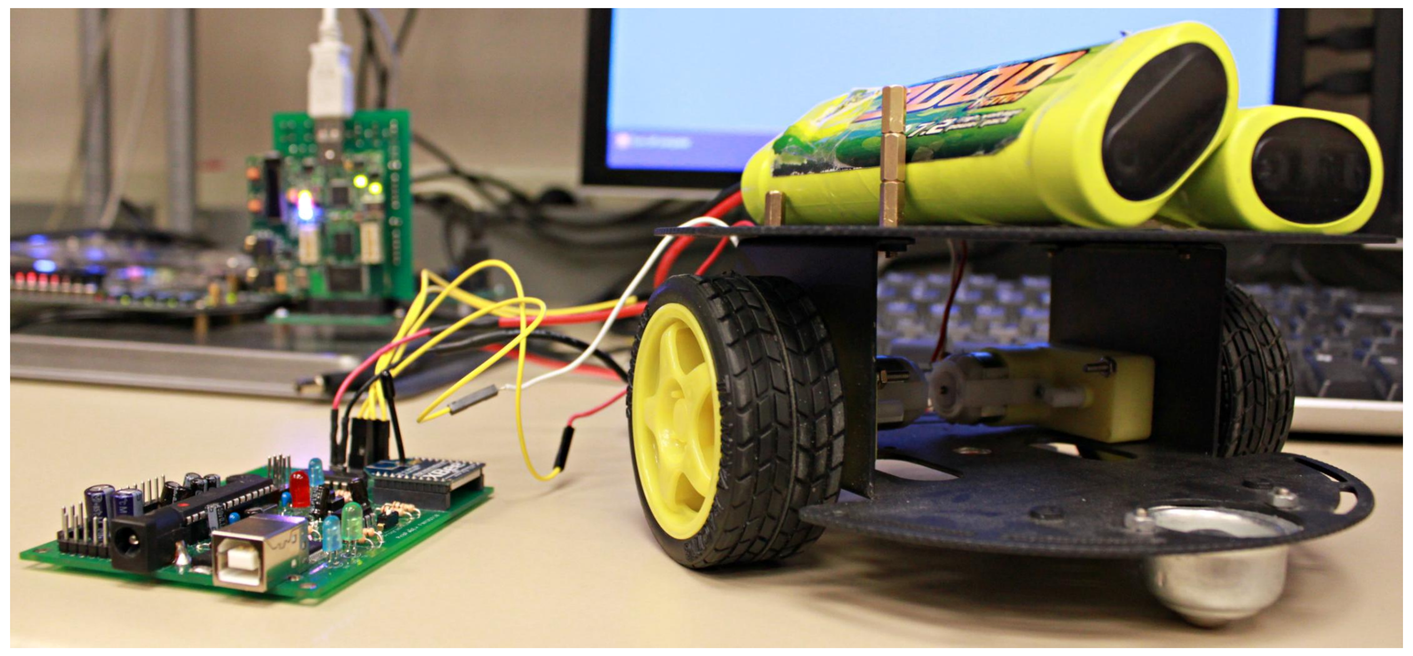
## System Design

Camera → FPGA Board & C5515 → Robot Cart → Move to Color Circle → Return to Starting Point → Relinquish Item & Stop

- Positioned camera above center of simulation mat
- Image processing system calibrated to recognize: black mat and three color circles (green/purple/red)
- Camera programmed to locate centers of each circle
- Circle locations stored in buffers, used in cart movement
- Communication from camera to robot cart achieved through FPGA board, C5515, and XBee modules
- In SPI system: C5515 serves as master of slave FPGA board, to instruct cart on proper course



The robot cart employs XBee modules for wireless communication to the FPGA board.



- Two color circles distinguish front and back of cart
  - Midpoint of robot cart defined as center point between centers of the two circles
  - Angle and distance of movement calculated from midpoint to center of final destination color circle
  - Initial location stored in memory for robot cart to return to starting place
- XBee modules: one on robot cart, one on FPGA board
  - Designed algorithm in Verilog to send message
  - Utilized Arduino code to receive message
  - Configuration of XBees done in X-CTU program
- Two 7.2-Volt batteries power two DC motors on cart
- C5515 continuously analyzes video image input to update robot cart on correct course of movement
  - VGA display allows user to watch the color data analyzed by SPI algorithm
  - Cart can travel in four primary directions: left, right, forward, backward
- When on top of desired location, robot cart rotates to sweep collected item back to start
- Upon return to start location, robot cart travels in reverse to relinquish item for user to collect

## Discussion

The image processing component consists of: color calibration, conversion from RGB to HSV color space, color detection, and location of centers of the circles.

- For color calibration: we record the color information of specified pixel coordinates. This data is then converted from the RGB to the HSV color space and each pixel is compared to the calibrated color. If the result falls within a specific range, the pixel is flagged as ‘1’, ‘0’ otherwise. The pixel with the flag is displayed on the VGA monitor and the rest is displayed as whitespace.
- For locating the centers of the circles: we calculate the center as the sum of flagged pixels. The row and column that has the largest sum is more likely to be the center of the color circle.

This algorithm is efficient. It minimizes the compilation time and works quite well under different lightning conditions.

## Future Work

Due to the primary constraints of time and resources, we were not able to develop the storage coordination system to its full potential. To improve this project, we recommend:

- Further development of the image processing algorithm to recognize a greater number of colors/items
- Improving the robot cart control system for more fluid movement and fewer path corrections
- Additional focus on the efficiency of the code
- Designing a better method of moving items from their original location to the starting point of the robot cart
- Creating a Graphical User Interface for a cellular device to allow the user to wirelessly select their desired items

## References


- Brehob, Mark. “Lab 1: Introduction to Arduino.” (2011).
- Image Analyst. "Color Segmentation by Delta E Color Difference." (2011).
- Terasic Technologies. *Altera DE2-70 User Manual* 1.08 (2009).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