Mobile 2D Barcode Scanner and Decoder for Medical Device Auto-programming

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Introduction

I. 2D Barcodes

Bar codes, particularly 2D ones, are machine-readable representations of data that are used in a variety of modern applications, such as e-commerce, mobile flight boarding ticketing, printed media, and commercial marketing. The earliest versions of barcode scanners were for 1D barcodes and consisted of a single photosensors; now, we are able to use our smartphones to get information from both one- and two-dimensional barcodes. Recently, 2D barcodes such as QR codes, Aztec codes, and 2D data matrix codes have become more popularized for connecting users to companies through social media, advertising, and other means, since they can store more data per area.

This project will particularly focus on 2D data matrix barcodes, as these are widely used for medical electromechanical device labels. A data matrix barcode consists of black and white individual pixels arranged in a square or rectangular format, and it can encode either text or numerical data (up to 2335 alphanumeric characters). It consists of three main components: a L shaped finder pattern, which is used as an identifier for the data matrix code and defines the code's orientation and location, a clock track pattern, which consists of the two other borders with alternating black and white squares and defines the code's size (which typically ranges between 10x10 and 144x144), and the encoded data [3]. This format is as shown below in Figure 1.

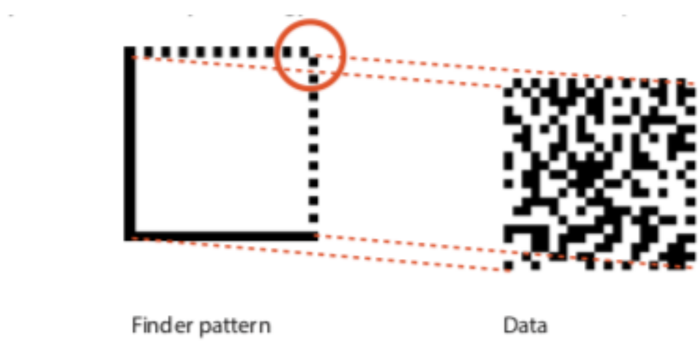

Figure 1: ECC 200 Data Matrix code, showing L finder pattern and clock track pattern separate from encoded data[3]

The newest version of data matrix barcodes, called ECC 200, is unique because codes of this type will always have an even number of rows and columns. Therefore, a white square will always be the top right pixel of this code, as shown in the image above. It is also unique because it uses the Reed-Solomon error correction method to encode data. This will the data matrix format focused on in this project.

The decoding of these data matrix codes is defined in ISO/IEC 16022, assuming an ideal image that has been converted to binary values [3].

II. Peritoneal Dialysis Devices for At-Home Renal Care

Peritoneal dialysis (PD) is a process that removes waste from your blood when kidneys are not able to do so. To do this, a catheter is inserted in a patient's abdomen in an area known as the peritoneum cavity, and waste is filtered after a certain specified amount of time. A large benefit to doing peritoneal dialysis rather than hemodialysis (which is a more common procedure) is the flexibility to do the treatment in the comfort of a patient's home or at work so that he/she has more freedom during the day. Within the PD treatment, there are two types of exchange schedules: CAPD (continuous ambulatory peritoneal dialysis) and CCPD (continuous cycling peritoneal dialysis), the latter of which uses an automated cycler to perform the multiple exchanges within the abdomen and allowing a patient to do the treatments fully at night while asleep [4].

III. Motivation

Most current on-the-market automated cyclers are manually programmed and do not include any auto-programming capabilities. This means that a patient has to spend a lot of time programming his/her devices before he/she can actually begin treatment, and if doing this programming at night when a patient is less awake, this could lead to human error. In a hospital setting, auto-programmable devices are especially popular for confirming patient medications between the pharmacy and other hospital wards, especially in high-pressure situations where human error increases. This method for faster care can lead to better outcomes for patients, better results for hospitals, and more profit for the medical device companies that create devices with such capabilities. The purpose of this project is to create a proof of concept mobile 2D data matrix barcode scanner for APD cyclers as a first step to creating a wireless auto-programmable system.

Related Work:

The work examined for the purposes of this project looked at 2D data matrix barcode computational imaging techniques on a broader application spectrum, not specifically for medical devices. Balan and Parvu [1] proposed a 2D data matrix barcode scanning algorithm for mobile devices that uses contour tracing to identify the key corners and segments of the matrix. Their general approach includes pre-processing the image, trace the region contour, finding the two best segments that identify the L finder pattern, approximating the fourth corner, using arc circle fitting to identify the entire region of the bar code, finding the data pattern's midpoint coordinates, extracting the binary pattern information based on the midpoints, and then finally decoding the barcode region information. Chen et al [7] focus on finding the exact L finder pattern and dashed border locations in an image by using the line segment detector (LSD) linear algorithm for the L pattern portion and the RANSAC algorithm proposed by another source to find the alternating borders. Compared to other algorithms used, they found that their approach had three advantages: robustness, accuracy, and ability to be used in real-time applications, especially compared to other work that had been done that used the Hough transformation algorithm instead of the implemented LSD approach. A paper written by Brouwer [5] includes a pre-processing algorithm that transforms a raw image into a clean version of the 2D barcode that uses canny edge detection, determines the barcode bounds, smooths the image with LPF smoothing, and rotates the image after estimating the ideal angle. Several different machine learning classification algorithms are tested to determine the midpoint of the white and black pixels. Brunelli et. al [2] looked at a general approach for all 2D barcodes (including data matrix codes) that included the following: a) region of interest identification using Sobel masks, b) code location, where for data matrix barcodes, a point which is at the intersection of two orthogonal long segments was identified as one of the main 4 corners, c) code segmentation, where an algorithm that sets a threshold for a point given the averaged grey level of neighboring pixels (called the Niblack algorithm) was used, and d) decoding, where the area is meshed and then evaluated to identify the binary value. Gaur and Tiwari [6] proposed a method for QR codes (but can be applied to other 2D code structures) to pre-process the image via color mode conversion, image edge detection, bounding box formation, region of interest segmentation, and masking of the image in binary form. An open source library that is written to decode 2D bar codes, called ZX-ing library, is used in this paper for the decoding portion. Blurred images and deformed images are also used to compare the detection rate using the proposed methodology versus images without blur.

Project Overview:

This project will start by using images of 2D data matrix barcodes taken from the back of automated peritoneal dialysis devices, which encode the cycler's product number. This will be particularly useful information to decode first, since we need to know what device to program our information to in an auto-programming application. The sizes will vary between 12x12 and 16x16 barcodes, depending on the device it is taken from. An example of these input images are as shown below:

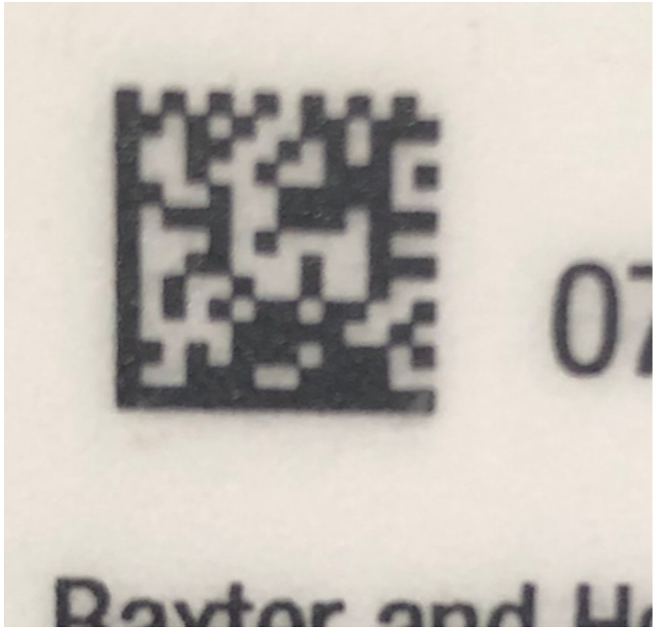

Figure 2: 12x12 2D Data Matrix on APD cycler

Figure 3: 16x16 2D Data Matrix on APD cycler

As mobile images such as these are particularly blurry and noisy when zooming in closely to the barcode, I plan on experimenting with the denoising and deblurring techniques that we used in the homeworks for this class to better distinguish the edges of the input images. Then, pre-processing techniques to separate the bar code from the rest of the image, which will include edge detection filtering, gray level thresholding, and segmentation, will be attempted. To get a more minimal bounding box on the code, I'd like to try using my own versions of the methodologies described in [2] and [5], which mainly focus on finding the L pattern and then the other two corners. I hope to find the most time and memory efficient approach possible for this part while still maintaining accuracy, as a quick solution is needed in more time-critical medical situations.

Once the barcode is segmented out, I'd like to try to develop my own decoding algorithm, which will first identify the midpoints of each of the pixels in the barcode to better identify the separation point between pixels. In particular, I'd like to take advantage of Stanford course EE 368's resources, where a class-wide course project was done in the 2005/2006 year for visual code detection (visual codes are another form of 2D barcodes, with a different finder pattern to those of data matrix barcodes). In the results for that year, it seems that a lot of students attempted to use built in properties such as eccentricity and centroid of segmented to help identify the finder's pattern, so I will try to utilize this for my application. Should time permit, I will use the resources available on the Youtube channel robomatics (see link here) which has videos on how to identify 12x12 and 16x16 data matrix barcodes to create my own decoding masking function. If not, I will look into using the open source ZX-ing library used in [6] to handle decoding.

Also, if time permits, I'd like to again use EE 368's resources to develop a app via Android Studio that will allow a user to take an image and then have the app display the decoded device information back to the user. The exact design of this app hasn't been finalized but would at a minimum include a) a homepage, b) allow a user to take a picture of a data matrix barcode (with perhaps a square drawn in to have the user fit the matrix into this shape), and c) a page describing the resulting information. In the future, this app could be developed to also scan the dialysate bags and then wirelessly program the scanned cycler with the necessary treatment parameters.

With the proposed solution, there should be no additional costs in terms of materials, as any possible tools used will be free and open source.

Milestones and Timeline

Week 1 (2/13-2/20): Segment out 2D data matrix code from input image. Identify L finder's pattern and other corners for better results

Week 2 (2/21-2/26): Implement code to identify midpoints of pixels within barcode for better decoding

(2/27: Course exam)

Week 3 (2/27-3/6): Implement decoding algorithm, begin developing mobile app

Week 4 (3/7-3/15): Finalize app, prepare for poster session and final report

(3/15: Turn in final report)

References

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