Handheld PC with Camera Used for Reading Information Dense Barcodes

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***Abstract*—We have made a working demonstration of a vision system using a personal digital assistant (PDA) with an integrated low resolution camera for reading a two dimensional (2D) barcode code. This demonstration will show the systems ability to decode information dense 2D barcodes in near real-time. Image analysis is done locally on the PDA with no external services used.**

***Index Terms*—Mobile communication, cameras, machine vision, bar code**

I. Introduction

HANDHELD electronic devices such as PDAs (personal digital assistants) and cell phones are increasingly often delivered with integrated low resolution CMOS cameras. These devices make up an advanced sensor system that can be used for retrieving information not easily readable by humans, like barcodes used on merchandises.

We have made a system that uses a commercially available PDA with camera for reading an information dense 2D barcode. Both the PDA and the camera used are first generation PDAs delivered with a plug in-camera (in 2001).

The high information density allows the system to give information about items without accessing an external database. Example applications are extracting information from business cards, address labels or machine parts.

The demonstration shows the complete system integrated on a PDA. We will let users capture images with the PDA's camera. The PDA will automatically analyze the images and display information contained in the code on the PDA's screen. This decode operation is done in near real time.

We will start describing the solution constraints in section II. The chosen design strategy is sketched in section III. In the final section we give a brief conclusion.

II. Design Constraints

There are two kinds of constraints posed upon this particular application: Functional constraints given by the customer's solution requirements, and inherent system constraints given by the hardware platform.

A. System constraints

We used a Casio Cassiopeia PDA with a Casio JK-710 PC camera plug-in card for development, which was state-of-the-art at the time of implementation (autumn 2001). It was chosen as we thought it representative of coming camera cell phones.

This system has a 150 MHz MIPS processor and 32 MB RAM. This means that any algorithms we design have to be simple and not resource intensive.

The camera supplied with the system has rather low resolution (640x480) and a F2.8 lens with macro function. The macro function allows us to shoot close-ups without focus blur. However, the lens' barrel distortion is large, and there are significant perspective effects. These lens effects must be handled by the designed algorithm.

B. Functional constraints

The goal of this particular application was to transfer as much information as possible using a single code and one user-captured image. Our goal was to encode 200-300 bytes in one barcode. By comparison, common barcodes encode 8-10 bytes.

The decoding application is interactive. It is thus necessary that decoding is done in real-time, as the user will not have patience to wait more than 2-3 seconds for a successful result.

User-captured images also mean that we must allow the user to shoot images without too precise alignment of code and camera. This requires the algorithm to automatically adjust for the capturing angle.

III. System Design

The constraints listed above – simple decoding algorithm, large lens distortion and a satisfying user interaction – were handled by crafting a new barcode suitable for the application and designing a fitting decoding algorithm.

We have tried to put much thought into the matrix code design in order to make the decoding algorithm simple and implementable on a weak processor.

A. Matrix Code Design

There is an abundance of barcode standards. Many are based on 1D codes with too low information density for our purpose [1], [2].

There are numerous 2D codes as well. Many of these share a common design pattern [3]-[5]:

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- Ensure robustness by encoding data first using Reed-Solomon encoding
- Encode the information using a grid of black or white dots. Zeros are rendered black; ones are white.
- Include a pattern which facilitates a later estimation of grid axis parameters under a linear image transformation. This pattern consists usually of three dots, one or more concentrical circles or two perpendicular lines.

The assumption about only linear transformations does not hold in our case. The perspective effect is significant and perspective-planar transform occurs. This transform requires at least four reference points to do grid axis parameter estimation. In addition, a significant lens distortion occurs as well. This makes existing 2D codes unsuitable.

We therefore chose to create our own code which incorporates four square corner dots (Fig. 1) for estimating the global transform parameters precisely. In addition, we have also included an alternating black-white border between these points in order to explicitly specify the density of the grid. This pattern allows us to correct some local non-linear transforms in the image. The central part of the code contains Reed-Solomon encoded data, where each grid dot represent one bit in the encoded message.

B. Image Analysis Overview

The decoding of the image is entirely performed on the PDA. The decoding can be split roughly into six steps:

1. Lens correction to correct for global lens distortion using a pre-calculated correction function.
2. Contrast enhancement using Niblack's algorithm [6] followed by thresholding the image using the algorithm of Ridler & Calvard [7].
3. Recognition of the square corners are done with shape analysis and subsequent square verification using geometrical considerations.
4. Robust recognition of alternating border pattern, and use of these locations to accurately span the grid thus defining the center position of all grid dots.
5. Extraction of the message encoded into the grid by converting each grid dot into a bit in the encoded message.
6. The decoding step of Reed-Solomon (RS) is performed in order to correct any read errors. If RS fails, the code is rotated up to three times and decoding reattempted.

In our demo application, the time consumption from image capture to result is typically 5-6 seconds.

IV. Conclusion

We have successfully implemented a vision based barcode reader for information dense bar codes on PDA with a low resolution camera. All analysis is preformed on an off-the-shelf PDA with no external services used. This demonstrates the viability of such systems.

In addition, this paper has listed some of the concerns that have to be taken into account when designing computer vision systems for PDAs, camera cell phones, or similar systems. These include camera and lens properties, the degrees-of-freedom introduced by user shot images, and the limitations of the PDA's processor and memory.

This system helps change the included cameras on cell phones and PDAs from mere entertainment gadgets into useful tools for commercial, practical, or professional applications.

Acknowledgment

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References

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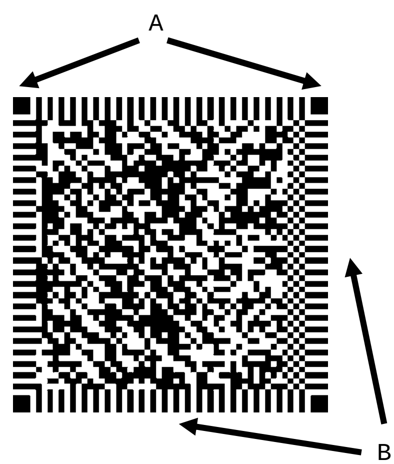

Fig. 1. The designed 2D barcode containing the first author's contact details. A) Square corners to estimate linear or perspective transform. B) Alternating black/white pattern to find the grid points. The centre area encodes the actual information.