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ORIGINAL RESEARCH PAPER

Robust real-time detection of multi-color markers on a cell phone

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Abstract We describe a fast algorithm to detect special multi-color markers with a camera cell phone. These color markers can be used for environmental labeling, for example, as a wayfinding aid for persons with visual impairment. Using a cascade of elemental detectors, robust detection is achieved at an extremely low computational cost. We also introduce a strategy to select surfaces for the marker that ensure very low specular reflection, thus facilitating color-based recognition.

Keywords Color constancy · Mobile vision · Cascade classifiers · Assistive technology · Fiducial design

1 Introduction

Camera-equipped programmable cell phones have become the platform of choice for a wide variety of mobile computer vision applications, including augmented reality [26], gaming [31], mobile OCR (http://www.knfbreader.com), and barcode reading [10]. Our work is motivated by a specific goal: helping a blind person to find their way around in a suitably equipped environment. Specifically, our system is based on simple 'markers', easily detectable by a cell phone, that can be placed in key locations in the environment. A blind person can search for such markers by orienting the camera phone in different directions, effectively 'scanning' the environment. Once a marker is detected by the camera phone, the user is prompted by an acoustic signal. If desired, the user can move towards the marker (which could be placed near a point of interest) by keeping track of the marker location via the camera phone. The marker may also contain a certain amount of information, for example, in the form of an ID that can be used as a query to a locational database. In this way, the user could be provided with turn-by-turn instructions to reach a specific destination.

Our system uses multi-colored pie-shaped markers, specifically designed for fast recognition via mobile vision (see Fig. 1). Normally, color-based recognition requires some sort of color constancy operation to deal with varying and unknown illuminants [11]. In our case, this is not necessary because the colors of the different surfaces in the marker are approximately co-variant with respect to changes in illumination. Because no pre-processing is necessary, our color-based detection algorithm is inherently fast. For added speed, a cascaded scheme is implemented. Most pixels are ruled out by the first stages of the cascade, which reduces the overall average computational cost. Further processing stages filter out any remaining false detections and compute the approximate distance to the marker (by measuring the amount of foreshortening).

We introduced our marker design elsewhere [5], along with a very simple detector and a post-processing (segmentation) algorithm [6]. User studies with blind testers of this system have been reported in Manduchi et al. [17]. In this contribution, we present a new marker detection algorithm, which is more efficient and accurate than previous approaches, while achieving high computational efficiency. For example, our system only needs to perform 1.1 multiplication and additions and 1.65 comparisons per pixel (on average) when searching for a color marker with 98% correct detection rate and 0.001% false positive rate. Note that the false alarms rate is then reduced further via geometry-based processing [6]. On a Nokia N95 8GB cell phone processing images at VGA resolution, we

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