Towards next generation barcode scanning

[Poster Supplement]

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ABSTRACT

Smartphones and tablets are increasingly used to scan visual codes that act as physical hyperlinks to digital information. Compared with the outstanding performance of enterprise laser scanners, smartphone cameras suffer from defocus and motion blur. In this project, we propose to turn every smartphone into an enterprise-grade barcode scanner by adapting the latest research results in photograph restoration to the very specific properties of barcode images.

Categories and Subject Descriptors

J.7 [**Computers in Other Systems**]: Consumer products; I.4.4 [**Image Processing and Computer Vision**]: Restoration; I.5.4 [**Pattern Recognition**]: Applications

General Terms

Algorithms

Keywords

visual codes, motion blur, deblurring

1. INTRODUCTION

Cameras in today's smartphones and tablets are increasingly used to scan visual tags (e.g., barcodes, QR-codes) that act as physical hyperlinks to digital information [1]. Consumers are scanning codes on products to compare prices, read reviews, and analyze nutrition information; merchants are using tablets as mobile point of sale systems, or to redeem coupons. Factory workers and employees, on the other hand, need to carry dedicated enterprise handhelds with active laser scanners. These devices are heavy, their proprietary protocols are difficult to integrate into business software, but most importantly, they are very expensive and therefore only selected employees can use them.

While dedicated barcode scanners provide excellent performance, smartphone-based solutions suffer from motion and shake blur and require the user to align the code close to the camera. These limitations make their use challenging in enterprise applications where scanning speed and reliability are of great importance. One may expect that RFID will soon replace visual codes but we argue that they will remain an indispensable object identification method because of the limitations of RFID in certain scenarios (e.g., metallic parts or water content).

In this project, we propose to turn every smartphone into an enterprise-grade barcode scanner with laser-like scanning performance. Our approach will take advantage of multiple images in a video stream and adapt the latest research results in motion blur compensation to the barcode domain. Such a ubiquitous, smartphone-based scanning solution will improve business processes because each employee can have a programmable barcode scanner in the pocket and can access digital information on every object across the whole value chain.

2. CHALLENGES

We consider two typical scanning scenarios. First, the user holds the smartphone in one hand and one or more objects in the other hand. The main challenges here are out-of-focus blur, non-uniform camera shake blur, and motion blur with parallax effects caused by the depth difference between the background and the handheld object. Second, the user swipes the object(s) past a static camera. In this scenario the fast object movement has to be compensated and probably several blurred barcodes have to be detected simultaneously.

Current barcode scanning solutions by companies such as RedLaser [2] and Scandit [3] can successfully compensate for out-of-focus blur. This allows barcode scanning on smartphones without built-in autofocus and accelerates the scanning on devices with autofocus. The existing solutions, however, cannot compensate for blur caused by the relative motion between the camera and the scanned object, and for shake blur caused by the user's hand.

High-end cameras address the latter case with optical image stabilization, where motion sensors control mechanical actuators that shift the sensor or the lens during exposure to compensate for motions of the camera. Unfortunately, image stabilization neither prevents motion blur caused by the movements of the object, nor extreme translational movements of the camera, nor rotation around its optical axis. We expect the spread of handhelds with image stabilization hardware in the future, but the mentioned limitations de-

MUM '12, Dec 04-06 2012, Ulm, Germany
ACM 978-1-4503-1815-0/12/12.

mand software-based enhancements.

Furthermore, there is no laser beam anymore that shows the user where the scanner is currently reading. Therefore, we first have to find the codes in a larger image area. However, an efficient code localization algorithm can immediately open the doors for scanning many codes simultaneously, which is not possible with dedicated readers. If we want to be able to scan multiple smaller codes as well, the resolution of the image sensor may not be high enough.

3. RELATED WORK

Post-shoot photograph deblurring has been an active research area in the last decade. Unfortunately, finding the original sharp image and the blur function from a given blurry image is an ill-posed problem. Both defocus blur and motion blur can be modeled as a convolution with a blur kernel (also called point-spread function or PSF), but while the defocus kernel is well approximated by a 2D Gaussian, a motion blur kernel can have practically arbitrary form. Moreover, the kernel may even vary over the image. Despite the amazing progress in this research area, a method for a arbitrary kernels is not known. While recent techniques (for a survey please refer to [4]) produce impressive results on natural images, they all have to make assumptions that may not be true in barcode scanning:

Uniform kernel and regularization: Earlier attempts posed regularization constraints on the PSF, while recent methods constrain the latent sharp image (e.g., by shaping the distribution of the gradients). These techniques all assume a uniform PSF over the image and iteratively estimate the sharp image in one step and the PSF in another step. While they achieve impressive results, they also have their limitations. In particular, they cannot handle in-plane rotations and parallax effects, and assume a static scene. All these assumptions are violated in the situation of handheld barcode scanning. The joint optimization scheme of these algorithms involves excessive computations therefore they are not suitable for a live scanner application.

Special hardware: Alternative approaches are those that use dedicated hardware to aid the deblurring process. Examples include fluttered camera shutter, varying exposure time of subsequent frames, or combining a high frame rate video camera with a still camera to help in recording the PSF. These methods rely on precise motion segmentation and/or the knowledge of object velocities, and cannot handle blur caused by camera rotations.

Motion models: These approaches can deal with spatially varying blur, but restrict the problem to a specific motion model (e.g., affine motion, rigid body motion). Determining the camera motion during the exposure time can be assisted by inertial sensors, or it can be treated as an image registration problem. To keep the model tractable, one has to assume a planar scene far away from the camera.

Multiple images: Earlier attempts showed how significant improvements can be achieved when multiple blurry images of the same object are available, which is the case when scanning a barcode with a mobile camera.

Overall, the general photograph deblurring algorithms today have very high computational requirements and are tuned for natural scenes. Our experiments showed that they often fail with artificial image content such as visual codes because their assumptions (e.g., PSF uniformity, natural image priors) do not hold. Our contribution will be a new blurry decoder algorithm that exploits the very distinct properties of barcode images and runs in milliseconds on a smartphone.

4. TOWARDS NEXT GENERATION BARCODE SCANNING

Recent methods such as [5] recover the PSF from its Radon projections by inspecting how sharp edges of the scene get blurred in the final image. This approach is especially appealing since visual codes contain a large number of sharp edges. Moreover, 2D codes are also rich in corners that are more distinctive under blur and make blurry tracking feasible. The code region itself is planar, so a uniform PSF assumption is valid in the code area. We have access to multiple images of the camera stream, and the inertial sensors available in today's smartphones allow further improvements in the precision of PSF estimation. A fundamental difference between deblurring photographs and deblurring barcodes is that codes do not necessarily need to be very sharp for decoding. Therefore, we may arrive at an acceptable image within a few iterations.

5. OUTLOOK AND IMPACT

We have shown that deblurring visual codes differs from deblurring general photographs and why existing algorithms fail on them. Currently, we are investigating various PSF estimation algorithms with the above mentioned barcode properties in mind. To limit our search space to uniform PSFs, we have developed a localization algorithm which is able to find various kinds of (blurry) visual codes in an image. Given an efficient PSF estimation algorithm, we still have to explore how existing non-blind deconvolution algorithms need to be adjusted for visual tag content to avoid the common ringing artifacts. As part of the project, we will further optimize for speed by exploiting the capabilities of multi-core CPUs and mobile GPUs.

Realizing laser-like barcode scanning performance with smartphones would have a significant impact on business processes in the enterprise domain but it would also bring many benefits to consumers. For employees, smartphones could simply be put into a rugged shell and replace the expensive dedicated scanning hardware. For consumers, the improved performance means that barcode scanning gets even easier - facilitating price comparison, accessing product information and building shopping lists. Overall, enterprise-grade barcode scanning would assert the role of the smartphone as the essential go-to tool for bridging the gap between the physical and virtual world.

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