An Adaptive Thresholding Algorithm for the Augmented Reality Toolkit

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Abstract

It is well known that fixed global thresholds have adverse effects on the reliability of marker-based optical trackers under non-uniform lighting conditions. Mobile Augmented Reality applications, by their very nature, demand a certain level of robustness against varying external illumination from visual tracking algorithms. Currently, ARToolKit depends on fixed-threshold image-binarization in order to detect candidate fiducials for further processing. In an effort to minimize tracking failure due to uniform shadows and reflections on a marker surface, we propose a fast algorithm for selecting adaptive threshold values, based on the arithmetic mean of pixel intensities over a region-of-interest around candidate fiducials.

Keywords: ARToolKit, Adaptive Thresholding

1. Introduction

In a recent paper [1], Naimark and Foxlin go into some detail illustrating the lack of robustness against varying lighting conditions exhibited by existing fiducial-trackers. The authors particularly point out the weakness of a global threshold, as currently implemented in ARToolKit [2]. Clearly, a fixed-level thresholding for fiducial-segmenting is occasionally inadequate to cope with even the most generic lighting phenomena, such as shadows or reflections off a marker's surface.

Particularly for Mobile Augmented Reality, where one cannot assume the luxury of operating in a controlled environment, it is imperative to introduce a certain level of adaptivity towards varying illumination. In an effort to overcome ARToolKit's problems with temporary uniform shadows cast on markers, as well as sporadic reflections off the marker's dark areas, we have devised an adaptive thresholding algorithm that seamlessly fits within ARToolKit's existing function framework.

2. Algorithm

Our algorithm operates on a per-marker basis and evaluates the mean pixel luminance over a thresholding region-of-interest (ROI), which we defined as bounding rectangle around the marker's axis-aligned corner vertices in screen space. If a marker has been detected in any given frame, its bounding rectangle will be used as thresholding-ROI prediction for successive frames. This method yields good thresholding levels in practice, given sufficiently high video frame rates. Whenever tracking of a marker is interrupted due to occlusions or motion blur, the previously obtained ROI will be progressively enlarged until it covers the whole video frame. Additionally, the thresholding level will gradually converge back towards a static initial value (global threshold), which is done by defining the adaptive threshold as the weighted average between the mean luminance distribution across the marker's ROI and a global threshold. The weight between the adaptive and static component shifts depending on the time elapsed since a marker was last detected.

3. Implementation

We implemented our algorithm as an extension to ARToolKit without modifying the core functionality. Intel's Integrated Performance Primitives library [3] has reduced the computational overhead of the threshold estimation to a small fraction of the overall processing complexity. Running our test applications at video resolutions of 720 x 576 pixels (at 25 Hz), we observed approximately 40-50% CPU usage on a Pentium 4 workstation.

4. Results

Obviously, our technique cannot compete with the more elaborate binary pixel classification algorithms found in Computer Vision literature. However, first tests [Fig. 1] have shown the algorithm to greatly outperform global thresholding, especially under conditions in which fiducial markers experience little movement relative to the camera, while remaining inside the camera's field of view most of the time.

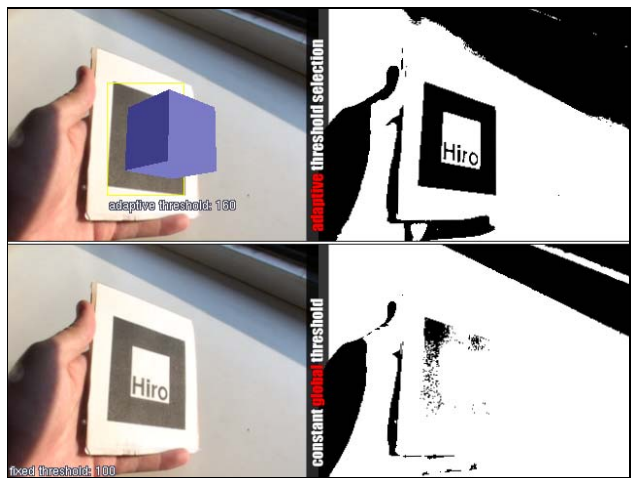

Fig. 1: Reflection off a marker's surface with adaptive thresholding (upper) and a global threshold (lower).

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6. References

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[2] Billinghurst, M. and Kato, H. (1999). Collaborative Mixed Reality. In *Proceedings of 1st Intl. Symposium on Mixed Reality (ISMR99)*, pp. 261-284.

[3] Intel® Integrated Performance Primitives http://www.intel.com/software/products/perflib/