A Shape-Free, Designable 6-DoF Marker Tracking Method

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1. Introduction

Markers are widely used for camera-based interaction. Yet, most of the marker tracking methods have considerable limitations in shapes and designs; they are not usually visually meaningful to the users. Such an issue on visually communicative designs can be very important to provide visual cues in a mobile/pervasive environment where a user must first notice a marker and understand its meaning before initiating interaction, unlike in an immersive environment with a head-mounted-display that keeps displaying information on the detected markers.

We have developed a novel tracking method with shape-free designable markers, based on topological region adjacency and a method similar to geometric hashing. It can also distinguish the different markers with the same topological structure and provide 6-DoF pose estimation. Lack of such features are significant deficits of existing topology-based methods.

2. Related Work

We briefly review *D-Touch* system by Costanza et al. [1], since *D-Touch* is also based on topological region adjacency for its marker recognition and is focusing on visually communicative designs similar to our new method.

Figure 1 (left) shows an example of a *D-Touch* marker, taken from [1]. The topological region adjacency graph, (or the containership information of black/white regions) of this marker is shown on the right. Such a topological structure is sought from the binarized/segmentized input image to recognize a marker. The branch nodes of this tree are sorted by the number of their leaf nodes. Adding the color to this sequence, its marker ID is obtained. (In Figure 1, the ID is *1;1;1;4;black* as shown .)

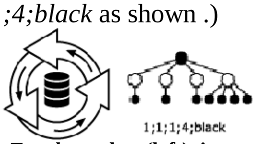

Figure 1. A *D-Touch* marker (left), its topological region adjacency graph and ID (right) [1]

Such a topology-based method gives considerable freedom in marker design, since the shapes of each region are not involved in recognition. However, such a method based only on topological information is inherently incapable of distinguishing two different markers with the same topological structure. It also cannot provide 6-DoF pose estimation, since topological information doesn't convey position information; to estimate pose in 3D space from a given input image, the matching of at least 4 points between the input and the marker coordinate is required.

3. Description of Our Method

Figure 2 describes our tracking method. Our method is also based on topology, yet we use the topological information only to find marker candidates *(Figure 2. above*).

To determine the actual marker detected among these candidates, we apply a method similar to *geometric hashing* [2], voting the centroids of the leaf nodes in the region adjacency graph to the hash tables (*Figure 2. below*).

The models for each marker are prepared by projecting its leaf nodes to the hash table bins. In this phase, we first pick up 4 leaf nodes from the candidate, as a basis to find a homography between the input image and the model. The other leaf nodes are used to vote to test if the homography and the model are correct. If a leaf node can be projected to a bin where there is any preregistered entry, it is counted as a valid vote. If not, the vote simply fails.

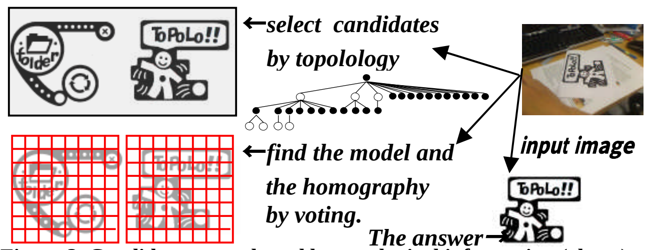

Figure 2. Candidates are selected by topological information (above). A model is determined by voting to the bin. (below). Notice the two markers above share the same topological structure.

Among those possible combinations of 4-point basis and the models, the most voted combination is selected as the answer (the detected marker). Now that the marker is determined and the matching of 4 points to the given input is known, they can be used for 6-DoF pose estimation.

We also utilize topological information to reduce the computation cost when finding a homography and voting. Matching and voting are tried only between those points that are topologically plausible. Such a use of topological information is quite important in our method, since unlike traditional geometric-hashing, our method currently tries all the possible homographies to make marker detection and pose estimation more robust and stable.

4. Experimental Application

The pictures from our prototype are shown in Figure 3. Two markers with the same topological structures were used. The prototype runs in real-time even on a low power CPU for mobile internet devices, about 70ms/frame on Atom Z520-1.33GHz/WinXP in 640x480, excluding the time cost to overlay 3D models (for a desktop CPU, 9ms/frame on Core2Quad-2.5Ghz, WinVista).

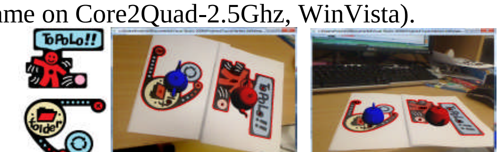

Figure 3. Two different markers with the same topological structure (left) are correctly distinguished and overlaid 3D models (right 2).

References

[1] Costanza, E. & Huang, J (2009). "Designable Visual Markers", in Proceeding. of SIGCHI09, 1879-1888

[2] Wolfson, H.J. & Rigoutsos, I (1997). "Geometric Hashing: An Overview", IEEE Computational Science and Engineering. 4(4), 10-21

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