Finding and refinement planes in 3D points cloud obtained under 3D recovery from image set

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Generally, a result of 3D recovery from an image set is a 3D points cloud. But a mesh is required to visualize 3D scene. Thus, a problem of mesh construction from 3D points cloud arises. The proposed algorithm partially solves this problem – it recovers plane areas and replaces proper points in 3D model by polygons. The algorithm analyses the structure of 3D points cloud with hierarchical randomized Hough transform for plane areas. Using original images these hypotheses are verified by the difference image and refined via optical flow technique. We look for connected domains where the difference image brightness is small and the domains boundaries are used to form flat polygons which replace proper points in 3D model forming fragments of a mesh.

Inputs of the algorithm are: a set of images (Figure 1), corresponding feature points founded on them, recovered 3D coordinates of these points (Figure 4) and their errors estimates.

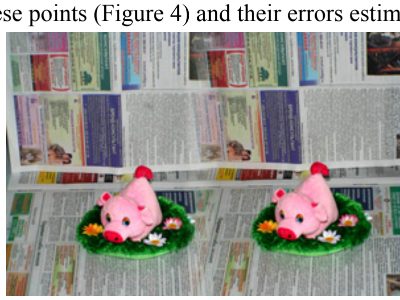


Figure 1. Stereo pairs of images were used in experiments.

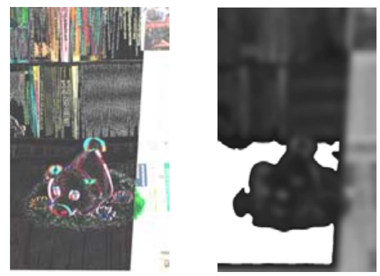
To form hypotheses of planes the hierarchical randomized Hough transform was applied to 3D cloud of points. Parameterization of plane with directional cosines and distance to origin was used**.** The 3D parameters space was separated into cells and plane searching was executed by consecutive detailing of separation.

On each detailing step, if amount of points $N > M$, then βN random sets of three points was considered, where $M:\ M(M-1)(M-2) \approx \beta \cdot N$. Else every set of three points was considered. For each such set, if points were not close to each other and to one line, plane parameters were calculated and points were placed into appropriate cell. For each cell containing more than $T_m < T_{m-1}$ points the next detailing step was executed. Then eliminating of outliers followed.

To check a hypothesis a homography matrix was found for the points related to this hypothesis. Normalized DLT algorithm [1] was used. The matrix was used to transform the first image via bilinear interpolation. Then a difference image (Figure 2) of the second image and the transformed first one was computed and matching of plane areas was refined using the Shi-Tomasi method [2]. If the hypothetic plane really exist on the images, corresponding area on the difference image is almost black.

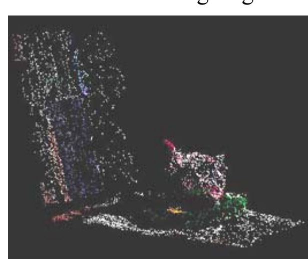
To pick out areas corresponding to the found plane Bresenham fill algorithm was applied to difference image. The filling was carried out for areas where intensity was close to zero and dispersion on original images was large (Figure 3). Then a boundary of this area was found and some of edge points (every 20^{th}) were selected to construct a flat polygon.

Transformations of 2D coordinates on image to coordinates on found plane in space and then to 3D coordinates were found by known feature points and their 3D prototypes. These transformations were used to find 3D coordinates of edge points. Then the corresponding polygon could be included into the model.



Figures 2, 3. Difference image and picked out plane area.

Testing has showed that the algorithm determines belonging of points to planes correctly (Figure 5), removes «wrinkling» of the model and widens the area corresponding to each plane in comparison with a direct 3D points triangulation. Points that aren't satisfy to the plane hypotheses often turn out to be separated into clusters allowing fragment-serial refinement of the model.



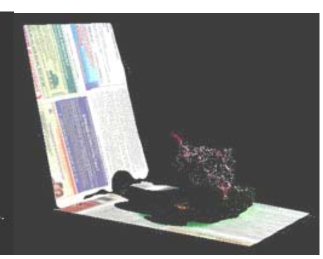


Figure 4. Input 3D points cloud. **Figure 5**. Model constructed using the proposed algorithm.

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[1] R. Hartley, A. Zisserman. *Multiple View Geometry in Computer Vision. Cambridge University Press 2004, 672 p.*

[2]J.Shi, C.Tomasi. *Good features to track //IEEE Conference on Computer Vision and Pattern Recognition (CVPR'94) (Seattle), June 1994, -P.* 593-600.