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3D Object Recognition with Keypoint Based Algorithms

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Dear colleagues and friends,

It is our great pleasure to invite you to attend the EURASIAN GIS Congress 2018 held in Baku on 04-07, September 2018. EURASIAN GIS Congress 2018 is a candidate of one of the most important event in the scientific schedule and tenders a possibility for researchers and academicians who researches on GIS and related disciplines. You can find a first class programme of plenary speakers, technical sessions, exhibitions and social events in this book. You will be able to catch up with the developments in Geographical Information Sciences, Information Technology, Environmental Management and Resources, Sustainable Agriculture, Surveying, Photogrammetry and Remote Sensing, meet friends and experience the traditional and fascinating culture of AZERBAIJAN. As a international congress in the field of geo-spatial information and remote sensing, EURASIAN GIS Congress 2018 is devoted to promote the advancement of knowledge, research, development, education and training in Geographical Information Sciences, Information Technology, Environmental Management and Resources, Sustainable Agriculture, Surveying, Photogrammetry and Remote Sensing, their integration and applications, as to contribute to the well-being of humanity and the sustainability of the environment. The EURASIAN GIS Congress 2018 will provide us an opportunity to examine the challenges facing us, discuss how to support Future Earth with global geo-information, and formulate the future research agenda.

150 scientists from 13 countries attended to the congress. 7 plenary speakers, 120 oral presentations and 8 poster presentations, all together with 135 in total, are presented during the congress. 135 presentations take place in 21 sessions in three days. **Atik, et al., (2019)** presented in the organization was selected for publication in **IJEGEO 6(1) as Short Communication.**

The Congress is carried out with the support of the organizations as the Konya Technical University, Selcuk University, Azerbaijan National Academy of Sciences Institute of Geography, Baku State University, Ministry of Agriculture of Azerbaijan Republic, General Directorate of Land Registry and Cadastre, General Directorate of Agricultural Reform of Turkey, International Federation of Surveyors (FIG), International Society for Photogrammetry and Remote Sensing (ISPRS) and Igdir University. In addition, the congress is also supported by the commercial organizations of INTEGRIS LLC, KUTLUBEY Engineering Co, RUBIKON Geosystems LLC, NETCAD, HARMIAD Surveying Engineers Businessmen Association, GEOGIS Engineering Co, MESCIOGLU Engineering Co, EMI Group Information Technology Co, PaksoyTeknik, and 4B Ölçüm.

Finally, we cheer on all of you to participate in this congress of EURASIAN GIS , and special thanks to all sponsorships and government partners for the congress. Enjoy your time and share your experiences with your friends.

Baku/Azerbaijan, September, 2018

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Short Communication

3D Object Recognition with Keypoint Based Algorithms

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Abstract

Object recognition is important in many practical applications of computer vision. Traditional 2D methods are negatively affected by illumination, shadowing and viewpoint. 3D methods have the potential to solve these problems, because 3D models include geometric properties of the objects. In this paper, 3D local feature based algorithms were used for 3D object recognition. The local feature was keypoint. This study aimed to research facilities of keypoints for 3D object recognition. Keypoint is feature of object that is detected by detector algorithms according to certain mathematical base. A recognition system was designed. For this purpose, a database that includes 3D model of objects was created. The algorithms were improved in MATLAB. The keypoints on the 3D models were detected using keypoint detectors. These keypoints were described by keypoints descriptors. The descriptor algorithms detect geometrical relation between each point of point cloud and create a histogram. In the third step, the keypoints in different point clouds are matched using the feature histograms obtained. Statistical methods are used to compare generated histograms. Thus, the two closest similar points between the different point clouds are matched. It is expected that the models with the most corresponding points belong to the same object. Euclidean distance between corresponding keypoints in the two point cloud is calculated. It has been accepted that the points are shorter than 10 mm. The positional accuracy of the matched points has been examined. Iterative Closest Point (ICP) was applied to the matching point clouds for this purpose. As a result, the graphics were generated that showed correct matching ratio and root mean square error. As a result, there are different approaches about 3D object recognition in literature. This study aimed to compare different keypoint detector and descriptor algorithms. Intrinsic Shape Signature (ISS) is keypoint detector algorithms. Point Feature Histograms (PFH) and Fast Point Feature Histograms (FPFH) are keypoint descriptor algorithms. The results of this study will provide guidance for future studies.

Keywords: 3D model, Recognition, Local Feature, Object

Introduction

Object recognition is a fundamental research area in computer vision. Detecting the identities and poses of the 3D objects is main task of a 3D object recognition system (Latharani, et al., 2011). 3D object recognition is used in much application such as robotics, biometrics, navigation, remote sensing, entertainment etc. (Guo et. al., 2015). The goal of 3D object recognition is to correctly identify objects in a point cloud and estimate their 3D pose (Lu et. al., 2014). There are two categories of existing 3D object recognition algorithms: global feature-based and local feature- based. Global feature-based algorithms extract feature from entire input object. These algorithms are affected by occlusion and clutter. Local feature-based algorithms are main focus of research of 3D object recognition, because local feature-based algorithms are robust to occlusion and clutter. Local feature- based algorithms extract local features from object stored in a library and input object. Then, the algorithms try to detect corresponding features from two objects (Guo et. al., 2015; Bayram et al., 2017).

In this study, a 3D object recognition system was developed by using local feature-based algorithms. Keypoint was used as local feature in the system. The system has three steps. In first step, the keypoints were detected by using 3D keypoint detector algorithm. In second step, the keypoints were described by using 3D keypoint descriptor algorithms. In final step, the corresponding points were detected by using histogram matching algorithm. The keypoint detector algorithm is Intrinsic Shape Signature (ISS). The keypoint descriptor algorithms are Point Feature Histograms (PFH) and Fast Point Feature Histograms (FPFH). Kullbeck-Leibler Divergence method was used to match local features. In next section, the mathematical models of the methods were explained. For accuracy analysis, Iterative Closest Point (ICP) method was applied. The aim of the study is to compare 3D local feature-based algorithms for object recognition.

Method and Materials

Intrinsic Shape Signatures (ISS)

In the ISS method, the support area of a point is determined by using a sphere that has certain radius. The points that are inside of the sphere are neighbour points of the central point. Firstly, the points are weighted.

$$\omega_i = \frac{1}{\|\{p_j : |p_j - p_i| < r\}\|} \quad (1)$$

Then, scatter matrix is computed. It is need to compute saliency value. Saliency is parameter that is used for selection of keypoints.

$$\Sigma(p) = \frac{1}{N}\sum_{q \in N(p)} (q - \mu_p)\,(q - \mu_p)^T \quad (2)$$

μ(p) is the average coordinate value of neighbour points of point p. Than the eigenvalue vector of the scatter matrix is computed. Calculated eigenvalues (λ1, λ2, λ3) are sorted from largest to smallest. When the ratios of the eigenvalues to each other are less than the specified threshold values, the point is selected as candidate for the keypoint. The points that has smallest λ3 in the its neighbourhood is selected as keypoint (Tombari et. al., 2013).

Point Feature Histograms (PFH)

Point Feature Histograms (PFH) are multidimensional histograms created using the different properties of each pair of points within the neighbourhood of a keypoint (Guo et. al., 2016). Local Reference System (LRF) of a keypoint is determined by using Darboux frame. Darboux frame uses normals to define LRF. Based on the LRF, geometric relation between all point pair in the support area are calculated.

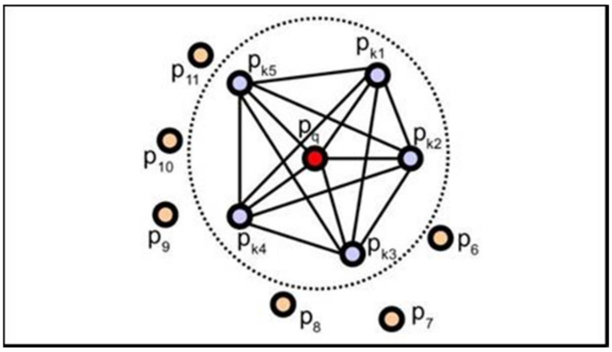

Figure 1. Point Feature Histograms (PFH) diagram.

Fast Point Feature Histograms (FPFH)

Fast Point Feature Histograms (FPFH) is faster version of the PFH method. FPFH calculates geometric relation between keypoint and its neighbours.

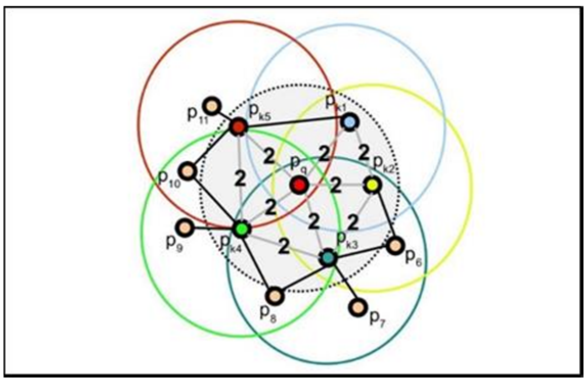

Figure 2. Fast Point Feature Histograms (PFH) diagram

It is named as Simplified Point Feature Histogram (SPFH).

$$FPFH(p) = SPF(p) + \frac{1}{k}\sum_{i=1}^{k} \frac{1}{w_k} . SPF(p_k) \quad (3)$$

Data

As application data, 3D point clouds of eight objects were used. Point cloud density is 1100/inc2. Point cloud density has been experimentally determined to decrease process load and to obtain sufficient geometric relation.

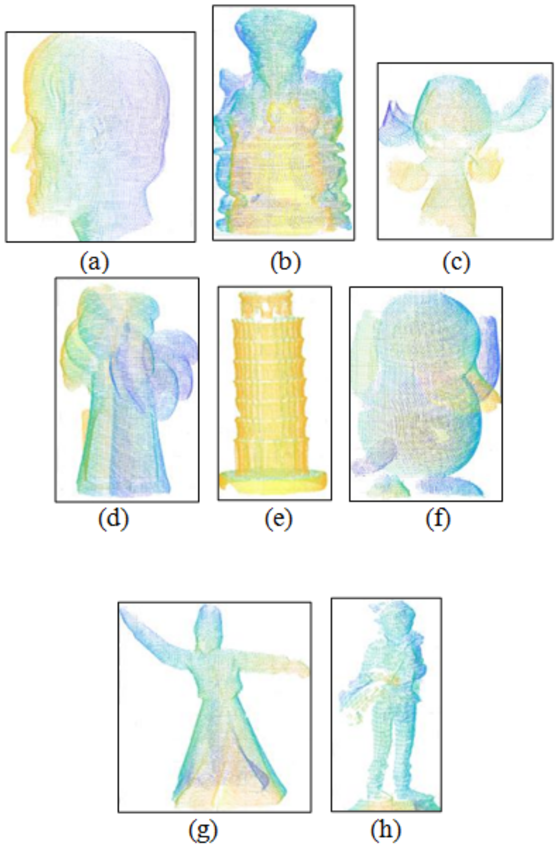

Figure 3. (a) Object 1 (b) Object 2 (c) Object 3 (d) Object 4 (e) Object 5 (f) Object 6 (g) Object 7 (h) Object 8

Application

3D Object Recognition

The algorithm consists of 3 steps. In the first step, 3D points are defined on the point clouds using ISS method. In the second step, key points are described using Point Feature Histograms (PFH) and Fast Point Feature Histograms (FPFH) histogram methods. In the third step, the keypoints in different point clouds are matched using the feature histograms obtained. Kullbeck-Leibler Divergence method (Wahl et al., 2003) was used for histogram matching.

$$\kappa(H_0, H_{O'}) = \sum_{i=1}^{d} (H_{O'}(i) - H_0(i)) \ln \frac{H_{O'}(i)}{H_0(i)} \quad (4)$$

3D Keypoint Detection

Keypoints were detected by using ISS method. For each scan 3D keypoints were determined with a 4 mm support radius.

Figure 4. Detected keypoints with ISS

Table 1. Number of ISS keypoints

Objects	Keypoints
Object 1	246
Object 2	183
Object 3	186
Object 4	73
Object 5	363
Object 6	122
Object 7	97
Object8	125

3D Keypoint Description and Object Matching

PFH and FPFH methods were applied to all keypoints detected by using ISS. The feature histograms were created for each keypoint. A histogram has 27 histogram group. An external model was given the system to detect same object from gallery. It is expected that the system will match the model with right object. Iterative Closest Point (ICP) was carried out for registration of the corresponding object models. If Euclidian distance between two corresponding points has lower values than 10 mm, this matching was accepted as correct. The histogram of correct matching and root mean square error were created.

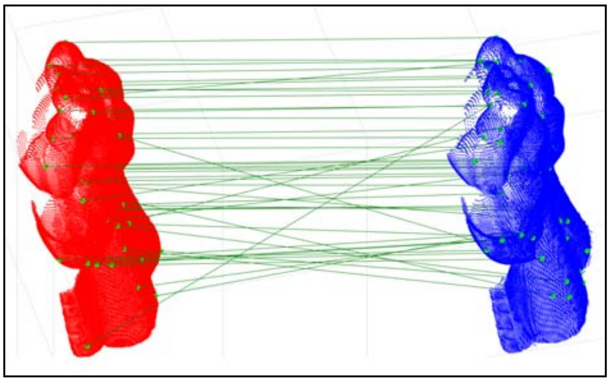

Figure 5. Matching points

Results and Discussion

In conclusion, with ISS-PFH 8 of 9 objects were truly recognized. With ISS-FPFH 7 of 9 object were truly recognized. When PFH is used, more key points are matching between the two point clouds. Considering the number of object recognized, it is seen that ISS-PFH is the best method to detect the right object. There is no significant difference between the methods according to root mean square error. In all methods a root mean square error of about 2 mm was determined with an accuracy of 10 mm.

The correct matching rate for both PFH and FPFH is up to 60% with 10 mm error. When all scans are examined, there is no difference between correct matching ratio. For the future works, there are many methods in literature used in 3D object recognition application. The study can be expanded using different methods. Otherwise, larger database can be used for evaluation of the methods.

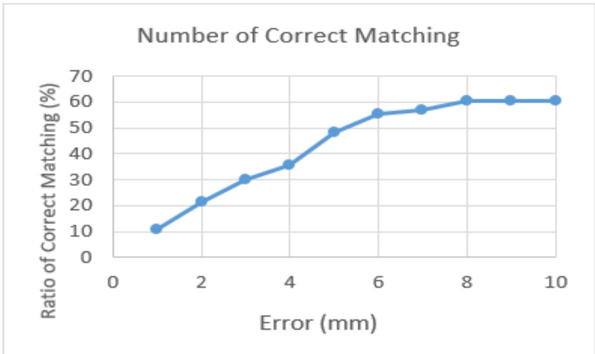

Figure 6. Number of correct match with ISS-PFH

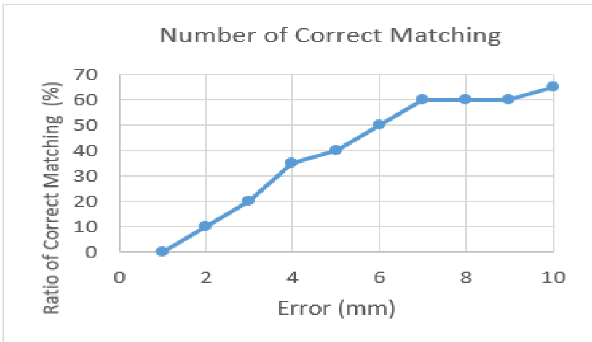

Figure 7. Number of correct match with ISS-FPFH

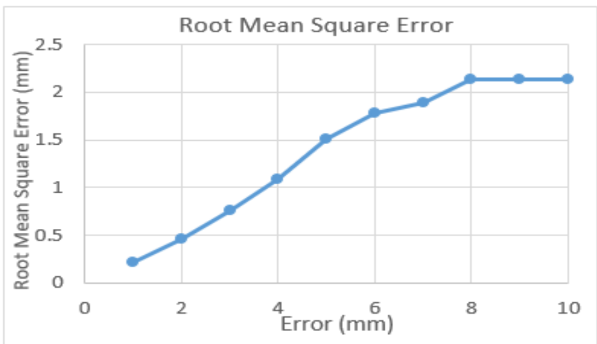

Figure 8. Root mean square error of ISS-PFH

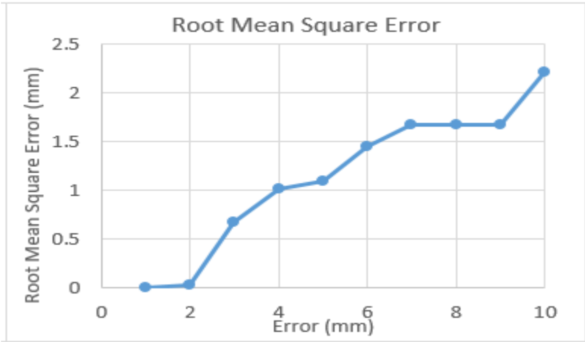

Figure 9. Root mean square error of ISS-FPFH

References

Bayram, B., Çavdaroğlu, GÇ., Şeker, DZ. & Külür, S. (2017). A novel approach to automatic detection of interest points in multiple facial images, *International Journal of Environment and Geoinformatics (IJEGEO),* Vol.4 (2), 116-127.

Guo, Y., Bennamoun, M., Sohel, F., Lu, M., Wan, J. & Kwok, N.M., (2016). A Comprehensive Performance Evaluation of 3D Local Feature Descriptors, *International Journal of Computer Vision,* 116(1), 66–89, 1411.3159.

Guo, Y., Sohel, F., Bennamoun, M., Wan, J., & Lu, M. (2015). A novel local surface feature for 3D object recognition under clutter and occlusion. *Information Sciences,* 293, 196-213.

Latharani, TR., Kurian, MZ. & Chidananda Murthy, MV. (2011). Various Object Recognition Techniques for Computer Vision, *Journal of Analysis and Computation,* Vol. 7(1), 39-47.

Lu, M., Guo, Y., Zhang, J., Ma, Y., & Lei, Y. (2014). Recognizing objects in 3D point clouds with multi-scale local features. *Sensors,* 14(12), 24156-24173.

Rusu, R. B., Blodow, N., & Beetz, M. (2009, May). Fast point feature histograms (FPFH) for 3D registration. In Robotics and Automation, 2009. ICRA'09. *IEEE International Conference,* 3212-3217.

Tombari, F., Salti, S. & Di Stefano, L., (2013). Performance evaluation of 3D keypoint detectors, *International Journal of Computer Vision,* 102(1-3), 198–220.

Wahl, E., Hillenbrand, U. & Hirzinger, G., (2003). Surflet-pair-relation histograms: A statistical 3D shape representation for rapid classification, *Proceedings of International Conference on 3-D Digital Imaging and Modeling,* 3DIM, cilt2003-Janua, s.474–481.