A NOVEL FILTERING APPROACH FOR ROBUST AND FAST KEYPOINT MATCHING IN MOBILE ENVIRONMENT

Jonghoon Seo, Seungho Chae,Yoonsik Yang, Heeseung Choi, Tack-Don Han

Author Affiliation(s)

ABSTRACT

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Index Terms— One, two, three, four, five

1. INTRODUCTION

Image matching is a fundamental problem in a variety of computer vision applications, including simultaneous localization and mapping[1, 2], object recognition[3], panorama stitching[4, 5], augmented reality[6, 7], and visual odometry[8, 9]. To enhance the image matching quality in various environments, many related techniques have been proposed, such as keypoint-based local matching, histogram-based global matching[10, 11], color-based matching[12, 13], and template-based matching[14], etc. Among them, keypoint detection and matching has created great interest since it can provide relatively high matching quality against severe occlusion and do not require segmentation for regions of interest. Also, recent work has concentrated on making invariant to image transformation with low computing power[15, 16].

The overall flowchart of keypoint matching and recognition is shown in Fig. 1. These procedure can be divided into two main phases: offline (training) and online (testing) procedure. Offline learning is prerequisite to online matching process. In offline learning phase, a set of reference images to be recognized is analyzed and stored as as types of descriptors in a database. In online learning phase, a newly captured image is analyzed and compared with the reference images in the database to find a nearest reference image. In each phase, common procedures for matching are keypoint detection, description, and matching. To analyze training images, at first, keypoints are detected from the images. Then, from those keypoints, local textures are analyzed and described. In this procedure, to provide robustness against rotation, scale, perspective transform, descriptors are constructed. Then, to be used in online phase, efficient matching structures, as databases, are constructed, such as partitioning trees[17, 18, 19], hashing[20, 21, 22]. In the online matching phase, the database is used to find the most similar corresponding keypoints pair with a given query image. To find the most similar keypoint pairs, with given a query image, keypoints are detected, detected keypoints are described about local texture, and compared with the preconstructed database.

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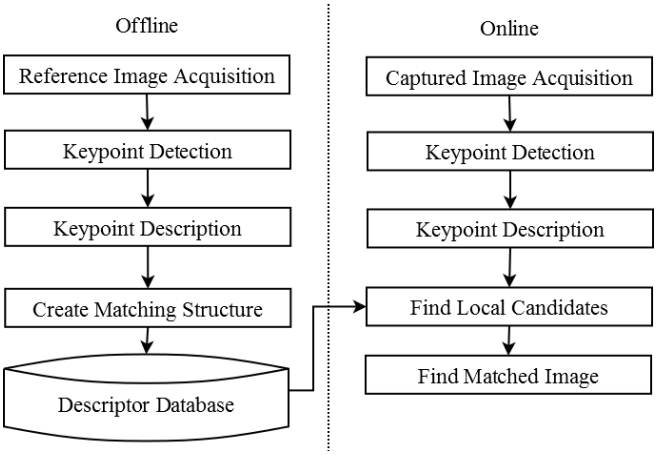

Fig. 1. Overall process of conventional keypoint-based matching

Conventional keypoint matching methods stores almost every keypoints which are detected by keypoint detection process. Keypoint detection processes are designed to extract repeatable keypoints and robust against arbitrary image transformation. Then, detected keypoints are independent to the follow matching procedures, and do not reflect quality of descriptors. Therefore, as seen Fig. some keypoints are not distinguishable, and they tend to cause inter-keypoint confusion and miss matching. `bad keypoint` 이미지 추가 Also, those detected keypoints are stored in database and are compared with keypoints in query images in every frame while matching. Then, it decreases the speed of matching. To overcome these problem, in offline learning procedure, detected keypoints are evaluated with respect to proposed matching quality criteria and filtered by the goodness score.

With this filtering method, only a small subset of keypoints is stored in the database. Accordingly, it provides more improved matching performance with faster matching speed.

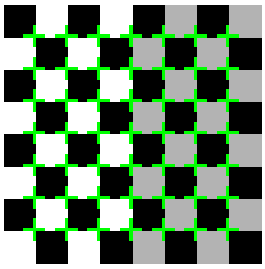

Fig. 2. Example of high repeatable but poor distinguishable keypoints. Conventional keypoint matching systems do not consider the discriminability of keypoints, so these keypoints usually stored and negatively affected matching.

2. PROPOSED METHOD

2.1. Problem

In general, keypoint matching methods 일반적으로 키포인트 기반의 매칭 방법은 미리 학습된 키포인트 데이터베이스 K^R와 입력된 영상을 분석하여 생성된 키포인트 집합 K^I를 비교하여, 가장 유사한 키포인트 pair 집합 $C = \{(k_i^R, k_j^I) | \underset{k_i \in K^R}{\operatorname{argmin}} \underset{k_j \in K^I}{\operatorname{argmin}} |k_i^R - k_j^I|\}$ 을 계산하는 과정이다. 기존의 키포인트 매칭 방법은 검출된 키포인트 집합 K^R을 그대로 사용하였으나, 본 논문에서는 키포인트 평가 함수($s(k)$)를 제안하여 이러한 평가 함수에 의하여 필터링된 집합 $K' = \{k | s(k) is \ \ high\} \in K^R$ 을 계산하고, 이러한 필터링 된 부분집합 K'는 필터링 되지 않은 K^R에 비하여 더 높은 인식성능을 보여줌을 증명하고자 한다. 조금만 더 늘여쓰자

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13. REFERENCES

[1] H.J. Chang, C. S G Lee, Yung-Hsiang Lu, and Y.C. Hu, "P-SLAM: Simultaneous localization and mapping with environmental-structure prediction," *IEEE Transactions on Robotics*, vol. 23, no. 2, pp. 281–293, Apr. 2007.

[2] AJ. Davison, ID. Reid, N.D. Molton, and O. Stasse, "MonoSLAM: Real-time single camera SLAM," *IEEE Transactions on Pattern Analysis and Machine Intelligence*, vol. 29, no. 6, pp. 1052–1067, June 2007.

[3] D. Nister and H. Stewenius, "Scalable recognition with a vocabulary tree," in *2006 IEEE Computer Society Conference on Computer Vision and Pattern Recognition*, 2006, vol. 2, pp. 2161–2168.

[4] M. Brown and D.G. Lowe, "Recognising panoramas," in *Ninth IEEE International Conference on Computer Vision, 2003. Proceedings*, Oct. 2003, pp. 1218–1225 vol.2.

[5] Daniel Wagner, Alessandro Mulloni, Tobias Langlotz, and D. Schmalstieg, "Real-time panoramic mapping and tracking on mobile phones," in *2010 IEEE Virtual Reality Conference (VR)*, Mar. 2010, pp. 211–218.

[6] G. Klein and D. Murray, "Parallel tracking and mapping for small AR workspaces," in *6th IEEE and ACM International Symposium on Mixed and Augmented Reality, 2007. ISMAR 2007*, Nov. 2007, pp. 225–234.

[7] Daniel Wagner, D. Schmalstieg, and H. Bischof, "Multiple target detection and tracking with guaranteed framerates on mobile phones," in *8th IEEE International Symposium on Mixed and Augmented Reality, 2009. ISMAR 2009*, Oct. 2009, pp. 57–64.

[8] Yang Cheng, M.W. Maimone, and L. Matthies, "Visual odometry on the mars exploration rovers - a tool to ensure accurate driving and science imaging," *IEEE Robotics Automation Magazine*, vol. 13, no. 2, pp. 54–62, June 2006.

[9] D. Nister, O. Naroditsky, and J. Bergen, "Visual odometry," in *Proceedings of the 2004 IEEE Computer Society Conference on Computer Vision and Pattern Recognition, 2004. CVPR 2004*, June 2004, vol. 1, pp. I–652–I–659 Vol.1.

[10] Xuesong Le and Ruben Gonzalez, "Improving histogram-based image registration in video sequences through warping," in *Advances in Multimedia Information Processing – PCM 2013*, Benoit Huet, Chong-Wah Ngo, Jinhui Tang, Zhi-Hua Zhou, Alexander G. Hauptmann, and Shuicheng Yan, Eds., number 8294 in Lecture Notes in Computer Science, pp. 269–280. Springer International Publishing, Jan. 2013.

[11] H. Goncalves, J.A. Goncalves, and L. Corte-Real, "HAIRIS: A method for automatic image registration through histogram-based image segmentation," *IEEE Transactions on Image Processing*, vol. 20, no. 3, pp. 776–789, Mar. 2011.

[12] Babu M. Mehtre, Mohan S. Kankanhalli, A. Desai Narasimhalu, and Guo Chang Man, "Color matching for image retrieval," *Pattern Recognition Letters*, vol. 16, no. 3, pp. 325–331, Mar. 1995.

[13] Mohan S. Kankanhalli, Babu M. Mehtre, and Ran Kang Wu, "Cluster-based color matching for image retrieval," *Pattern Recognition*, vol. 29, no. 4, pp. 701–708, Apr. 1996.

[14] S. Korman, D. Reichman, G. Tsur, and S. Avidan, "FasT-match: Fast affine template matching," in *2013 IEEE Conference on Computer Vision and Pattern Recognition (CVPR)*, June 2013, pp. 2331–2338.

[15] Gerardo Carrera, Jesus Savage, and Walterio Mayol-Cuevas, "Robust feature descriptors for efficient vision-based tracking," in *Progress in Pattern Recognition, Image Analysis and Applications*, Luis Rueda, Domingo Mery, and Josef Kittler, Eds., number 4756 in Lecture Notes in Computer Science, pp. 251–260. Springer Berlin Heidelberg, Jan. 2007.

[16] K. Mikolajczyk and C. Schmid, "A performance evaluation of local descriptors," *IEEE Transactions on Pattern Analysis and Machine Intelligence*, vol. 27, no. 10, pp. 1615–1630, Oct. 2005.

[17] Sunil Arya, David M. Mount, Nathan S. Netanyahu, Ruth Silverman, and Angela Y. Wu, "An optimal algorithm for approximate nearest neighbor searching fixed dimensions," *J. ACM*, vol. 45, no. 6, pp. 891–923, Nov. 1998.

[18] J.S. Beis and D.G. Lowe, "Shape indexing using approximate nearest-neighbour search in high-dimensional spaces," in *, 1997 IEEE Computer Society Conference on Computer Vision and Pattern Recognition, 1997. Proceedings*, June 1997, pp. 1000–1006.

[19] M. Muja and D.G. Lowe, "Fast matching of binary features," in *2012 Ninth Conference on Computer and Robot Vision (CRV)*, May 2012, pp. 404–410.

[20] Ruslan Salakhutdinov and Geoffrey Hinton, "Semantic hashing," *International journal of approximate reasoning*, vol. 50, no. 7, pp. 969–978, 2009.

[21] Aristides Gionis, Piotr Indyk, and Rajeev Motwani, "Similarity search in high dimensions via hashing," in *Proceedings of the 25th International Conference on Very Large Data Bases*, San Francisco, CA, USA, 1999, VLDB '99, pp. 518–529, Morgan Kaufmann Publishers Inc.

[22] Qin Lv, William Josephson, Zhe Wang, Moses Charikar, and Kai Li, "Multi-probe LSH: Efficient indexing for high-dimensional similarity search," in *Proceedings of the 33rd International Conference on Very Large Data Bases*, Vienna, Austria, 2007, VLDB '07, pp. 950–961, VLDB Endowment.