Zeng, Wenhan, Jiang, Xiang, Lou, Shan and Scott, Paul J.

A Key Point Method for Data Registration for MultiSensor Fusion

euspen's 16th International Conference & Exhibition, Nottingham, UK, May 2016
www.euspen.eu

A Key Point Method for Data Registration for MultiSensor Fusion

Wenhan Zeng[1,2], Xiangqian Jiang[1], Shan Lou[1], Paul Scott[1]

[1]*EPSRC Centre for Innovative Manufacturing In Advanced Metrology, School of Computing and Engineering, University of Huddersfield, HD33DH, UK*
[2]*State Key Lab of Digital Manufacture and Equipment, School of Mechanical Science and Engineering, Huazhong University of Science and Technology, Wuhan, Hubei, 430074, P.R. China*

z.wenhan@hud.ac.uk

Abstract

It has been recognized that multi-sensor data fusion can provide a more holistic, accurate and reliable information of the measured surface. Data registration, which is used to align data into one coordinate system, is a key step of data fusion. Widely used feature-based methods find correspondence between features, and then a geometrical transformation is determined to map the target data to the reference data. Reliable and accurate feature selection is thus very important for data registration. In this research, a reliable key point method called Scale Invariant Feature Method (SIFM) for data registration is investigated. By using this method, for each data, one can build a set of feature descriptors of the defined key points, which have the scale/shift/rotation invariant properties. Then the correspondence of two data and geometrical transformation can be achieved by finding the matching of two feature descriptors through closeness measurement. Initial tests on freeform and structured surfaces have proven the effectiveness and efficiency of the method.

Keywords: Data registration, Multi sensor data fusion, Scale invariant key point

1. Introduction

Data fusion or multi-sensor data fusion is the process of combining data from several information sources into a common representational format in order that the metrological evaluation can benefit from all available sensor information and data [1-3]. It has been recognized that data fusion can provide a more holistic, accurate and reliable information of the measured surface. Data fusion requires a set of computational techniques that combine the data from different systems into a unified metrology framework. The most important computational work within a data fusion framework includes: *Registration* and *Fusion*.

Accurate data registration is a key step of data fusion, which is used to align data from different sensors or same sensors that have different resolutions, sizes and coordinates into one coordinate system. Generally, the whole registration procedure is divided into two phases: initial registration (coarse registration or rough registration) and final registration (refinement). Most widely used final registration method is the ICP algorithms. Rough registration algorithms can be classified into six categories: global feature based methods; manufacturing feature recognition based methods; local feature based methods; surface geometry based methods; image based methods; and graph based methods. They all have their merits and shortcomings. For example, global feature based methods can capture global properties of the models but fail to discriminate among locally dissimilar shapes [1-3].

Feature-based methods find correspondence between features, and then a geometrical transformation is determined to map the target data to the reference data. Reliable and accurate feature selection is thus very important for data registration. In this research, a feature based method call Scale Invariant Feature Method (SIFM) is proposed. Compared with other feature based method, the main merits of SIFM are: scale, shift and rotate invariant; partly affine invariant; and robust to addition of noise. Due to these merits, the SIFM can match data with different resolution, size and coordinate. In the following sections, the SIFM will be introduced in Section 2, and Section 3 will give some examples, finally in Section 4 conclusions and discussion will be given.

2. Shift Invariant Feature Method for Data Registration

In the SIFM, a set of key points called Scale Invariant Key Points (SIKP), which have the scale, shift and rotation invariant properties, of the sensor data are defined. For each key point, a vector called Scale Invariant Feature Descriptor (SIFD) is then defined. Different from other feature based registration, the SIFM builds the correspondence of closeness measurement of two SIFD. Multi correspondence of SIFDs can be used to define the geometrical transformation of one data with respect to the other data.

2.1. Build Scale Invariant Feature Descriptor

To build a SIFD, the algorithm mainly consists of three major components: (1) Key point detection; (2) Orientation assignment and (3) Local feature descriptor.

Lindberg showed that the normalization of the Laplacian with the factor σ^2 is required for true scale invariance. Lowe has proposed to use the local extrema of Different of Gaussian (DoG) [4]:

$$\begin{aligned} DoG(x,y,\sigma) &= \big(G(x,y,k\sigma) - G(x,y,k\sigma)\big) * D(x,y) \\ &= L(x,y,k\sigma) - L(x,y,\sigma) \approx (k-1)\sigma^2\nabla^2 G \end{aligned}$$

where: $G(x,y,\sigma) = \frac{1}{2\pi} e^{-(x^2+y^2)/2\sigma^2}$, $D(x,y)$ is the sensor data. Figure 1 shows how to build DoG pyramid of different scale. By repeatedly convolving the initial data $D(x,y)$ with Gaussian the set of scale space data can be build. Subtracting the adjacent Gaussian data the set of DoG is generated. The key point can then be detected by finding the local extrema in DoG.

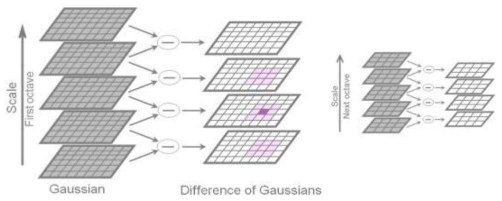

Figure 1. Define SIKP Using local extrema of DoG [4]

The orientation of each key point is assigned by finding the peak direction in the orientation histogram, which is built by counting the directions of points in the neighbouring region around the key points. This is the key step in achieving rotation invariance as the key point descriptor is represented relative to this orientation and therefore achieve invariance to data rotation.

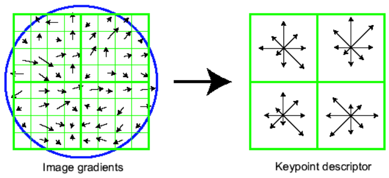

Figure 2. Definition of SIFD of Key Point

Recommend by Lowe [4], the SIFD can be created by first computing the gradient magnitude and orientation at each point in a region around the key point location. These samples are then accumulated into 8 bins orientation histogram summarizing the contents over 4X4 sub-regions. It is therefore the SIFD for each key point is a vector with length of 4*4*8=128.

2.2. Feature Matching

In order to find corresponding feature between two data, the sets of SIFD are compared using closeness measurement. Two different closeness measures are used.

Angle measure, $\alpha = cos^{-1}\left(\frac{\langle P,Q \rangle}{\|Q\|\|Q\|}\right)$

And Euclidean distance measure, $d = \|P - Q\|$

For each key point, the angle or the distance measure are then ranked in ascending order. If the ratio between the first and the second is smaller than a small threshold, a match is accepted; other matches are rejected.

For data registration, three matches are needed, (P_1, Q_1), (P_2, Q_2), (P_3, Q_3). The translation matrix T can be defined by the relative position of P_1 and Q_1, and rotation matrix R can be defined by the alignment of two triangles of $\overrightarrow{P_1P_2P_3}$ and $\overrightarrow{Q_1Q_2Q_3}$.

3. Examples

A set of measured data have been chosen to evaluate the SIFM for data registration. Figure 3 gives an example of matching two data from different part of the same surface with some overlapped area. Through the SIFM, overlapped area can be accurately defined. In figure 4, Data A and Data B (same resolutions, Data A is part of the surface) from the same F-theta lens surface, are tested. By using the SIFM, the SIKPs on both data have been extracted, and by matching their SIFD these two data are matched (Blue line shows the link). Correlation coefficient is used to evaluate the accuracy of the matching, and in this case it is 0.99998. In figure 5, two data with different sizes and resolutions (A has 2 times sampling spacing as that of B) are tested. By using SIFM, the Correlation coefficient of the registration area is still as high as 0.9885.

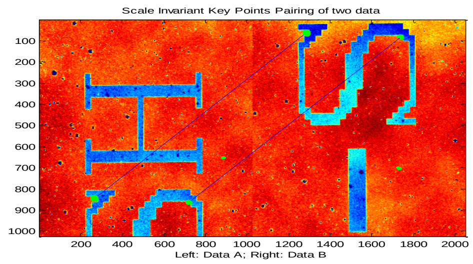

Figure 3. Key Point Matching of Structured Surfaces (green points: Key Points, Blue line: pair of key points)

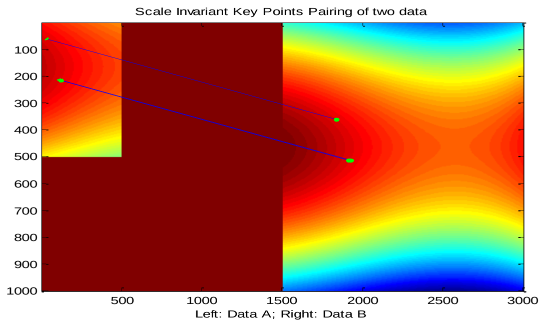

Figure 4. Key Point Matching of Smooth Surfaces of different sizes(green points: Key Points, Blue line: pair of key points)

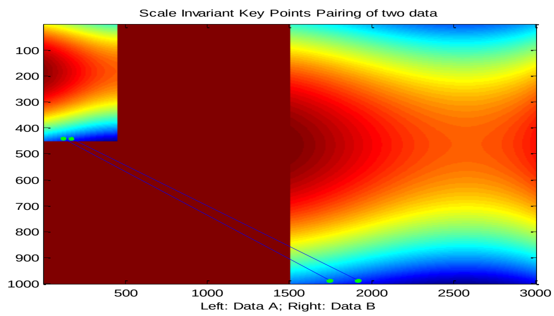

Figure 5. Key Point Matching of Smooth Surfaces with different resolutions (green points: Key Points, Blue line: pair of key points)

4. Conclusions

In this research, a reliable data registration method called SIFM is investigated. Compared with other feature based method, the main merits of SIFM are: scale, shift and rotate invariant, robust to addition of noise and fast. Thus it can be used for matching data with different resolution, size and orientation. The experimental work has shown that by using SIFM the registered have very high correlation coefficient (close to 1). The SIFM shows great potential for rough registration for multisensor data fusion.

References

[1] Weckenmann A, Jiang X, et al. 2009 Multisensor data fusion in dimensional metrology *CIRP Annals – Manuf. Tech* **58** 701-721

[2] Müller M, Krüger W, Saur G 2007 Robust image registration for fusion *Information Fusion* **8** 347-353

[3] Masuda T, Sakaue K, Yokoya N 1996 Registration and integration of multiple range images for 3-D model construction *Pattern Recognition* **1** 879-883

[4] Lowe D G 2004 Distinctive image features from scale-invariant keypoints *International Journal of Computer Vision* **60** 91-110