韓國地形空間情報學會論文集 第4卷 第1號 1996年 6月 pp. 67-73

다축척 수치영상에서 Förstner연산자의 거동

Förstner Interest Operator in Scale Space

조우석*
CHO, Woo-Sug

要 旨

본 논문은 수치영상으로부터 컴퓨터비전(Computer Vision), 수치사진측량학(Digital Photogrammmetry)분야에서 특이점(Distinct Point)이나 Linear Feature를 추출하기위해서 가장많이 이용되고 있는 Förstner interest operator의 Scale space에 관한 연구이다. 수치사진측량분야에서 사용되고 있는 수치영상자료의 크기를 고려할 때, Scale space 즉 Image pyramid는 수치영상 처리속도를 향상시킬 수 있는 방법으로 서서히 주목받고 있다. 본 연구에서는 Gaussian에 의해서 구축된 Scale space에서 Förstnerr interest operator의 거동을 고찰하였고, 실제 수치사진 영상에 적용하여 실제적용 여부를 검증하였다.

ABSTRACT

The objective of this research is to investigate the behavior of the Förstner interest operator, which has been widely used for detecting distinct points in the field of digital photogrammetry and computer vision, in scale space.

Considering the hugh volume of digital image utilized in digital photogrammetry, the scale space (image pyramid) approach which appears to be a solution for enhancing image processing, began to gain its attention. The investigation of the Förstner interest operator in scale space generated by the Gaussian kernel shows its behavior and feasibility for being used in practice.

1. Introduction

The scale space approach has been widely implemented in digital photogrammetry. The main reason for using scale space approach is to make implicit information imbedded in image function more explicit through image pyramid. The idea of scale space dates at least from Rosenfeld in early 1970s [Rosenfeld and Thurston 1971]. He Implemented the scale space approach to edge detection by considering that the size of operator must be compatible to the size of object to be detected. Marr extended this idea by a heuristic assumption called the spatial coincidence assumption [Marr and Hildreth 1980]. The concept of scale space was established by Witkin [Witkin 1983] using the scale parameter (Gaussian) as a continuous parameter. This scale space approach using zero-crossing contours has been further developed in many papers [Yuille and Poggio 1986] [Lu and Jain 1989] [Lindeberg 1990].

Recently, the behavior of Förstner interest operator

*국토개발연구원 국토정보실 책임연구원

in scale space was discussed. It shows interesting characteristics that can not be achieved by the LoG operator [Heikkilä 1989] [Förstner 1994]. The Förstner interest operator detects point features and locates the edge points, however it does not always produce the closed contours and it does not generate phantom edges [Heikkilä 1989]. The Förstner interest operator has the property that when the scale (standard deviation of Gaussian function) is large enough to interact with the features, the operator only produces a single feature around the center of features [Heikkilä 1989]. Similar results obtained by using extreme curvature analysis are shown in the paper [Vasselle 1994].

This paper is concerned with exploring the behavior of the Förstner interest operator in scale space. Real urban area images was experimented to prove the feasibility of Förstner interest operator in scale space.

2. Förstner interest operator

Distinct point-feature detection has been broadly investigated in many fields of science such as computer vision, electrical engineering, and digital photogrammetry. These previous works show that the Moravec operator and the Förstner interest operator perform best for real images. Compared with the Moravec operator, the Förstner interest operator has the salient features such as rotation invariant, subpixel accuracy and classification of detected features.

The Förstner interest operator is originally based on the least-squares matching between two gray image functions. In other words, it detects point features which are supposed to be used for least-squares matching. The basic idea of the Förstner interest operator is simply to measure the energy distribution of small image window in the first derivative of the image function. Detected and classified are blobs, corner features, center of circular features and edges as underlying features through the Förstner interest operator.

To extract point features, Förstner starts with mathematical models which are applied to image window (small image patch). One of mathematical models is edge element model for detecting corner point feature. The second one is slope element model for blobs and center of circular feature. The Förstner interest operator is gradient-based and non-directional operator so that it is crucial how to compute gradient distribution over image window. In most cases, Robert gradient operator (22 mask) for computing gradient is applied. It should be noted that since the Förstner interest operator is non-directional operator, the gradient operator should be non-directional. For a more detailed description of the Förstner interest operator the reader is referred to Cho[1995] and Förstner and Gülch[1987].

The implementation of the Förstner interest operator consists of three steps:

1. Selection of optimal windows for point detection.
2. Classification of selected windows.
3. Determination of the point location within the selected optimal windows

For selecting optimal windows for point detection, the distribution of gradient within small image patch is computed. Through the mathematical model, the gradient strength can be represented into 22 normal matrix. Analyzing 22 normal matrix leads to classification of selected windows, in other words underlying features lying in the selected window. Solving the normal equations determines the location of point feature which is contained in the small image window.

As shown in the paper [Cho 1995], the Förstner interest operator behaves well at high curvature areas because the mathematical model interacts well with those areas. In addition, a small bias is introduced when the gradient distribution is not symmetric around the features. Moreover, the Förstner interest operator never produces phantom features because of its property of implementing gradient distribution.

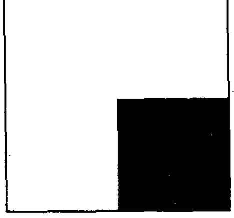
3. Förstner interest operator in scale space

Over the last few years, the scale space approach has become popular in the field of image analysis. One of good examples is coarse-to-fine tracking in digital photogrammetry. As mentioned before, the idea of scale space is dated from Rosenfeld and then Marr extended this idea by a heuristic assumption called the spatial coincidence assumption which states that intensity changes at some spatial location over two successive image spaces are due to a single physical phenomenon, an edge [Marr 1980]. Witkin established the concept of scale space using the scale parameter (Gaussian) as a continuous parameter. For constructing scale space, Gaussian convolution is applied due to its well-behavedness; symmetric and decreasing about the mean. The most important property of Gaussian with LoG operator is that additional zero-crossings may appear as decreases, but existing ones cannot in general disappear. In the context of coarse-to-fine tracking, a coarse scale may be used to identify the extrema while a fine scale is to locate the fine details.

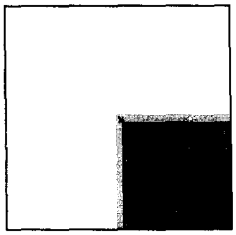
Heikkilä[1989] was first to discuss the behavior of the Förstner interest operator in scale space, followed by Förstner[1994]. In those two papers, the scale space with Förstner interest operator was constructed by Gaussian convolution utilizing the salient features of Gaussian. They found many interesting behaviors of the Förstner interest operator in scale space while comparing with LoG operator.

Figure 1 shows the behavior of the Förstner interest operator in scale space which was generated by a Gaussian kernel. In Figure 1, a 200200 ideal synthetic image is created with white color for the background and dark gray for the feature. In order to demonstrate the behavior of the Förstner interest operator in scale space, the non-maxima suppression is not implemented. The detected corner points are represented by black color and edge points by light gray color in the figure.

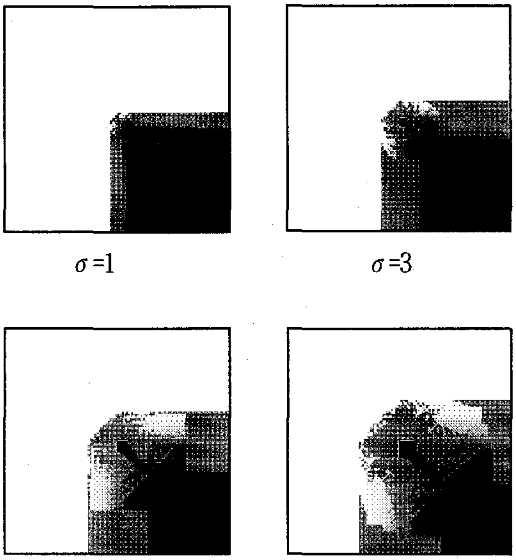
As shown in Figure 1, the Förstner interest operator responds well to the corner points as well as edge points through all five levels of image pyramid. As the scale of image pyramid is getting larger, the spatial distortion (dislocation, broadening, and flattening) of detected corner points and edge points is getting bigger. This property of the Förstner interest operator in scale space is exploited in this paper especially on tracing down corner points from large scale to small scale, that is, through the image pyramid.



Ideal Synthtic Image



σ=0.5



σ=1 σ=3

σ=5 σ=7

Figure 1. The Förstner interest operator scale space with corresponding Gaussian = 0.5, 1, 3, 5, and 7.

4. Experiments and Results

The image depicting the Ohio State University at a scale of 1:4000 was used for the experiments in this paper(see Figure 2). Originally, the diapositive was scanned by the Intergraph Photoscan with a resolution of 60m and then an image pyramid with three different levels was generated using a Gaussian kernel.

For corner point detection, the Förstner interest operator requires two thresholds to be set: (1) weight and (2) roundness measure. In this paper, weight is set to 1.5 and roundness 0.75, respectively. In addition, the corner points were detected at the 97% confidence and 77 for window size and nonmaxima suppression, respectively. The 22 Robert gradient operator was implemented to compute the gradient of the image function.

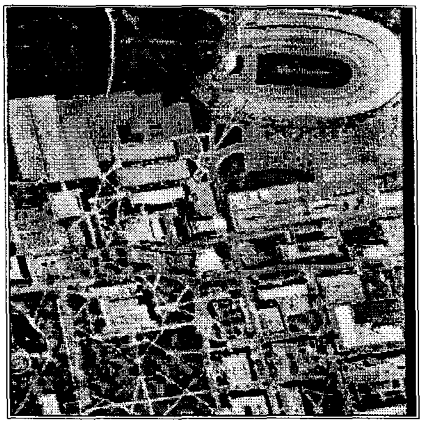
As shown in Figure 2, the original image was convolved with three different Gaussian = 3, 5, and 7. It is obvious that the blurring effect of the image is getting dominant while Gaussian is getting larger in value. Most of Förstner interest points were detected in small scale once they were extracted in large scale. This property is quite similar to that of zero-crossing when the image is convolved with a Gaussian kernel. The Förstner interest operator locates corner points at correct positions through the image pyramid while the LoG operator has the tendency to dislocate the zero-crossing in large scale space. It was also found that when the scale is large enough to simplify the fine details in the image function, the Förstner interest operator responds only to dominant features. This property is one of typical behavior of the Förstner interest operator.

σ=7

To show details of the behavior of the Förstner interest operator, small portion of image function is extracted from three levels of the image pyramid. As shown in Figure 3, the Förstner interest operator produced an interest corner point in all the levels of image pyramid at correct location. This is the most important property of the Förstner interest operator, which could be one way of describing the image function more explicitly and economically from the aspect of massive volume of digital image in use.

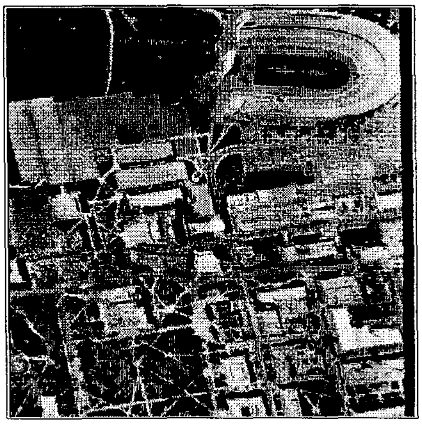
With the help of the scale space approach (image pyramid), a number of fundamental digital photogrammetric processes such as matching problem could be relieved from the burden of enormous execution time.

σ=5



σ=3

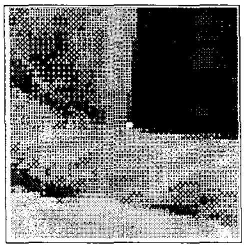
Like corner-point detection, the Förstner interest operator also requires two thresholds to be set for edge-point detection : (1) weight and (2) roundness measure. In this paper, weight is set to 1.5 and



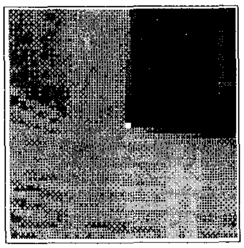
Original Image

Figure 2. An image pyramid (scale space representation) generated by a Gaussian kernel superimposed with Förstner interest corner points

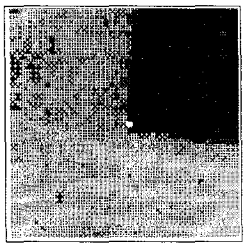
σ=7



σ=5



σ=3

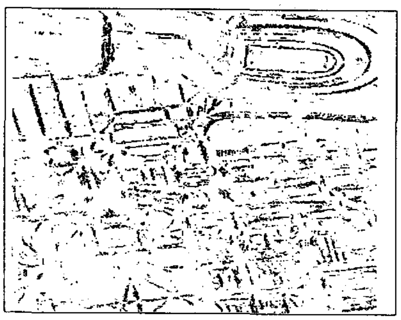


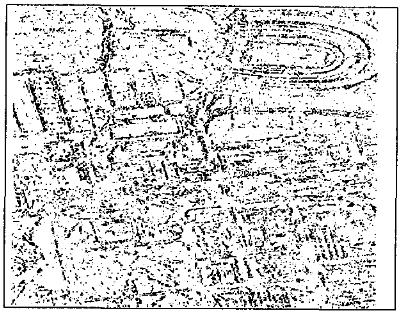
Original Image

Figure 3. A small portion of image function from the image pyramid with three different levels (= 3,

5, and 7) superimposed with the interest corner point roundness 0.3, respectively. In addition, the edge points were selected at the 97% confidence and 77 for window size and nonmaxima suppression, respectively. The 22 Robert gradient operator was applied to compute the gradient of the image function.

Figure 4 graphically shows that additional Förstne interest edge-points appear as scale (σ) decreases. This proves that the Förstner interest operator behaves similarly to the LoG operator in scale space. However, those edge points are not connected one another, but rather isolated. This behavior of the Förstner interest operator with real image is quite different from that of ideal image shown in Figure 1. From the practical point of view, this property can not be accepted as linearfeature detection. That is, extra post-processing should be investigated for further procedure.





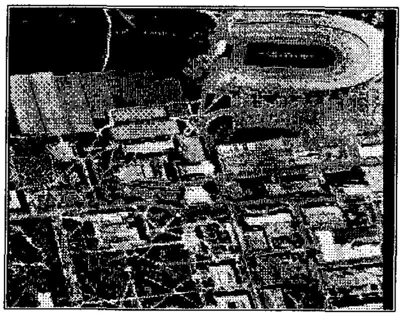


Figure4. An mage pyramid(scale space representation) generated by a Gaussian kernel with Förstner interest edge points

5. Conclusions

This paper describes briefly the description of the Förstner interest operator and its behavior in scale space. To investigate the feasibility of the Förstner interest operator in scale space approach, its implementation with real image was performed. As shown, the Förstner interest operator behaves quite similarly to the LoG operator in scale space. However, it has certain advantage over the LoG operator such as consistency on producing correct location of corner point. As for the behavior of edge-point in scale space, post-processing should be further investigated toward the practical implementation.

참 고 문 헌

1. 조우석, 한국측지학회 제13권 제2호 1995, 299-307
2. Ballard, Dana H. and Brown, Christopher M. (1982) Computer Vision. Prentice-Hall, Inc.
3. Förstner, Wolfgang and G詰ch, E. (1987) A Fast Operator for Detection and Precise Location of Distinct Points, Corners and Centers of Circular Features. ISPRS Intercommissiom Workshop, Interlaken, June, 281-305.
4. Förstner, Wolfgang (1994) A Framework for Low Level Feature Extraction. Lecture Notes in Computer Science, Vol. 801, Computer Vision-ECCV94, 383-394.
5. Heikkiläl Jan (1989) Multiscale Representation with Förstner Operator. The Photogrammetric Journal of Finland, Vol. 11, No. 2, 40-59.
6. Lu, Yi and Jain, Ramesh C. (1989) Behavior of Edges in Scale Space. IEEE Transactions on Pattern Analysis and Machine Intelligence, Vol. 11, No. 4, April, 337-356.
7. Marr, D. and Hildreth, E. (1980) Theory of edge detection. Proceedings of Royal Society of London, Vol. 207, 187-217.