ACCELERATION OF AREA SHIFT CALCULATION

Richard JUŘÍK
Černého 33, 635 00 Brno
Czech Republic

Abstract

The goal of the area shift measurement is to find the co-ordinates (location) of the searched pattern of one two-dimensional sequence in the second two-dimensional sequence. It is supposed that searched pattern is included in the searched sequence in the unknown location. As it was published in [3], it is possible to determine the area shift using either the correlation or difference method. The calculations using the definition equations of the correlation or difference method are very severe. This contribution shows how it is possible to significantly decrease needed amount of the calculation operations when appropriate characteristics of the compared two-dimensional sequences are used. The method, which uses histogram comparison, allows eliminating up to 90 % of the searched patterns from the calculations that use the definition equations. The method that uses the comparison of the mean values of the searched pattern segments reaches even better results. It can eliminate up to 99.9 % of the searched patterns. Both new eliminating methods significantly contribute to acceleration of the area shift calculation.

Keywords

Area shift, optimization, measurement, two-dimensional sequence, calculation

1. Introduction

The goal of the area shift measurement is to find the co-ordinates (location) of the searched pattern of one two-dimensional sequence in the second two-dimensional sequence. It is supposed that searched pattern is included in the searched sequence. We can imagine two-dimensional sequences as for instance digital photographs of the earth surface obtained during the aircraft fly. Patterns can be relatively small parts of these photographs (for instance 10×10 or 15×15 picture elements). Under certain circumstances finding the location of one snapshot in the following snapshot allows us to calculate the speed or the altitude of the aircraft from which the snapshots were made.

Area shift can be determined using either the correlation or difference method [3].

Using correlation method [1] the searched pattern is successively compared to every pattern of the following snapshot in the way the modified estimation of the two-dimensional norm cross-covariance sequence $c_k(r,s)$ is calculated

$$c_k(r,s) = \frac{\sum_{t=0}^{R-1}\sum_{u=0}^{R-1}\left[s_1(t,u)-\mu_1\right]\left[s_2(t+r,u+s)-\mu_2\right]}{\sqrt{\sum_{t=0}^{R-1}\sum_{t=0}^{R-1}\left[s_2(t+r,u+s)-\mu_2\right]^2}} \qquad (1)$$

$r, s = 0, ..., N\text{-}R$

The following symbols are used in the equation (1):

s_1 two-dimensional sequence corresponding to the first snapshot,

s_2 two-dimensional sequence corresponding to the second snapshot,

$\hat{\mu}_1$ mean value of the searched pattern (searched pattern is from the first snapshot),

$\hat{\mu}_2$ mean value of the compared pattern (compared pattern is from the second snapshot),

N number of the members of the sequences s_1 and s_2 in one direction (sequences s_1 and s_2 have $N \times N$ members),

R size of the searched and compared pattern in one direction (patterns have $R \times R$ members).

In the second step the indices of the maximal value of the sequence $c_k(r,s)$ are found. These indices are the co-ordinates of the searched pattern in the second snapshot. Known co-ordinates of the pattern in the first snapshot and found co-ordinates of the same pattern in the second snapshot allow us to determine the area shift of the pattern.

The difference method [2] calculates the two-dimensional sequence $c_d(r,s)$. Members of this sequence are sums of the absolute values of the differences corresponding members of the searched and compared pattern

$$c_d(r,s) = \sum_{t=0}^{R-1}\sum_{u=0}^{R-1}\left|s_1(t,u)-s_2(t+r,u+s)\right|, \qquad (2)$$

$r, s = 0, ..., N\text{-}R$

The same symbols are used in (2) as in (1).

Indices of the minimal value of the sequence $c_d(r,s)$ determine the location of the searched pattern in the second snapshot. The area shift is again calculated like difference between the co-ordinates of the pattern in the first and the second snapshot.

The diagram of the algorithm of the calculation using the original equations (1) and (2) is shown in the Fig. 1.

Because the snapshot can have size up to 2000×2000 pixels, it is necessary to perform large number of computation. My goal was to reduce the needful amount of calculations as much as possible.

```
┌──────────────────────────┐
<  for s:=0 to N-R  >
└──────────────────────────┘
           │
┌──────────────────────────┐
<  for r:=0 to N-R  >
└──────────────────────────┘
           │
┌──────────────────────────┐
│  calculate c_k(r,s) or   │
│  c_d(r,s) using equation │
│  (1) or (2)              │
└──────────────────────────┘
```
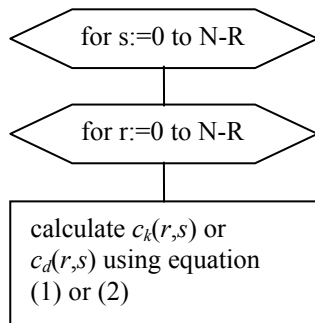
Fig. 1 The flow diagram of the calculation using the original equations (1) and (2).

I looked for such a characteristic of the compared patterns that surely validate the compared pattern is not the searched pattern and at the same time calculation and comparison of the characteristic needs significantly lower number of calculation operations in comparison to calculation using the correlation or difference method according to (1) and (2). There was also requirement that every member of the sequence of the compared pattern is used only once in the calculation of the characteristic. Flow diagram of the modified way of calculation is presented in the Fig. 2.

2. Methods of acceleration

Three methods for acceleration of calculation were proposed and tested: mean value comparison, histogram comparison and segment mean value comparison.

2.1 Mean value comparison

The first possibility that was published in [1] is to eliminate such patterns theirs mean value is different from the mean value of the searched pattern more than selected tolerance. Experiments showed that about from 30 to 70 % of the patterns could be eliminated from calculation when tolerance is properly set. When calculation and comparison of the mean value of the pattern is suitable programmed the calculation and comparison last only one fifth of the time needed for the calculation using the equation (2) and one fifteenth of the time needed for the calculation using the equation (1). Calculation of the one member of the sequence $c_k(r,s)$ lasts three times longer than calculation of the one member of the sequence $c_d(r,s)$.
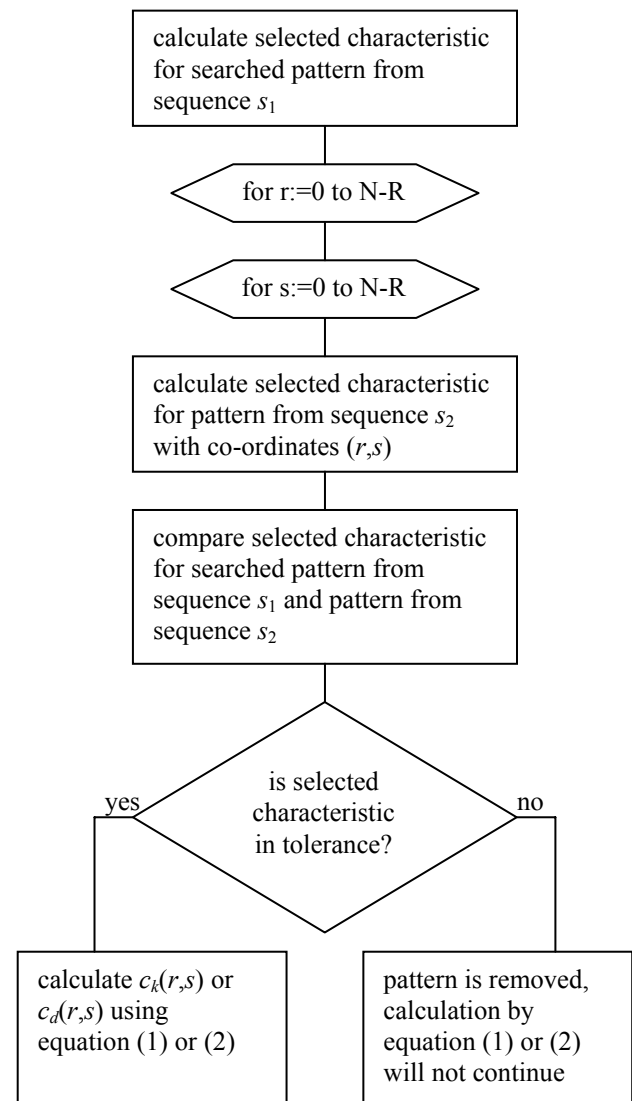

Fig. 2 The flow diagram of the modified calculation of the area shift.

2.2 Histogram comparison

Next applicable characteristic is calculation and comparison of the histogram of the pattern. A histogram calculation is little bit more severe than mean value computation but allows us to eliminate from 80 to 99 % patterns from calculations using the original equations. The amount of the eliminated patterns depends on number of histogram values and on the size of the allowed deviation of the histograms. From the programmer point of view it is advantageous when the number of the histogram values is equal to the power of number 2. Performed experiments proved it is sufficient to calculate only 4, 8 or 16 of the histogram values.

2.3 Segment mean value comparison

The last examined characteristic -- which gave the best results -- was pattern excluding based on the comparison of the mean values of the selected number of pattern segments. The searched and compared pattern is divided to regular segments. The mean value of the every pattern segment is calculated and the mean values of the searched pattern segments are compared to corresponding mean values of the compared pattern segments.

The mean value calculation of the particular segments of the pattern is slightly more severe than the calculation of the mean value of the whole pattern when suitable number of the segments is selected. The computer simulation proved it is possible to eliminate approximately from 90 to 99.9 % of patterns by this way. In this case the number of the eliminated patterns depends on the number of the segments and on the size of the allowed deviation of the mean values. For fast computation it is necessary to divide particular patterns to small segments that have the same number of members in both directions and number of the segments has to be the power of the small common number (patterns have to be divided to 4, 9 or 16 square segments). Performed experiments have shown the division of the pattern into more than 16 segments on one side boosts the reliability of the pattern removal (more patterns are removed) but the period of the calculation of this characteristic is enlarged (more mean values need to be compared).

3. Conclusions

Tab. 1 indicates approximate values of computation abbreviation in %. Following symbols are used in Tab. 1:

p   ratio of the number of the removed patterns and number of all patterns,

p_k ratio of the period of the characteristic calculation and the period of the calculation by equation (1),

p_d ratio of the period of the characteristic calculation and the period of the calculation by equation (2),

K   number of % the calculation using particular characteristic is shortened against the calculation using (1),

D   number of % the calculation using particular characteristic is shortened against the calculation using (2).

characteristic	p	p_k	p_d	K[%]	D[%]
mean value comparison	0.5	0.067	0.2	43	30
histogram comparison	0.9	0.11	0.33	79	57
segment mean value comparison	0.99	0.083	0.25	91	74

Tab. 1 Approximate values of the computation abbreviation in %.

Tab. 1 shows a significant conclusion: pattern removal using comparison of mean values of pattern segments can cut the time of the computation to one fourth for difference method and to one tenth for correlation method.

The proposed calculation acceleration can be used for similar methods for linear shift measurement [3] as well. In this case it is not possible to achieve substantial timesaving because during the linear shift computation considerable less amount of data is processed.

References

[1] JUŘÍK, R.: Correlation Measurement of the Aircraft Track Velocity Vector. In: Proceedings of the Fifth Electrotechnical and Computer Science Conference EKR '96, volume B, Portorož, Slovenija, 1996, p. 275-276.

[2] JUŘÍK, R.: Segment Shift Measurement Using the Difference Method. In: Proceedings of the Digital Signal Processing '97. FEI TU in Košice, Dept. of Electronics and Multimedia Communications, Košice, 1997, p. 189-190.

[3] JUŘÍK, R.: Optical Measurement of Linear and Area Shift Using Correlation and Difference Method. [PhD Thesis.] FEECS TU of Brno, Institute of Radioelectronics, Brno, 1999.

About author...

Richard JUŘÍK was born in Kyjov in 1965. He received Ing. (M.Sc.) degree in Radioelectronics in 1988 and Ph.D. degree in Electronics, measurement and communication technique in 1999, all at the Technical University in Brno. From 1990 to 1994, he worked in the Institute of Radioelectronics TU in Brno. From 1994, he works as the network administrator in softwarehouse Berit in Brno. His research interests include technology of optical sensors, analog-to-digital conversion, optical measurements, calculation optimization and related topics.