An Image Analysis Algorithm of Estimates Calculation on a Plane

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Abstract. An implementation of image recognition algorithms based on estimate calculation (2D AEC) with rectangular support sets is proposed. The article includes the sample. Let we have a photo of starry arch star map. The problem is to recognize stars on the photo. The algorithm calculates the array of estimates, and then we apply a decision rule.

1 Statement of the Problem

The article is concerned with an implementation of image recognition algorithms based on estimate calculation (2D AEC) with rectangular support sets [2]. Let *K* is a set of objects. The set *K* is called class. We have two tables *S* and *T* describing objects. Each table S row and each table *T* row contains an object description. Class *K* is described both in *S* and in *T*. We do not know, which rows of the tables *S* and *T* describe the class *K*. Put this another way, the class *K* has two descriptions, the first one is in the table *S*, the second one is in the table *T*. The table *S* and the table *T* have an equal number of columns *n*.

Some object attributes are changed when system of axes is changed, another attributes are not changed. Let the first n_1 tables columns are changeable ($n_1 \leq n$), another ones are invariants. In other words, the first n_1 tables' columns are object space coordinates, other ones do not depend on object space system of axes.

Suppose space angles are invariants for any object space system of coordinates.

The problem is to find which table S rows and which table T rows are descriptions of the objects of the class K.

We shall deal with the problem for $n_1=2$ (a plane).

Definition. By an elementary fragment of table we shall mean a set of three table rows.

Let $\Phi^S = \{e_1^S, e_2^S, ..., e_{i_S}^S\}$ is a set of elementary fragments of the table *S*, $\Phi^T = \{e_1^T, e_2^T, ..., e_{i_T}^T\}$ is a set of elementary fragments of the table *T,* Ω is the system of reference subsets of $\{ n_1+1, n_1+2,...,n\}$ [1], $\omega \in \Omega$ is a reference set. Suppose B_ω is a proximity function [1]. Proximity function has two arguments (table rows). In our case these arguments can be both from one and from different tables

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$(B_\omega(S_i,S_j), B_\omega(T_i,T_j), B_\omega(S_i,T_j), \text{etc.})$. Proximity function takes a value of 1 if appropriate parts of objects descriptions are similar to each other and zero elsewhere. Here S_i, S_j are objects of the table S described by rows i, j, T_i, T_j are objects of the table T described by rows i, j ($i \geq n_1$, $j \geq n_1$).

Let us extend definition of proximity function to elementary fragments e^S, e^T.

$B_\omega(e^S, e^T) = 1$, if

1) triangles associated with elementary fragments e^S and e^T are similar (we consider only columns $1,\ldots,n_1$ here);
2) objects related to equal angles are closely adjacent:
   $B_\omega(S_i, T_j) = 1$,

and $B_\omega(e^S, e^T) = 0$ elsewhere.

2 Estimates Γ(S$_i$) and Γ(T$_j$) with Respect to the Class K

Let Φ_i^S is a set of elementary fragments of the table S having an object S_i. Then

$$\Gamma(S_i) = \sum_{\substack{e^S \in \Phi_i^S, \\ e^T \in \Phi^S, \\ \omega \subset \Omega}} B_\omega(e^S, e^T).$$

Let Φ_j^S is a set of elementary fragments of the table T having an object T_j. Then

$$\Gamma(T_j) = \sum_{\substack{e^S \in \Phi^S, \\ e^T \in \Phi_j^T, \\ \omega \subset \Omega}} B_\omega(e^S, e^T)$$

3 Decision Rules

if $\Gamma(S_i) > C_S$ then $S_i \in K$

if $\Gamma(T_j) > C_T$ then $T_j \in K$, the constants C_S and C_T are based on a model.

4 Estimate of Complexity of the Algorithm

Let $n_1 = 2$, m_S is number of rows of the table S, m_T is number of rows of the table T, $m = max(m_S, m_T)$. Considering that number of elementary fragments of a table is no more than $\binom{3}{m}$, upper bound of complexity of the algorithm may be written as $C_1 m^6$.

To improve algorithm performance let us sort the sets of elementary fragments of the tables by angles before estimates calculation.

5 A Sample

Let the file 1.txt contains

101,255
170,195
229,193
300,186
416,106
437,179
343,231 stars coordinates from the

Fig. 1. Ursa Major Constellation [4].

and file 2.txt contains
106,553
157,551
186,570
223,590
308,589
300,628
233,626
246,415
228,405
255,373
271,387
306,367
344,370
367,375

two constellation stars coordinates from the

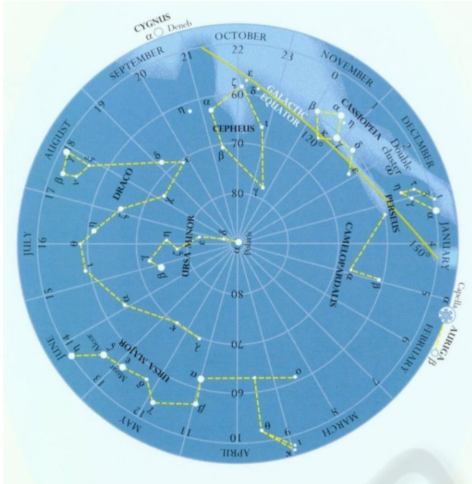

Fig. 2. The North Polar Constellations [5].

The first seven lines describes Ursa Major constellation, the other seven lines describes Ursa Minor constellation.

6 Algorithm

1. Read star coordinates from the file 1.txt into array ar1.
2. Read constellation map star coordinates from the file 2.txt into array ar2.
   Let list1 is an array of Triangles with Vertices from ar1, list2 is an array of Triangles with Vertices from ar2.Vertices from ar1, list2 is an array of Triangles with Vertices from ar2. Triangle is an array of 3Vertices (Items). Vertex is a pair of index and angle, where index is a star number from ar1 or ar2. Angle is a triangle vertex angle. Array of Vertices of a Triangle is sorted by angle. Arrays of Triangles list1, list2 are sorted by Triangle.Items[0].angle, Triangle.Items[1].angle.
   Γ[i,j] is array of estimates.
   i is index of a star from list1,
   j is index of a star from list2.
   EPS is a small value.
3. Create and sort list1, list2;
4. *i := 0; j:=0;*
5. if $i \geq list1.Count$ then go to 20;
6. if $j \geq list2.Count$ then go to 20;
7. if $list1[i].items[0].angle + EPS \leq list2[j].Items[0].angle$ then $i := i+1;$
   go to 5;
8. if $list1[i].items[0].angle \geq list2[j].Items[0].angle + EPS$ then $i := i+1;$
   go to 5;

9. *k := 0;*
10. if *i+k* ≥ *list1.Count* then go to 14;
11. if |*list1[i+k].Items[0].angle – list2[j].Items[0].angle*| ≥ *EPS* then go to 14;
12. if |*list1[i+k].Items[1].angle – list2[j].Items[1].angle*| < *EPS* then
    Γ[list1[i+k].Items[0].index, list2[j].Items[0].index]++;
    Γ[list1[i+k].Items[1].index, list2[j].Items[1].index]++;
    Γ[list1[i+k].Items[2].index, list2[j].Items[2].index]++;
13. *k := k+1;* go to 10;
14. *k* := 1;
15. if *j+k* ≥ *list2.Count* then go to 19;
16. if |*list1[i].Items[0].angle – list2[j+k].Items[0].angle*| ≥ *EPS* then go to 19;
17. if |*list1[i].Items[1].angle – list2[j+k].Items[1].angle*| < *EPS* then
    Γ[list1[i].Items[0].index, list2[j+k].Items[0].index]++;
    Γ[list1[i].Items[1].index, list2[j+k].Items[1].index]++;
    Γ[list1[i].Items[2].index, list2[j+k].Items[2].index]++;
18. *k := k+1;* go to 15;
19. *i := i+1; j := j+1;* go to 5;
20. Print array of estimates Γ.

7 Results

The table of estimates for the sample (the array *Γ[i,j]*) is

	1	2	3	4	5	6	7
1	16	10	3	0	3	1	0
2	5	12	3	1	0	0	0
3	4	6	10	5	1	4	1
4	0	1	9	11	3	3	1
5	1	0	0	3	10	10	1
6	0	1	8	8	4	11	0
7	1	0	1	2	1	3	7
8	2	2	2	3	6	5	2
9	4	3	1	4	2	3	2
10	2	1	6	4	2	0	4
11	2	5	3	4	1	2	0
12	1	3	6	3	3	1	2
13	1	3	3	5	1	1	2
14	0	7	3	4	0	2	5

A cell of the table *Γ[j,j]* is estimate of the object S_i from the set of objects of the fig.1 with respect to the object T_j from the set of objects of the fig.2.

Decision Rule. If we set maximal number in each column to 1, another numbers to 0, we have the mapping from the objects of [4] to the objects of [5]:

	1	2	3	4	5	6	7
1	1	0	0	0	0	0	0
2	0	1	0	0	0	0	0
3	0	0	1	0	0	0	0
4	0	0	0	1	0	0	0
5	0	0	0	0	1	0	0
6	0	0	0	0	0	1	0
7	0	0	0	0	0	0	1
8	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0

and we can make a conclusion that the stars from the photo [4] are from Ursa Major constellation.

References

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