Spatial Match Retrieval Using Signature Files for Iconic Image Databases

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New Representation Scheme

In multimedia information retrieval applications, content-based image retrieval is essential for retrieving relevant multimedia documents. The purpose of our paper is to provide effective representation of images when a pixel-level original image is automatically or manually transformed into its iconic image containing meaningful graphic descriptions, called icon objects. For spatial match representations, the 2D and the 9DLT schemes were proposed to search image results efficiently, satisfying certain spatial relationships [1, 2]. However, both representation schemes have a critical problem in that they represent each icon object of an original image as a point. As a result, they are not accurate enough to express spatial relationships between objects for handling original images with a complex scene. Therefore, we propose a new spatial match representation scheme to support effective content-based image retrieval.

A generic scene is defined as a set of icon objects in its iconic image. Therefore, an iconic description of the scene is a set of spatial relationships between pairs of icon objects. The spatial relationship(SR) is expressed as $SR = p\ O_p\ q$, where p and q are the projections over the X-axis (or Y-axis) of A and B objects, respectively, and O_p is a positional operator, which relates the intervals originated by the projections of p and q on the X-axis (or Y-axis). For this, we propose fifteen positional operators which can express all of the possible relationships between a pair of intervals. For each axis, projection of p and q are referred to as $p = [x_{p1}, x_{p2}]$ and $q = [x_{q1}, x_{q2}]$, respectively, where $x_{p1} < x_{p2}$ and $x_{q1} < x_{q2}$.

(a) p far-away-after (>>) q
(b) p strictly-after (>+) q
(c) p after with right adjacency (>=) q
(d) p after (>) q
(e) p is-included-by with left adjacency (>−) q
(f) p includes with right adjacency (>|) q
(g) p includes (><) q
(h) p spatial-coincidence (=) q
(i) p is-included-by (<>) q
(j) p includes with left adjacency (<|) q
(k) p is-included-by with right adjacency (<−) q
(j) p includes with left adjacency (<|) q
(k) p is-included-by with right adjacency (<−) q
(l) p before (<) q
(m) p before with left adjacency (<=) q
(n) p strictly-before (<+) q
(o) p far-away-before (<<) q

To define a spatial string for representing the pairwise spatial relationships between objects in a two-dimensional image, we express two types of spatial strings so that they can support both the exact and the approximate match. First, an exact-match i-axis spatial character, E_i^{AB}, is a character describing a spatial relationship between objects A and B when the projections of A and B in terms of the i-axis are referred to as $p = [x_{p1}, x_{p2}]$ and $q = [x_{q1}, x_{q2}]$. E_i^{AB} is ranged from 0 to 14, according to the order of positional operators. That is, $E_i^{AB} = 0$ if $p >> q$ and $E_i^{AB} = 14$ if $p << q$. An approximate-match i-axis spatial character, A_i^{AB}, is a character describing a spatial relationship between A and B objects so that it can be used to support the approximate match of user queries. Using a procedure to determine approximate-match relationships among operators, which is omitted due to space, the approximate-match spatial character is written as the following:

$$
\begin{array}{lll}
A_i^{AB} = 0 \text{ and } 1 & \text{if } p >> q \\
A_i^{AB} = 0{,}1 \text{ and } 2 & \text{if } p >+ q \\
A_i^{AB} = 1{,}2 \text{ and } 3 & \text{if } p >= q \\
A_i^{AB} = 2{,}3{,}4 \text{ and } 5 & \text{if } p > q \\
A_i^{AB} = 3{,}4{,}7 \text{ and } 8 & \text{if } p >- q \\
A_i^{AB} = 3{,}5{,}6 \text{ and } 7 & \text{if } p >| q
\end{array}
$$

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Retrieval effectiveness	9-DLT Scheme		Our Scheme	
	Approx.	Exact	Approx.	Exact
Precision	0.09	0.13	0.39	0.69
Recall	0.67	0.50	0.85	0.62

Table 1: Retrieval effectiveness

A_i^{AB} = 5,6 and 9 if $p >< q$
A_i^{AB} = 4,5,7,9 and 10 if $p = q$
A_i^{AB} = 4,8 and 10 if $p <> q$
A_i^{AB} = 6,7,9 and 11 if $p <| q$
A_i^{AB} = 7,8,10 and 11 if $p <- q$
A_i^{AB} = 9,10,11 and 12 if $p < q$
A_i^{AB} = 11,12 and 13 if $p <= q$
A_i^{AB} = 12,13 and 14 if $p <+ q$
A_i^{AB} = 13 and 14 if $p << q$

Therefore, an exact-match spatial string of objects A and B, SE^{AB}, is a string formed by concatenating A, B, and exact-match spatial characters E_X^{AB} and E_Y^{AB}, where E_X^{AB} is the spatial character along the X-axis, and E_Y^{AB} is the spatial character along the Y-axis. Similarly, an approximate-match spatial string of objects A and B, SA^{AB}, is a string formed by concatenating A, B, and exact-match spatial characters A_X^{AB} and A_Y^{AB}. Thus, the exact-match and the approximate-match strings of objects A and B are expressed as follows:

- exact-match string
  $SE^{AB} = \{(A, B, E_X^{AB}, E_Y^{AB})\}$
- approximate-match string
  $SA^{AB} = \{(A, B, A_X^{AB}, A_Y^{AB})\}$

Performance Evaluation

For our experiment, we use 5000 iconic images, each consisting of two to ten icon objects, having 25 different types. In order to evaluate retrieval effectiveness [3], we make use of recall and precision measures. When a variety of queries are executed two hundred times, Table 1 shows the retrieval effectiveness of our spatial match representation scheme. Compared to the 9-DLT scheme. Our representation scheme improves retrieval precision by 0.56 in the exact match and by 0.3 in the approximate match, while their recall values are kept higher than those of the 9-DLT scheme.

Efficiency measures	9-DLT Scheme		Our Scheme	
	Approx.	Exact	Approx.	Exact
Fd	0.032	0.033	0.040	0.034
SO(Mbyte)	0.23	0.67	0.24	2.76

Table 2: Fd and SO

In order to evaluate the retrieval efficiency, we make use of the probability of false drops(Fd) [3]. Table 2 shows that the retrieval efficiency of our spatial match representation scheme is slightly decreased, compared to that for the 9-DLT. Namely, Fd is increased by 0.001 in the exact match, and by 0.008 in the approximate match. Moreover, Table 2 shows the storage overhead(SO) of our representation scheme, in terms of signature file size. It is shown from the result that our representation scheme requires four times larger signature storage in the approximate match than the 9-DLT one, while it requires almost the same signature storage in the exact match.

Conclusion

We proposed our spatial match representation scheme so as to support content-based image retrieval in an effective way. Our representation scheme accurately described spatial relationships between icon objects because it could represent the icon object as a rectangle and make use of precise positional operators. We showed from our experiment that our representation scheme improved retrieval precision by about 0.5 in the exact match, and by 0.3. For further work, our representation scheme should be applied to real application areas using iconic images, proving the efficiency of our schemes in these areas.

References

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