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Language Descriptions of Spatial Relation based on F-histogram

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Abstract

In this paper, we introduce a system able to generate human-like linguistic descriptions of the spatial relation between two objects in intrinsic reference framework. The description includes directional relation terms, topological relations terms, and adverbs commonly found in daily communications. Each description is built based on fuzzy rules and the information extracted from F-Histograms. Excellent results show that the method of linguistic descriptions is feasible.

Keywords: *intrinsic reference framework; directional relation; F-Histogram; language descriptions*

1. Introduction

As description of human space perception is a basic ability of human cognition, it is an important basic task for computer audio-visual information processing to build automatically the description of spatial relation between objects in the image.

In everyday situations, space is often viewed as a configuration induced by spatial relation, rather than as a container that exists independently of the objects located in it. The past fifteen to twenty years have seen significant advancements in the development of mathematical and computational modeling of distance relation, directional relation, and topological relation between image objects [1-5]. Over the same period, several methods [6-7] have been proposed for generating automated linguistic descriptions of these relations.

However, different reference frameworks will lead to different understandings of spatial relation, so we should build linguistic description method according to different reference framework. Intrinsic reference framework is an important reference framework, but the research in intrinsic reference framework is few. To address this issue above, we propose a method of linguistic combination descriptions in intrinsic reference framework. This method can generate linguistic descriptions consistent with human cognition by using F-Histogram and fuzzy rules in intrinsic reference framework.

2. F-Histogram

2.1. Background

Significant work has been reported on spatial relation representation. Many authors have stressed the importance of qualitative spatial relation [2]. Approaches have been based on cone-shaped model, projection model, 2D-String model, MBR model and directional relation matrix model. All of these approaches assimilate an object to very

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elementary entities such as the centroid or the minimum bounding rectangle. This simplification process can not give a satisfactory model of the spatial relation. Because these approaches can't take into account the effects of shape, size and distance information to judging directional relation.

Miyajima [3] firstly proposes the notion of angle histogram, as shown in Figure 1. This approach takes into account the angle of all point pairs between objects and computes the frequency of all points to get the angle histogram between objects. Angle histogram contains information of the spatial relation between objects, so we can extract information of spatial relation from the histogram to represent spatial relation. This approach can take into account shape, size and distance information, but the amount of computation is very large because of too many points. Moreover, distance information is not taken into account.

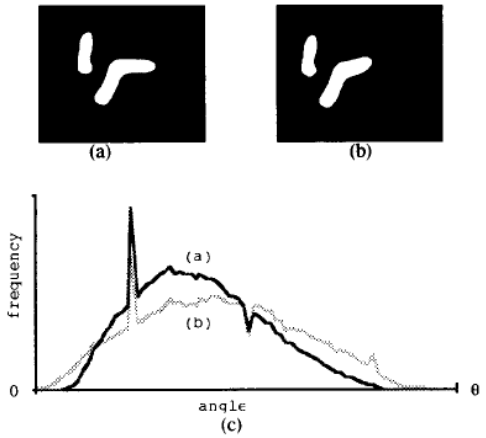


Figure 1. Angle Histogram

2.2. F-Histogram Model

Matsakis [4] proposes F-Histogram as shown in Figure 2, F-Histogram is also based on angle histogram, but longitudinal sections of all angles are taken into account, not the point pairs. The F-histogram is built by computing the integral sum of longitudinal sections of different angles. This histogram added metric parameters in initial establishment, considering that different distances impact on spatial relation by setting different parameters. The computational complexity of F-Histogram is relatively small, and anisotropy is considered.

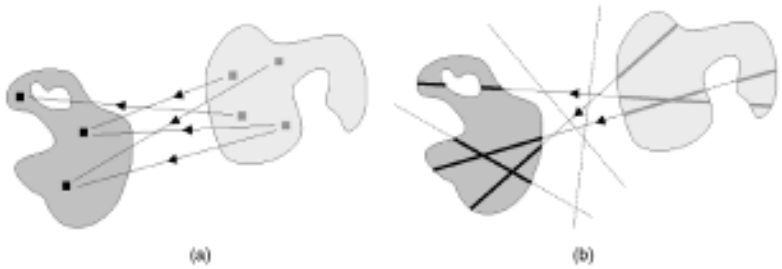


Figure 2. F-Histogram Model

Ni [5] reduces the time complexity of F-Histogram from $O(KN\sqrt{N})$ to O ($N\log N$). Now the F-Histogram is becoming a study hot point for its advantages, and many improved methods and applied researches have constantly emerged. For example Matsakis and others [6-7] propose language description methods of spatial relation.

2.3. Three Reference Frameworks

The reference framework of directional relation is the viewpoint of human to directional relation, and different viewpoint leads to different human's cognition of directional relation. The reference framework most greatly impacts on the directional relation, more than topological relation and distance relation. In this paper we define three basic reference frameworks: intrinsic reference framework, extrinsic reference framework and observer reference framework.

(1) Intrinsic reference framework is a spatial relation reference system built by an observer with certain observation angle inside the reference object. In this reference framework directional relation is often described in terms of *in front of, in back of, in the left of and in the middle of*, etc. For example in a house, entrance door is *in front of* it, the balcony is *in back of* it, and the bedroom is *in the left of* it, *etc*.

(2) Extrinsic reference framework is a spatial relation reference system built by an observer with certain observation angle outside a reference object, when the observer is different from the reference object. In this reference framework directional relation is often described in terms of *in the front of, behind, on the left of and on the east of*, etc. For example, Beijing is *on the north of* Shijiazhuang.

(3) Observer reference framework is built by an observer with certain observation angle outside a reference object, when the observer is same as the reference object. In observer reference framework observer divides space by *front, back, left, right* or *above, below, left* and *right* of itself. For example, the obstacle is *front-left of* the robot.

In order to get the detailed and accurate linguistic descriptions of spatial relation, we need generate linguistic descriptions based on directional relation, topological relation and distance relation. So it is necessary to discuss the relationship between reference frameworks and topological relation. In this paper we consider eight basic topological relations: *disjoint, meet, overlap, equal, inside, contain, cover* and *covered-by*.

In intrinsic reference framework, target object A should be inside of object B, so applicable topological relation should include *inside, covered-by, contain, cover* and *equal*.

In extrinsic reference framework and observer reference framework, target object A should be outside of reference object B, so applicable topological relation should include *disjoint* and *meet*.

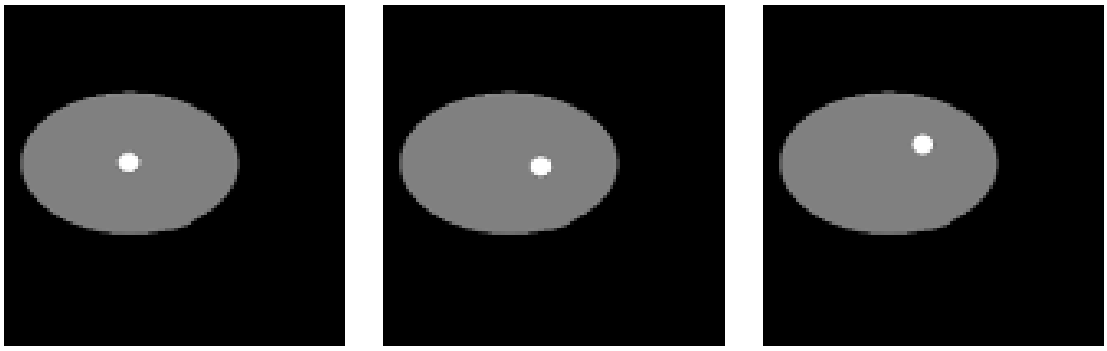
When topological relation is *overlap*, parts of target object are inside of reference object and the other parts are outside of reference object. We can respectively research inside and outside regions in intrinsic reference framework and extrinsic reference framework.

3. Generating Linguistic Descriptions of Spatial Relation in Intrinsic reference framework

3.1. Linguistic Descriptions of Spatial Relation in Intrinisc Reference Framework

Linguistic descriptions of spatial relation refer to using the natural language to describe spatial relation between two objects. In different reference framework we may need different description method. In this paper we discuss the case in intrinsic reference framework.

Take examples for the three pictures in Figure 3, we can artificially generate their linguistic combinatorial descriptions as follows.



(A) (B) (C)

Figure 3. Examples 1

The description of Figure 3A: The white object is *in the middle of* the gray object.

The description of Figure 3B: The white object is *in the middle of* the gray object, but a little in the right of it.

The description of Figure 3C: The white object is *in the middle of* the gray object, but *a little in the front-right of* the gray object.

Firstly, adverbs usually are used in descriptions, such as *a little, somewhat*, etc. Secondly, these descriptions consider both directional relation and topological relation, and can accurately describe the relative position between objects in intrinsic reference framework. Although the descriptions of different people may have slight difference, the location information of its performance should be the same. Thirdly, descriptions of spatial relation is usually adopted a series of fixed sentences, such as "A is … B, but …", so we can use template-based method to generate linguistic descriptions of spatial relation.

In this paper, we will use the fuzzy rules and template-based method to generate linguistic descriptions of spatial relation in intrinsic reference framework.

3.2. Choosing spatial terms based on fuzzy rules

In order to generate descriptions of spatial relation based on templates, we firstly choose spatial terms and adverbs. In this paper the terms include directional relation terms, and adverbs, as follows:

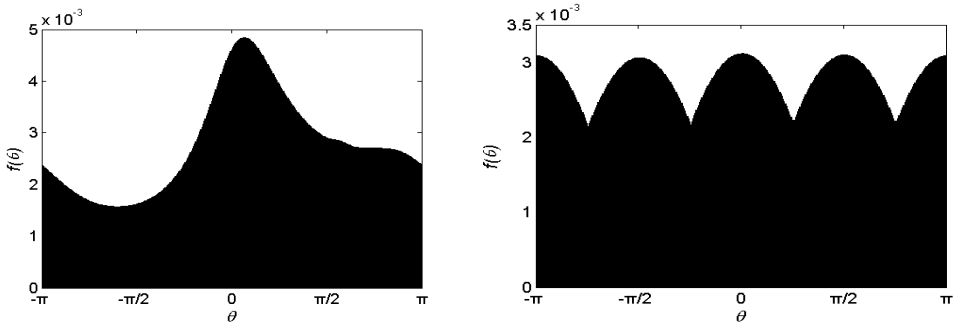
Directional relation terms: *in front of, in back of, in the left of, in the right of* and *in the middle of*.

Adverbs: *a little, somewhat, perfectly, strongly, very*.

Different kinds of terms can adopt different methods for judgment. Take Figure 3C for example, the choosing process of terms is given as follows:

Firstly we calculate F_0-Histogram and F_2-Histogram which can be recognized as probability distribution of θ as shown in Figure 4. We can see that F_2-Histogram can not represent the directional relation information, so we use F_0-Histogram as the basic input data. Secondly we use formula 1and membership functions as shown in Figure 5 to calculate the gravity of membership degrees of four directions on the distribution of θ. Thirdly considering the weaken effect [7], we calculate the final membership degrees of four directions by formula 2. Finally, we determine primary direction and secondary direction between objects by comparing the value of membership degrees, and give a membership degree for *in the middle of* by formula 3 and membership function as shown in Figure 6. In this formula μ_p is membership degree of primary direction and μ_s is membership degree of secondary direction. As shown in Table 1, μp=0.142, μs=0.114 and μ_{middle}^{FH}=0.441, *in the right of* and *in front of* respectively are primary direction and secondary direction.

$$\begin{cases} \mu_{left}^{FH} = \sum_{\theta} \mu_{left}(\theta) f(\theta) \\ \mu_{right}^{FH} = \sum_{\theta} \mu_{right}(\theta) f(\theta) \\ \mu_{front}^{FH} = \sum_{\theta} \mu_{front}(\theta) f(\theta) \\ \mu_{back}^{FH} = \sum_{\theta} \mu_{back}(\theta) f(\theta) \end{cases} \quad (1)$$



(A) (B)

Figure 4. F_0-Histogram and F_2-Histogram

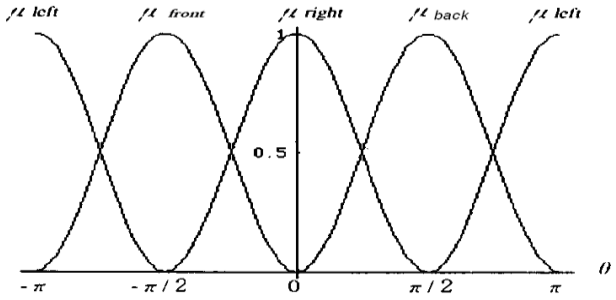


Figure 5. Membership Functions of Four Directions

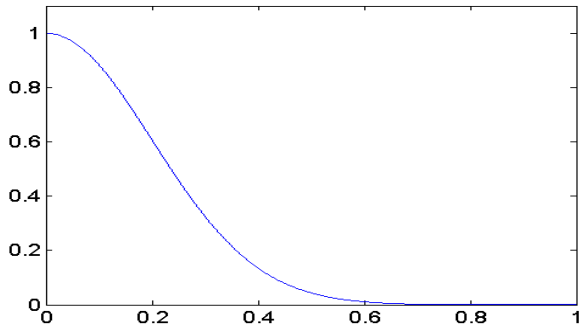


Figure 6. Membership Function of *in the middle of*

Table 1. The result of directional relational words

Directional relational terms	*In front of*	*In back of*	*In the left of*	*In the right of*	*In the middle of*
Member ship degrees(F_0)	*0.114*	*0*	*0*	*0.142*	*0.441*

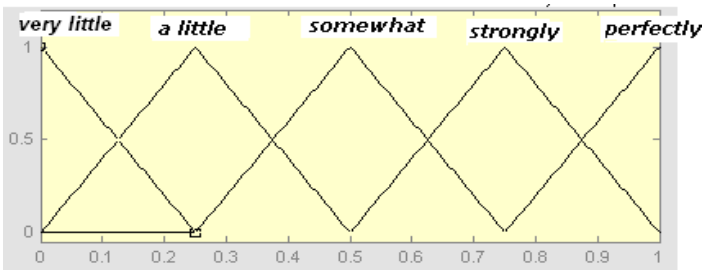
In this paper, we construct membership function of adverbs in Figure 7A to determine adverbs of *in the middle of* by comparing the values of membership degrees. As shown in Table 2, the result is *somewhat*. In addition, we adopt formula 4 to calculate membership difference μ_{Δ} of primary direction and secondary direction. Then we construct membership function of adverbs in Figure 7B, and determine adverbs of four directions. Fuzzy set "void" expresses no adverb, we can use compound directional relation words such as *front-right*. As shown in Table 3, the result is *in the front-right of*.

$$\begin{cases} \mu_{left}^{FH} = \begin{cases} \mu_{left}^{FH} - \mu_{right}^{FH} & if\ (\mu_{left}^{FH} - \mu_{right}^{FH}) \geq 0 \\ 0 & else \end{cases} \\ \mu_{right}^{FH} = \begin{cases} \mu_{right}^{FH} - \mu_{left}^{FH} & if\ (\mu_{right}^{FH} - \mu_{left}^{FH}) > 0 \\ 0 & else \end{cases} \\ \mu_{front}^{FH} = \begin{cases} \mu_{front}^{FH} - \mu_{back}^{FH} & if\ (\mu_{front}^{FH} - \mu_{back}^{FH}) \geq 0 \\ 0 & else \end{cases} \\ \mu_{back}^{FH} = \begin{cases} \mu_{back}^{FH} - \mu_{front}^{FH} & if\ (\mu_{back}^{FH} - \mu_{front}^{FH}) \geq 0 \\ 0 & else \end{cases} \end{cases} \quad (2)$$

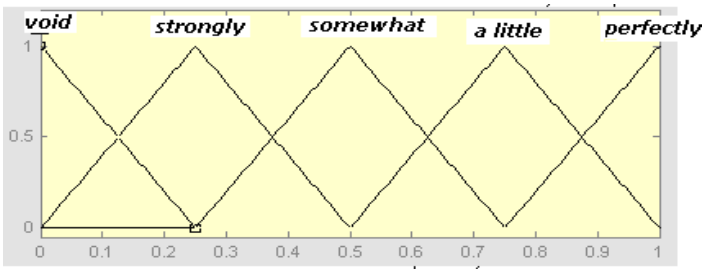
$$\mu_{middle}^{FH} = \mu_{middle}(\mu_p + \mu_s) \quad (3)$$

$$\mu_{\Delta} = \frac{(\mu_p - \mu_s)}{(\mu_p + \mu_s)} \quad (4)$$

Finally, we can get the description of Figure 3C based on template. The description is "The white object is *somewhat in the middle of* the gray object, and the white object is *in the front-right of* the gray object."



(A)



(B)

Figure 7. Membership Function of Adverbs

Table 2. The results of adverbs of *in the middle of*

μ_{middle}^{FH}			0.441		
Adverbs	Very little	A little	Somewhat	Strongly	Perfectly
Membership degrees	0	0.236	0.764	0	0

Table 3. The results of adverbs of four directions

μ_{Δ}			0.109		
Adverbs	Void	Strongly	Somewhat	A little	Perfectly
Membership degrees	0.564	0.436	0	0	0

4. Examples

Using the description method above computer can automatically generate linguistic descriptions of spatial relations for seven pictures in Figure 3 and Figure 8. The results are as follows:

The descriptions of Figure 3A: "The white object is *perfectly in the middle of* the gray object."

The descriptions of Figure 3B: "The white object is *strongly in the middle of* the gray object, and the white object is *in the right of* the gray object."

The descriptions of Figure 3C: "The white object is *somewhat in the middle of* the gray object, and the white object is *in the front-right of* the gray object."

The descriptions of Figure 8A: "The white object is *perfectly strongly in the middle of* the gray object"

The descriptions of Figure 8B: "The white object is *a little in the middle of* the gray object, and the white object is *in the front-left of* the gray object."

The descriptions of Figure 8C: "The white object is *a little in the middle of* the gray object, and the white object is *in the left of* the gray object."

The descriptions of Figure 8D: "The white object is *perfectly in the middle of* the gray object."

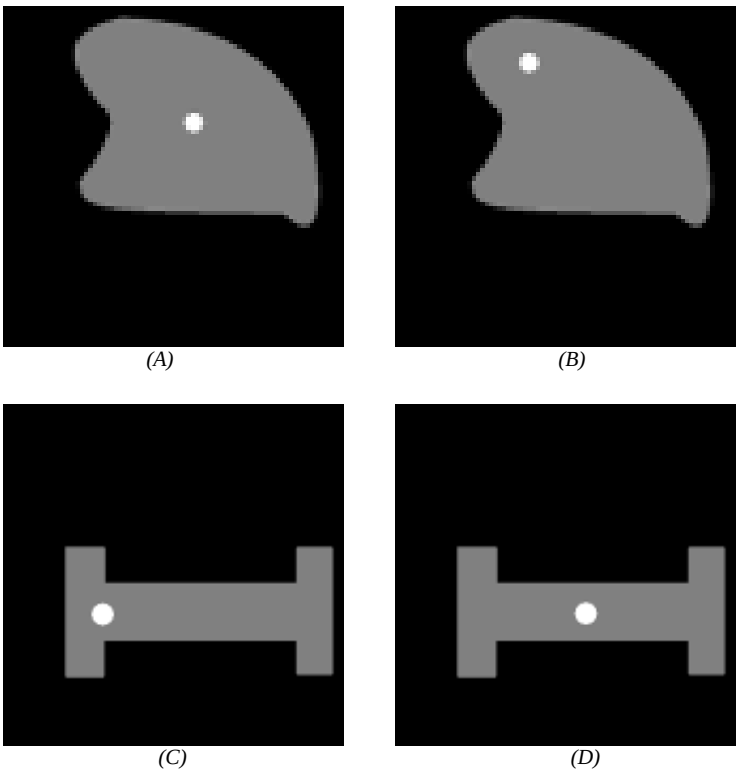


Figure 8. Examples 2

We can see that the descriptions by the method in this paper are almost the same as the descriptions by artificial method. These descriptions can accurately describe three kinds of spatial relation and conform to the human cognition by using adverbs. But because of the difference of people's habits, cultures, thoughts, understandings of spatial relations are more or less different. For instance *a little* and *somewhat* have not a clear division. So we should set reasonable parameters of membership functions according to different people groups and application scenes to make descriptions of spatial relation more accurate.

5. Conclusion

A method for generating linguistic descriptions of spatial relation in intrinsic reference framework has firstly been introduced. Each linguistic expression is built by F-Histogram and fuzzy rules. The descriptions are rich and human-like as demonstrated by the many examples shown. In the future, such features could be used to improve and refine even more the descriptions in other reference framework..

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