Object Configuration Reconstruction from Descriptions using Relative and Intrinsic Reference Frames

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Abstract. We provide a technique to reconstruct an object configuration that has been described on site by only using intrinsic and relative frames of reference into an absolute frame of reference, as seen from the survey perspective.

1 Motivation

You probably recognize the following scenario: You invited a friend to your house and gave him extraordinary directions to easily find the place. However, your friend suddenly phones you and tells you that he 'somehow' cannot find your house. Furthermore, he even had lost his orientation completely. Now it is your task (because you are supposed to know the area) to figure out where he is and guide him from there to your house. You probably let him describe the objects he sees around him and you try to match the described to some mental or external map of the suspected area. Having a survey perspective of his mental or external reconstruction, you (the listener) needs to translate all relative object relationships that your friend (the observer) provides into the global frame of reference. The observer is therefore encouraged to produce an object configuration description that contains the information needed to recognize the object configuration from a survey perspective.

2 Description

In the present work, we assume descriptions consisting of a combination of a *route tour* [9, 6] and several embedded *gaze tours* [9, 6], one for each step within the route tour. Furthermore, a *momentarily applied absolute frame of reference* is used in addition to each gaze tour to report the relative positions between the objects, seen from a particular viewpoint. An activity diagram illustrating the route tour is presented in figure 2.

All three description types use on of the two rectangular frame of reference, shown in figure 1. The frame of reference in figure 1a) is similar to many current approaches to qualitative reasoning about orientation. See for example [8, 3, 7, 4, 1].

Considering that people in way-finding or route-description tasks usually distinguish between eight direction classes [5], the eight directions *right back* (*rb*), *right neutral* (*rn*), *right front* (*rf*), *straight front* (*sf*), *left front* (*lf*), *left neutral* (*ln*), and *left back* (*lb*) shall be used as possible object orientations. The first time a frame of reference is used during the route tour, it automatically sets a corresponding projection-based global frame of reference that captures the concept of a representation of position in latitude and longitude [2].
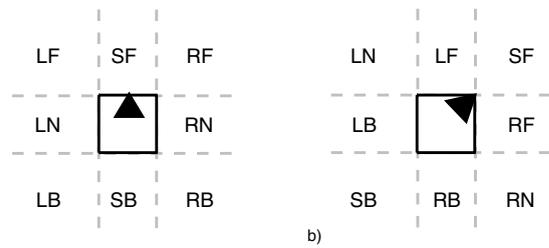
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Figure 1. The frames of reference used.

As described in [9] people are able to change perspectives during a task. Further they are often willing to accept a higher cognitive load if they feel that this may alleviate the cognitive load for their communication partners. Therefore we ask the observer to switch between both reference frames in the continuation of the description process.

3 Reconstruction

Assuming (for readability reasons) that the listener uses the terms *north*, *northeast*, *east*, *southeast*, *south*, *southwest*, *west*, and *northwest* as global directions in the reconstruction, he may choose the orientation *north* for object *1*. Accordingly, the other relationships are translated. The information in which direction the observer moved enables the listener to follow the angle that the applied frame of reference has in relation to the underlying global frame of reference. For a smooth reconstruction, it is advantageous if the description is sorted. The position of an object is only described in relation to objects that have been mentioned within the description before.

Incorporating an additional object into a configuration is done as follows. In the order the relationships of this object are given to other objects that already are reconstructed, the area of the new object is calculated by intersecting all the qualitative regions of the new object to all its reference objects. For instance is the estimated region for object *5* in figure 3a) the intersection of the regions *north 1*, *northeast 2*, *northwest 3*, and *northwest 4* (printed in grey).

Sometimes space has to be made between some already placed objects, for instance when the new object happens to be 'in the middle' of them. For instance consider to insert object *8* into the configuration shown in figure 3b) using the relationships (*8 southeast 5*), (*8 southwest 7*), and (*8 northeast 1*). The intersection of the regions *southeast 5*, *southwest 7* and *northeast 1* contains no space. We can solve this problem by dividing all objects in the reconstruction in two groups,
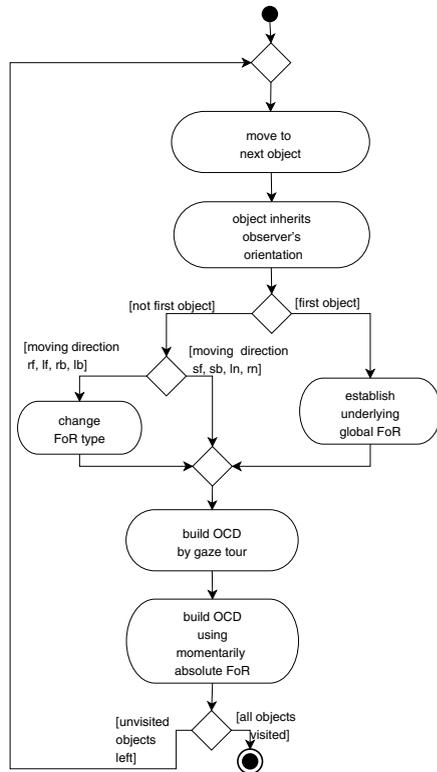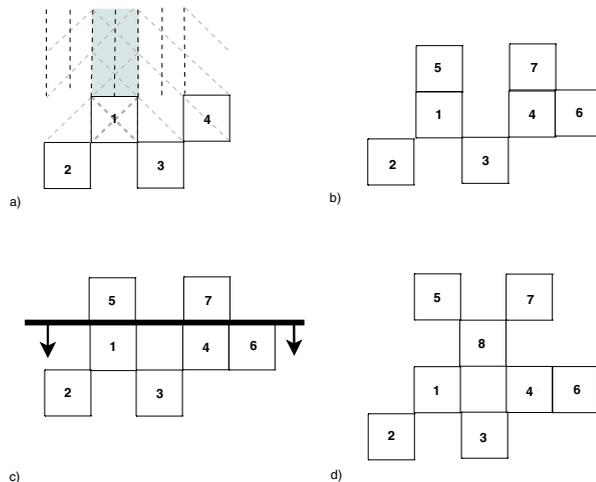
Figure 2. The route tour process.

Figure 3. Reconstruction of an object configuration.

one group containing all the objects that will be north of object 8 and and the other group containing all objects that will be south of object 8. Then the two groups, as they are, are moved apart from each other in vertical dimension indicated by the black line in figure 3c). This procedure does not influence any of the relationships of the reconstructed objects. The intuitive proof is as follows: At the beginning, the reconstruction is correctly containing all objects' relationships. Objects will only be moved in increasing vertical dimension (southwards) and will therefore never cross any reference frame line that separates regions vertically. For all objects that are *north*, *northwest*,

or *northeast* of the moved object and are not moved, the object is *southwest*, *south*, or *southeast* of each of them. These regions are infinite to the south and the object will never leave them by moving southwards. All other objects are moved in the same way as the object itself and therefore its relationships to these objects does not change. Figure 3d) presents the result where object *8* has been inserted into the new obtained space. The procedure to obtain space in the horizontal dimension works accordingly.

An object's orientation is given by an arrow pointing in the object's front edge or front corner. The representation of all objects aligned with the underlying global frame of reference allows the listener to draw objects into the reconstruction, whose orientation is unknown and to add the orientation later without need to redraw the object, or to change its frame of reference. Furthermore, it is necessary to apply the described reconstruction procedure.

4 Summary

e We provide a technique to reconstruct an object configuration that has been described on site by only using intrinsic and relative frames of reference into an absolute frame of reference, as seen from the survey perspective. A set of eight basic relations is sufficient to describe eight positional object relations and allow for eight object orientations.

On one hand, the use of eight orientation classes seems natural for people, on the other hand, the use of eight orientation classes (opposed to for instance four orientation classes) adds a higher cognitive load for the description process by making it necessary for the observer to switch between two different types of frame of reference.

Decisions had to be made to what extent to manufacture an easy reconstruction process and to what extent to be responsive to psychological results of typical human behavior in object configuration description. Both components are important in order to develop a representation scheme that is usable by a person from each side of the process. Nevertheless, these two aims are conflicting. However, Tverksy et al. [9] experienced that people accommodate the acceptable amount of inconvenience according to the cognitive load that the task requires of their communication partners. Therefore, it seems reasonable to balance the effort on both sides.

REFERENCES

[1] J. Fernyhough, A. G. Cohn, and D. C. Hogg, 'Constructing qualitative event models automatically from video input', in *Image and Vision Computing*, volume 18, pp. 81–103, (2000).
[2] A. U. Frank, 'Qualitative spatial reasoning with cardinal directions', in *Seventh Austrian Conference on Artificial Intelligence*, ed., H. Kaindl, Informatik Fachberichte, pp. 157–167, Wien, Austria, (September 1991).
[3] C. Freksa, 'Temporal reasoning based on semi-intervals', in *Artificial Intelligence*, volume 54, pp. 199–227, (1992).
[4] R. K. Goyal and M. J. Egenhofer, 'Similarity of cardinal directions', in *SSTD 2001*, ed., C. S. Jensen, LNCS 2121, pp. 36–55. Springer-Verlag Berlin Heidelberg, (2001).
[5] Alexander Klippel, 'Wayfinding choremes', in *Spatial Information Theory: Foundations of Geographic Information Science*, eds., W. Kuhn, M. F. Worboys, and S. Timpf, pp. 320–334, Berlin, (2003). Springer.
[6] Willem J. M. Levelt, *Speech, Place and Action*, chapter Cognitive Styles in the Use of Spatial Direction Terms, 251–268, John Wiley & Sons Ltd., 1982.
[7] Gerard Ligozat, 'Reasoning about cardinal directions', *Journal of Visual Languages and Computing*, **9**(1), 23–44, (1998).
[8] A. Mukerjee and G. Joe, 'A qualitative model for space', in *Proceedings of the AAAI*, pp. 721–727, Boston, (1990).
[9] Barbara Tversky, Paul Lee, and Scott Mainwaring, 'Why do speakers mix perspectives?', *Spatial Cognition and Computation*, **1**, 399–412, (1999).