Generalized life and motion configurations reasoning model

Pierre Hallot & Roland Billen

Geomatics Unit, University of Liege, 17 Allée du 6-Août,
B-4000 Liege, Belgium
{P.Hallot, rbillen}@ulg.ac.be

Abstract. Although intensive work has been devoted to Spatio-temporal (ST) qualitative reasoning models, some issues such as management of complex objects life and motion remain. First, ST histories' clustering using a set of *life and motion configurations* is briefly presented. Then, we discuss a model based on the generalization of the life and motion configurations into a set of *25 relationships.* These generalized configurations are assimilated to *line-line topological relationships* obtained by projecting life and motion configurations in a *primitive space*. Finally, interpretation of these generalized relationships in natural language is given.

Keywords: ST reasoning, life and motion configuration, ST generalization, natural language interpretation.

1 Introduction

Spatio-temporality is key research issue in Geographic Information Science [1]. It is crucial to develop efficient spatio-temporal (ST) reasoning processes to fully exploit incredible ST information sources. A solution is to integrate time to existing qualitative spatial reasoning models such as RCC [2] or 9-intersection [3]. However, there exists others way to develop ST reasoning models. As mentioned in [4], it is sensible to develop ST reasoning models based on the description of ST shapes. Nevertheless, limitations occur. For instance, most of trajectories descriptions models postulate that moving objects do not share the same place during their evolution [5]. Secondly, most of the models consider only coexisting objects. However, it could happened that one of the studied object disappear for a while. Finally, using these models requires implementing new ST operators. We propose a ST reasoning model valid for coexisting and non coexisting moving objects. At this stage of the research, objects are assimilated to points. Based on life and motions configurations (i.e. formal representation of ST histories using successive ST state) [6, 7], we wish to propose a spatio-temporal qualitative calculus that uses topological relationships, more especially the 9-intersection line-line relationships. The underlying ideas are to link spatio-temporal histories to life and motion configuration and then to project them in a primitive space [8], i.e. a space where spatial and temporal dimensions are not differentiated. This projection allows us to generalize life and motion configurations into a small finite set of primitive relations between two moving objects (corresponding to two lines) with enough remaining information to perform spatio-temporal analyses. Thus, in a preliminary step, we will be able to reason about spatio-temporal information using already implemented topological operators. The paper is structured as follow. First we briefly present the concept of life and motion configurations. Then, we present our reasoning model which is the projection of the life and motion configurations in a primitive space and we give some common sense explanation of it in natural language. Finally, we conclude.

2 Life and motion configuration

2.1 Spatio-temporal states

ST evolution of one object can be rather complex; it is not limited to sharing or not sharing common place during a given time interval. Question like existence, presence can occur: does a baby exist before his birth? Does a key is still present when in a pocket? We gather notions of existence, presence and spatial interaction between two objects at a given time into a concept called "ST state". Considering that there is a time period where an object has not yet existed and one where it will not exist anymore and that an object could not revive, we introduce the notion of existence between two objects at a given time; Four possibilities occur between points A and B: $\{\nexists A \wedge \nexists B\}$, $\{\exists A \wedge \nexists B\}$, $\{\nexists A \wedge \exists B\}$ and $\{\exists A \wedge \exists B\}$. When existent, an object can be present or not (e.g. an existing object that is out of the analyzed space, or not visible). As a result, other specific combinations appear; no presence of object A is denoted by (A). When two objects are present (and therefore are existent), it becomes possible to consider spatial interactions between them at a given time. Topological relationships have been selected to characterize these interactions. At a given time, two possibilities occur between points A and B: A and B are equal {e} or A and B are disjoint {d}.Conceptual Neighborhood Diagram and dominance graph have been realized. A complete description of the concept of state is given into [6]

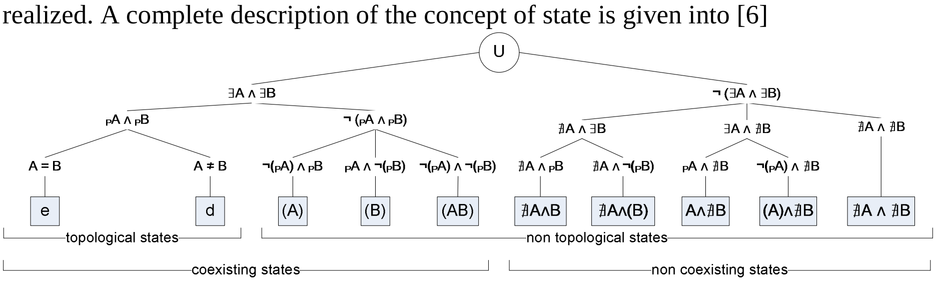

Fig.1. Decision tree of the ten possible "states". (A) means that the object A is not present.

2.2 Life and motion configurations

According to Hayes, ST regions traced over time are called ST histories. There is infinity of ST histories when considering continuous objects movements. However, it is possible to characterize (summarize) ST histories using a set of successive states ordered in time. Possible successions of states will define a finite set of life and motion configurations (i.e. all the possible interaction between two points from a topological and temporal point of view). The entire set of life and motion configuration has been established [7]. They can be represented into a degenerated concept of space-time where spatial axis is limited to the description of a disjoint or an equal topological relationship (see fig. 2).

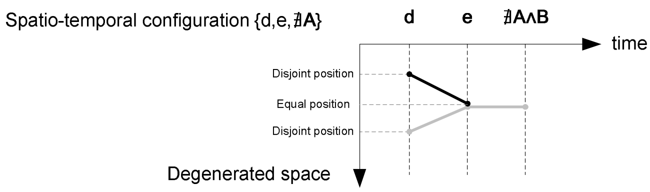

Fig.2. Life and motion configuration {d,e, ∄A } represented in degenerated temporal space with three possible position for representing relationships.

3. Spatio-temporal generalised model

Although there are a finite number of life and motion configurations regarding spatio-temporal histories, it is still high and rather difficult to reason with. We propose to generalize life and motion configurations into line-line topological relationships by projecting them into a primitive space (i.e. a spatio-temporal space where spatial and temporal dimensions are not differentiated [8]). Our aim is to associate spatio-temporal meaning to these generalised spatio-temporal relationships and take advantage of the existing calculus and operators already developed for such topological relationships. In other words, we use a topological calculus on the spatio-temporal histories (through their corresponding life and motion configurations) to extract information from them. We switch from spatio-temporal analysis of a moving point to analysis of lines in a two dimensional space. Figure 3 presents the generalization process from a spatio-temporal history to the corresponding topological relationship in primitive space. Topological relationships are represented through their corresponding topological matrix intersection patterns [9].

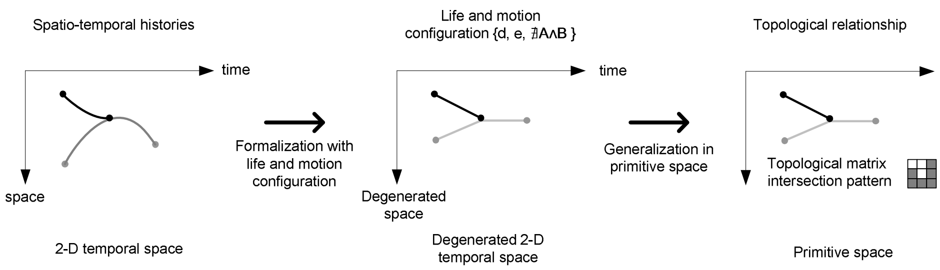

Fig.3. From left to right, formalization of ST histories into a life and motion configuration and Generalization of life and motion configuration into topological relationships through a primitive space.

From the 33 topological relationships between two lines in a 2D space [10], 8 of them are impossible (fig.4). Indeed, Egenhofer and Herring defined 15 conditions reducing the number of possible relationships between to lines to 33. To represent generalized spatio-temporal relationships, we defined a new one. This condition express both that points can not move backward in time and that they can not instantaneously move in space. This mean that if object B is born (or dies) during object A's existence, object A can not born and dies during B's existence and vice versa.

Condition: If A's boundaries not intersect B's exterior, then B's boundaries may not intersect A's interior and vice-versa.

$$\mathbf{R}_{\{\varnothing,\neg\varnothing\}}\mathbf{(A,B)} \neq \begin{array}{|c|c|c|c|} \hline A/B & A^0 & \partial A & A^- \\ \hline B^0 & & & \\ \hline \partial B & \neg\varnothing & & \\ \hline B^- & & \varnothing & \\ \hline \end{array} \vee \begin{array}{|c|c|c|c|} \hline A/B & A^0 & \partial A & A^- \\ \hline B^0 & & \neg\varnothing & \\ \hline \partial B & & & \varnothing \\ \hline B^- & & & \\ \hline \end{array}$$

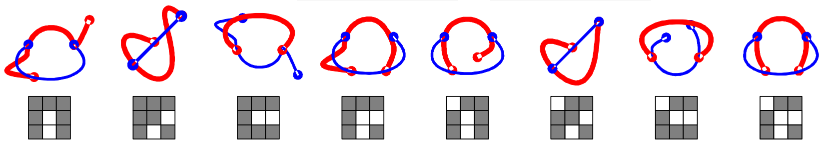

Fig.4. Eight impossible topological relationships between spatio-temporal histories projected in a primitive space with pattern.

The level of generalisation is high. Obviously, part of spatio-temporal information is lost during the generalisation process. We assume that generalized spatio-temporal relationships contain enough meaning to perform efficient spatio-temporal analyses. The CND of 25 topological intersection matrixes obtained from the generalization are represented into the figure 5.

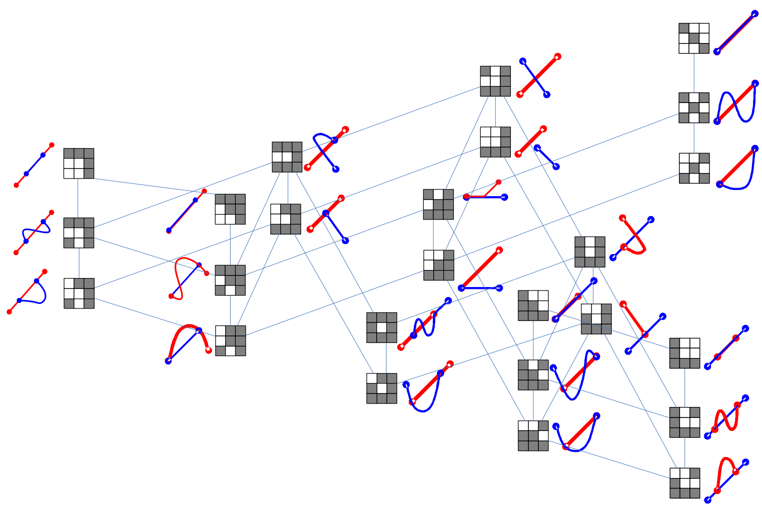

Fig.5. Conceptual neighbourhood diagram and matrix intersection patterns of the twenty-five generalised life and motions configurations (inspired from [11]).

4. Interpretation in common language

Some recent works including [12-15] has shown the importance of associating to configurations and relationships common sense interpretation in natural language. It is necessary to improve their understanding and facilitate their integration into intelligent systems. Figure 6 presents a natural language interpretation of the 25 generalised spatio-temporal relationships. Theses interpretation may also be retrieve by analysing the topological intersection matrixes. Topological intersection matrix patterns are also represented. Theses commonsense interpretation shows the importance of remaining spatio-temporal information after generalization process. Theses can be used to perform preliminary queries on spatio-temporal information.

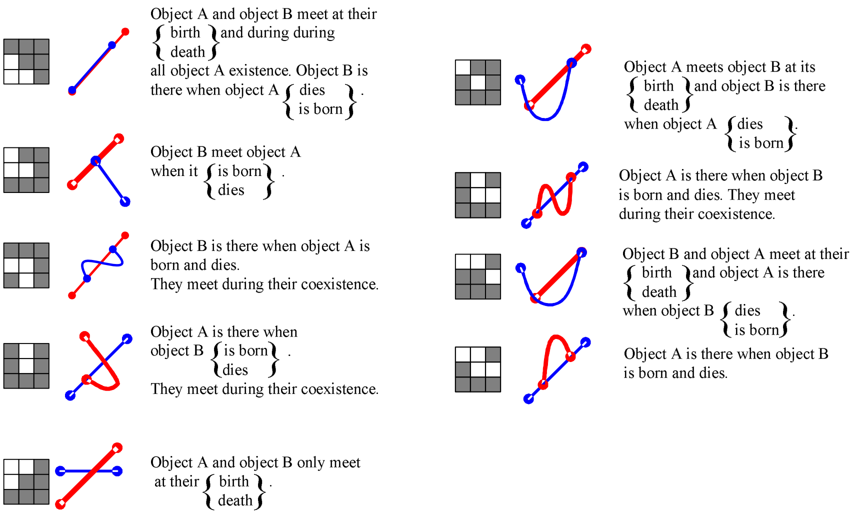

Fig.14. Commonsense interpretation in natural language of the twenty-five generalized of life and motion configurations.

Currently, generalized spatio-temporal relationships model is only available for objects with continuous presence, i.e. continuous ST history. Next step of the research will be to propose a generalization including cases of discontinuity presence.

5 Conclusion

ST reasoning models are needed to fully exploit increasing available ST data. Dealing with qualitative trajectory analyses and movement descriptions are very efficient to describe movement between two disjoint coexisting objects. However, they imply new operators and cannot deal with not existing and not present objects. Our model aimed to overcome these limitations. First, based on life and motion configuration model [6], we have proposed a formalization of ST histories. The created exhaustive set of life and motion configurations was a strong basis to build our ST generalized reasoning model. Indeed, the main idea of our research was to project life and motion configurations into a primitive space, i.e. where spatial and temporal dimensions are not differentiated, and to use topological calculus between lines to extract information. This operation gives us a set of 25 generalized ST relationships. We have showed that out of the 33 spatial topological relationships between lines, 8 were impossible for representing spatio-temporal information. Finally, we have proposed a commonsense interpretation in natural language of the generalized ST relationships. The relative richness of theses interpretations shows the usefulness of the generalized model. Future researches will be to check our model‘s validity with real dataset. Note that its implementation should be straightforward as topological operators between lines are implemented in every S(T)DBMS. Among other future developments, integration of other line-line calculi should be envisaged to manage more general cases where life-lines are not continuous.

References

1. Yuan, M., Hornsby, K.: Computation and Visualization for Understanding Dynamics in Geographic Domains: A Research Agenda. CRC Press (2007)
2. Randell, D.A., Cui, Z., Cohn, A.G.: A Spatial Logic Based on Regions and Connection. In: Nebel, B., Rich, C., Swartout, W. (eds.): Principles of Knowledge Representation and Reasoning: Proceedings of the Third International Conference. Morgan Kaufmann, San Mateo, California (1992) 165-176
3. Egenhofer, M.: A formal definition of Binary Topological Relationships. In: Litwin, W., Schek, H. (eds.): Third International Conference on Foundations of Data Organization and Algorithms (FODO), Vol. 367. Springer-Verlag, Paris, France (1989) 457-472
4. Kontchakov, A., Kurucz, A., Wolter, F., Zakharyaschev, M.: Spatial logic + temporal logic = ? In: Aiello, M., Pratt-Hartmann, I., van Benthem, J. (eds.): The Logic of Space. Kluwer (2007) 72
5. Claramunt, C., Jiang, B.: A representation of relationships in temporal spaces. In: Atkinson, P., Martin, D. (eds.): Innovations in GIS VII: GeoComputation, Vol. 7. Taylor & Francis, London (2000) 41-53
6. Hallot, P., Billen, R.: Life and Motion configuration. In: Science, L.N.i.C. (ed.): SeCoGis, Madrid, Spain (2008, to appear)
7. Hallot, P., Billen, R.: Spatio-Temporal Configurations of Dynamics Points in a 1D Space. In: Gottfried, B. (ed.): Behaviour Monitoring and Interpretation BMI'07. Centre for Computing Technologies (TZI), University of Bremen, Germany, Osnabrück, Germany (2007) 77-90
8. Muller, P.: Topological Spatio-Temporal Reasoning and Representation. Computational Intelligence **18** (2002) 420-450
9. Kurata, Y., Egenhofer, M.: The Head-Body-Tail Intersections for Spatial Relations between Directed Line Segments. In: Raubal, M., Miller, H.J., Frank, A., Goodchild, M. (eds.): Fourth International Conference on Geographic Information Science (GIScience'06), Vol. 4197. Lecture Notes in Computer Science, Muenster, Germany (2006) 269-286
10. Egenhofer, M., Herring, J.: Categorizing Binary Topological Relations Between Regions, Lines and Points in Geographic Databases. Technical Report. Department of Surveying Engineering, University of Maine (1990) 28
11. Kurata, Y., Egenhofer, M.: The 9+-intersection for Topological Relations between a Directed Line Segment and a Region. In: Björn, G. (ed.): Workshop on Behaviour Monitoring and Interpretation (BMI'07), Vol. 42. University of Brement, TZI Technical Report, Osnabrück, Germany (2007) 62-76
12. Bandini, S., Mosca, A., Palmonari, M.: Commonsense Spatial Reasoning for Context–Aware Pervasive Systems. Location- and Context-Awareness (2005) 180-188
13. Noyon, V., Devogele, T., Claramunt, C.: A formal model for representing point trajectories in two-dimensional spaces. International Conference on Conceptual Modelling ER'05, Vol. 3770. Springer-Verlag, Klagenfurt, Austria (2005) 208-217
14. Worboys, M., Duckham, M., Kulik, L.: Commonsense Notions of Proximity and Direction in Environmental Space. Spatial Cognition & Computation **4** (2004) 285-312
15. Mark, D.M., Egenhofer, M.: Modeling Spatial Relationships Between Lines and Regions: Combinig Formal Mathematical Models and Human Subjects Testing. Cartography and Geographic Information System **21** (1994) 195-212