Universität Rostock

Traditio et Innovatio

An Approach for Spatial Pattern Matching in Simulation Trajectories

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Abstract

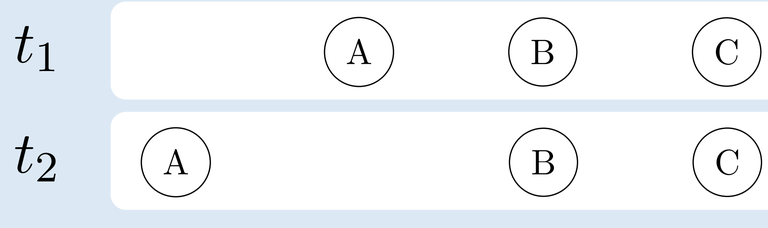
For models that include spatial aspects, the description and recognition of spatio-temporal patterns is an important building block for the analysis of simulation trajectories. We propose an approach that makes use of user-definable qualitative spatial relations between moving entities to represent simulation trajectories as directed labeled graph. In this graph, spatio-temporal patterns can be found through a graph pattern matching algorithm. We implemented the approach using the graph database Neo4j and successfully tested it on movement data from the Robocup Soccer Simulation as well as spatial cell biological simulations.

Case studies

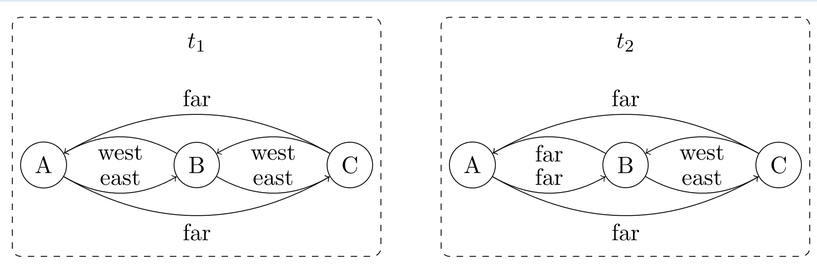
- Robocup 2D Soccer Simulation League: a multi-agent system with 22 agents [4]
  - Specification of interesting match sequences (e.g., a certain attack play)
  - Search match records for occurrences of the specified pattern
- Cell Biology: Spatial models of intercellular signalling pathways [1]
  - Movement of proteins gives clues about function and interaction (e.g., binding)
  - Search simulation logs for occurrences of patterns

Algorithm Sketch

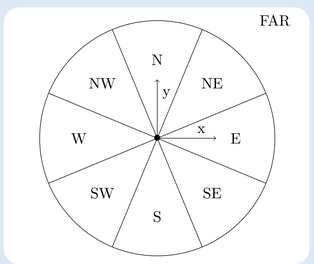
Snapshots of moving objects (trajectories)



Compute relations at each time point

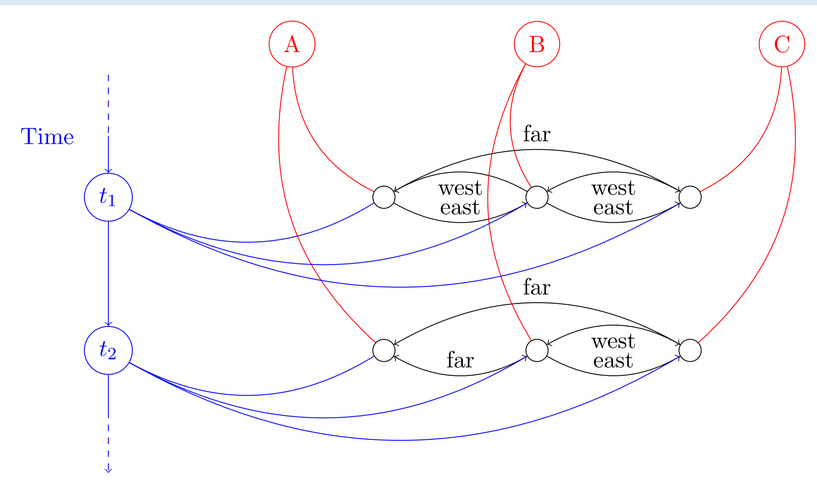


Qualitative spatial relations between two objects



- Set of relations defined between two objects
- JEPD: jointly exhaustive and pairwise disjoint [2]
- Every pair of objects in exactly one relation
- Computable from x and y deltas
- Relations chosen to fit analysis task at hand
- Examples: direction, distance, both [3]

Create data graph containing all relations at all time points



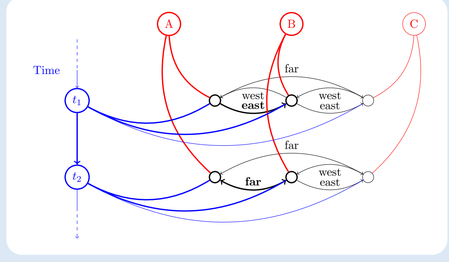
- Contains qualitative knowledge about all trajectories
- One node for each time point (blue)
- Time point nodes are connected and ordered with directed edges
- One labeled node for each object (red)
- One labeled node for each position of an object at a time point
- Each position node is connected with corresponding time point and object node
- All position nodes of same time point are connected with directed edges
- Edges between position nodes are labeled with spatial relation
- Built automatically & saved in Graph Database Neo4j (`http://www.neo4j.org/`)

Search for pattern in data graph

Specify pattern in Neo4j's query language Cypher:

```
MATCH (p1:Position)-[:EAST]->(p2:Position),
   (p1)<--(o1:Object),(p2)<--(o2:Object),
   (p1)<--(t:TimePoint),(t_next:TimePoint)<-[:NEXT]-(t),
   (t_next)-->(p1_next:Position),
   (p1_next)-[:FAR]->(p2_next:Position),
   (p1_next)<--(o1),(p2_next)<--(o2)
RETURN o1.id, o2.id, t.id
```

- Very powerful language
- Actively developed environment
- But pattern specification as query is
  - verbose
  - tedious
  - error-prone
- Automatic generation would be nice



Results

The implementation has successfully been tested for the analysis of simulated soccer matches as well as spatial cell biology models. In both cases, starting with simulation logs and a pattern query, results could be obtained in a few minutes. The current approach is focusing on points in time and space. Future work will be directed towards developing and evaluating domain specific languages for including also nonpointlike constructs in spatio-temporal patterns.

References

[1] Bittig, A. T., F. Haack, C. Maus, and A. M. Uhrmacher. 2011. “Adapting rule-based model descriptions for simulating in continuous and hybrid space”. In Proceedings of the 9th International Conference on Computational Methods in Systems Biology, 161–170.

[2] Düntsch, I. 2005, June. “Relation Algebras and their Application in Temporal and Spatial Reasoning”. Artificial Intelligence Review 23 (4): 315–357.

[3] Frank, A. U. 1992, December. “Qualitative spatial reasoning about distances and directions in geographic space”. Journal of Visual Languages & Computing 3 (4): 343–371.

[4] Noda, C. F. I., H. Matsubara, K. Hiraki, and I. Frank. 1997. “Soccer Server: a tool for research on multi-agent systems”. Applied Artificial Intelligence 12:233–250.

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