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Doctoral Consortium Extended Abstract:
Nonmonotonic Qualitative Spatial Reasoning

Abstract
My work on PhD thesis consists in nonmonotonic reasoning about spatial relations and how they change in time. The work has accomplished so far consists in a collaborative research with Mehul Bhatt and Carl Schultz which resulted in establishing the ASPMT(QS) system [1] which is a novel approach for reasoning about spatial change within a KR paradigm. ASPMT(QS) is based on a paradigm of Answer Set Programming Modulo Theories (ASPMT) [2] and polynomial encodings of spatial relations. The system is capable of sound and complete spatial reasoning, and combining qualitative and quantitative spatial information when reasoning nonmonotonically. Its first version is already implemented. We have demonstrated (see [1]) that no other existing spatial reasoning system is capable of supporting the key nonmonotonic spatial reasoning features (e.g., spatial inertia, ramification) provided by ASPMT(QS) in the context of a mainstream knowledge representation and reasoning method, namely, answer set programming.

Example (Attach): geometric reasoning and frame problem
In S0, the car is attached to the trailer and they are outside the garage. In S1, the car is inside the garage. What actions have been performed?

Allowed domain-specific actions:
• the car can move: move(car, X)
• the trailer can be detached, detach(trailer, car, X) in time step X.

Attachment I. Given the topological information in S0, ASPMT(QS) infers that there are two possible solutions:
(a) the car is detached from the trailer
(b) the car, together with the trailer move into the garage.

Attachment II. Given additional geometric information: r(car) = 2, r(trailer) = 2 and r(garage) = 3, ASPMT(QS) infers that (b) is now inconsistent, and the only possible solution is (a).

Evaluation
In [1] we have performed an empirical evaluation of ASPMT(QS) in comparison with other existing spatial reasoning systems:
• Clingo – an ASP grounder and solver [3].
• GQR – a binary constraint calculi reasoner [4].

The range of problems demonstrate the unique, nonmonotonic spatial reasoning features that ASPMT(QS) provides beyond what is possible using other currently available systems.

Cumulative results of performed tests are presented in the below table, where "—" indicates that the problem can not be formalised, "•" indicates that indirect effects can not be formalised, "<" indicates that default rules can not be formalised.

<table>
<thead>
<tr>
<th>Problem</th>
<th>Clingo</th>
<th>GQR</th>
<th>CLP(R)</th>
<th>ASPMT(QS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Growth</td>
<td>0.004s</td>
<td>0.016s</td>
<td>0.619s</td>
<td>0.395s</td>
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<tr>
<td>Motion</td>
<td>1.918s</td>
<td>1.952s</td>
<td>13.394s</td>
<td>1.386s</td>
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<td>Attach I</td>
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<td>—</td>
<td>2.789s</td>
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<tr>
<td>Attach II</td>
<td>1.218s</td>
<td>0.375s</td>
<td>2.789s</td>
<td>0.642s</td>
</tr>
</tbody>
</table>

Tests were performed on an Intel Core 2 Duo 2.00 GHz CPU with 4 GB RAM running Ubuntu 14.04.

Future work
Extensions of the ASPMT(QS) system:
• performing complex spatio-temporal reasoning
• applying to practical problems: computer-aided architecture design, mobile robots control, etc.

Additionally, introduce another approach for nonmonotonic spatial reasoning based on Equilibrium Logic, that has been used for temporal reasoning but not for spatial reasoning.

References