Collective Adaptation through Concurrent Planning: the Case of Sustainable Urban Mobility

Antonio Bucchiarone[1], Daniel Furelos-Blanco[2], Anders Jonsson[2], Fahmida Khandokar[3] and Monjur Mourshed[3]

[1]Fondazione Bruno Kessler [2]Universitat Pompeu Fabra [3]Cardiff University

Abstract

We address the challenges that impede collective adaptation in smart mobility systems by proposing a notion of **ensembles**. Ensembles enable systems with collective adaptability to be built as emergent aggregations of autonomous and self-adaptive agents. Adaptation in these systems is triggered by a run-time occurrence, which is known as an **issue**.

The **novel aspect** of our approach is, it allows agents affected by an issue in the context of a **smart mobility scenario** to adapt collaboratively with minimal impact on their own preferences through an **issue resolution** process based on **concurrent planning** algorithms.

Roles and Ensembles

Our approach to collective adaptation involves the following concepts:

- An **ensemble** is an emergent aggregation of autonomous and self-adaptive agents.
- Each agent is defined by a set of **roles**.
- Collaboration involves taking **actions** and generating **issues** (e.g. blocked streets that force agents to take alternative routes).
- When an issue arises, a role handles the issue using one of its **solvers**.

Concurrent Planning

We adopt the formalism of **temporal planning** [1, 2] to generate concurrent solutions.

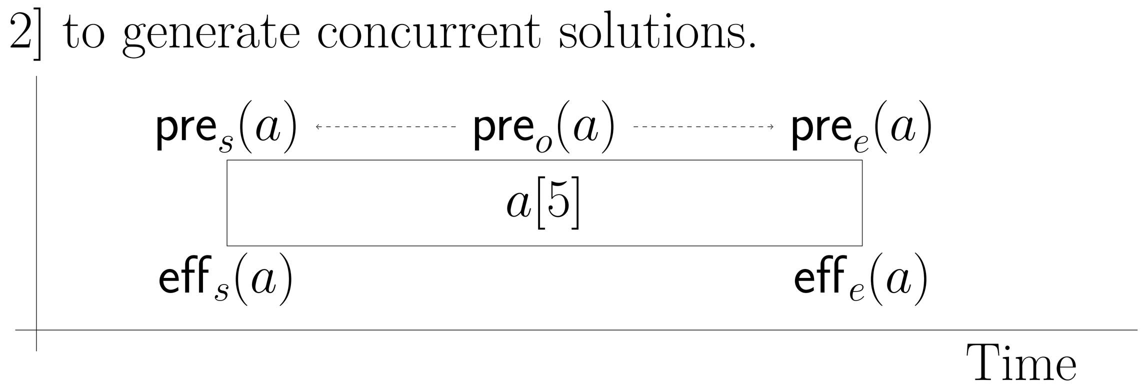

Figure: Model of an action in temporal planning.

Problem Modeling

There are two types of agents (passengers and carpools) distributed in a map. Each agent has an initial and a target location.

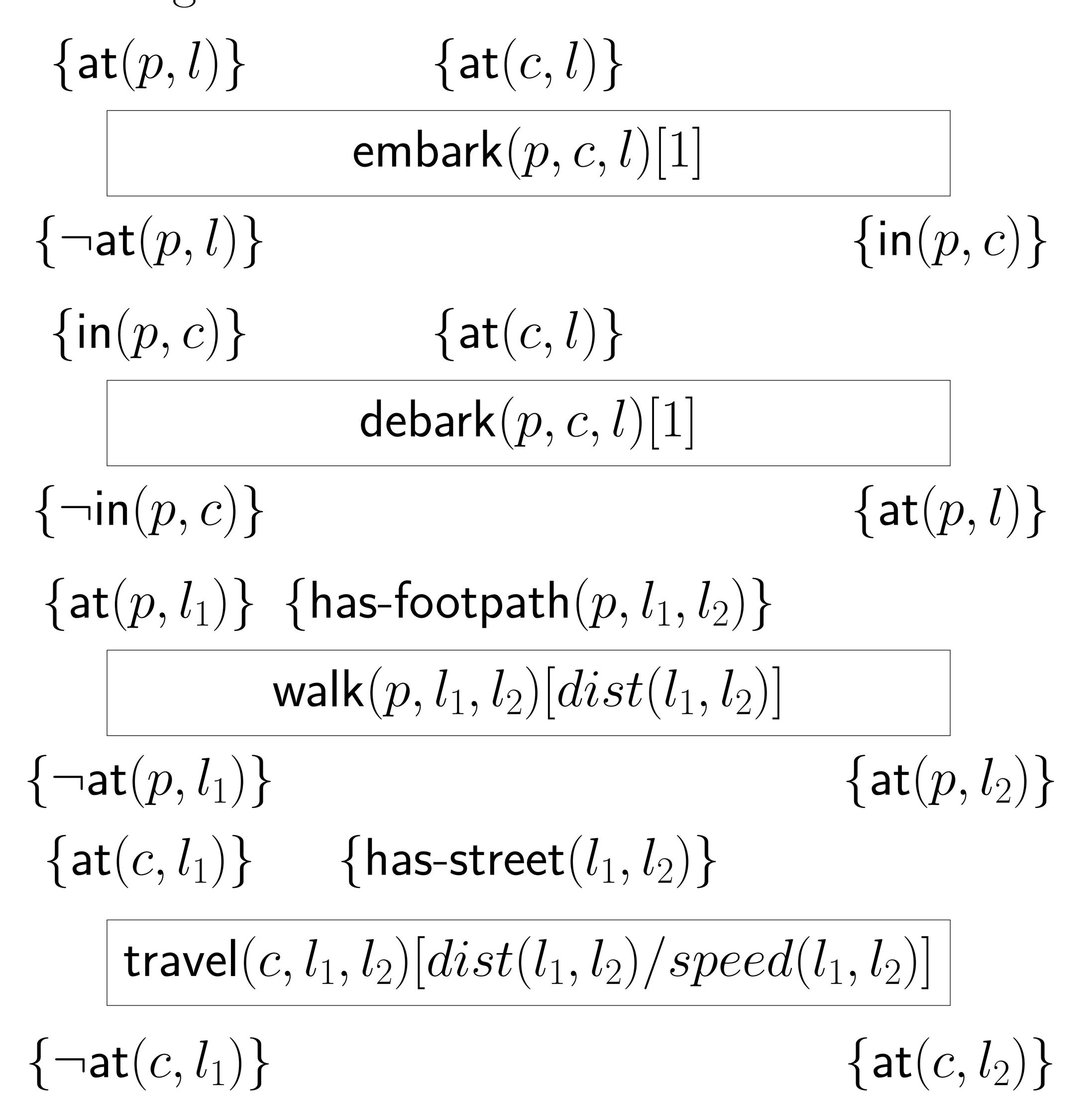

Figure: Temporal actions of the domain.

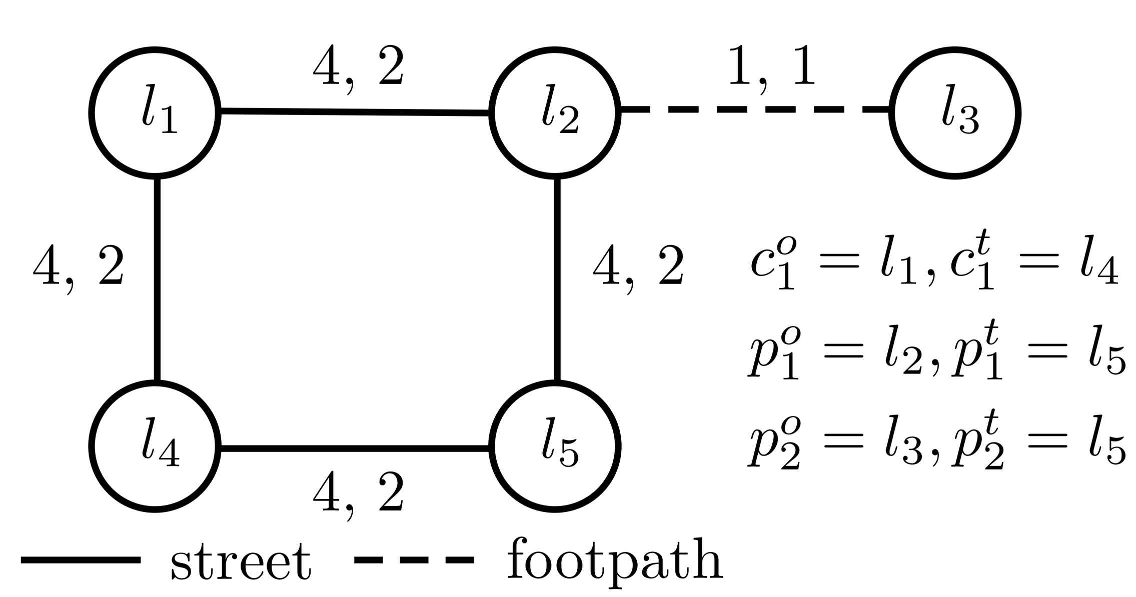

Figure: Simple smart mobility scenario.

start time	action	duration
0.0000	$\mathsf{travel}(c_1, l_1, l_2)$	2.0000
0.0000	$\mathsf{walk}(p_2, l_3, l_2)$	1.0000
2.0002	$\mathsf{embark}(p_1, c_1, l_2)$	1.0000
2.0002	$\mathsf{embark}(p_2, c_1, l_2)$	1.0000
3.0004	$\mathsf{travel}(c_1, l_2, l_5)$	2.0000
5.0006	$\mathsf{debark}(p_2, c_1, l_5)$	1.0000
5.0006	$\mathsf{debark}(p_1, c_1, l_5)$	1.0000
6.0008	$\mathsf{travel}(c_1, l_5, l_4)$	2.0000

Figure: Temporal plan for the previous scenario.

Evaluation

How are problems generated and solved?

1. Build problems using:
   - A real map of Trento obtained from OpenStreetMap [3].
   - A given number of agents (carpools and passengers).
2. Set random initial and target positions for the agents.
3. Convert the resulting scenarios into concurrent planning problems.
4. Solve the problems using the TPSHE planner [4].

How is evaluation done?

We generated 45 problems for different combinations of maps and number of agents:

- Maps of Trento with different number of links/streets: 2700, 5500 and 8200.
- The total number of agents ranged from 2 to 10.

The average solving time is measured for each combination of maps and number of agents.
Each experiment had a time limit of 5 minutes and a memory limit of 4 GB.

Results

$\uparrow$ # agents, $\uparrow$ #links $\rightarrow$ $\downarrow$ # instances solved within budget.

- Small map (2700 links): 99.8%.
- Medium map (5500 links): 70.4%.
- Large map (8200 links): 39.6%.

Future work: Use a hierarchical approach to reduce the number of streets and decrease time.

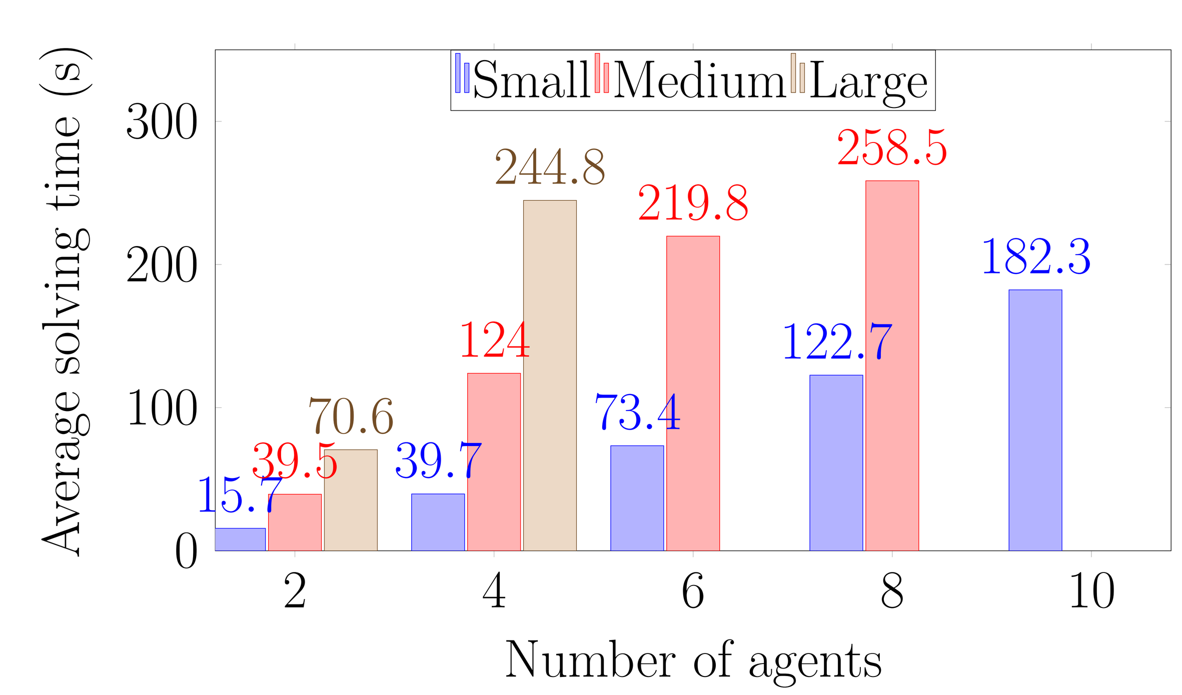

Figure: Average solving times for different combinations of maps and number of agents.

Conclusions

- Approach to Collective Adaptation Systems resilient to changes.
- Adaptation issues solved within an ensemble.
- Solve issues collectively with concurrent planning.

References

[1] M. Fox and D. Long. PDDL2.1: an extension to PDDL for expressing temporal planning domains. *J. Artif. Intell. Res. (JAIR)*, 20:61–124, 2003.

[2] J. Rintanen. Complexity of Concurrent Temporal Planning. In *ICAPS'07*, pages 280–287, 2007.

[3] M. Haklay and P. Weber. OpenStreetMap: User-Generated Street Maps. *IEEE Pervasive Computing*, 7(4):12–18, 2008.

[4] S. Jiménez, A. Jonsson, and H. Palacios. Temporal Planning With Required Concurrency Using Classical Planning. In *ICAPS'15*, pages 129–137, 2015.

Acknowledgments

This work has been partially funded by the Maria de Maeztu Units of Excellence Programme (MDM-2015-0502).

Contact Information

- Software: https://github.com/aig-upf/smart-carpooling-demo
- Email: daniel.furelos@upf.edu

FONDAZIONE BRUNO KESSLER FUTURE BUILT ON KNOWLEDGE
upf. Universitat Pompeu Fabra Barcelona
CARDIFF UNIVERSITY PRIFYSGOL CAERDYDD
EXCELENCIA MARÍA DE MAEZTU