Behavior and path planning for the coalition of cognitive robots in smart relocation tasks

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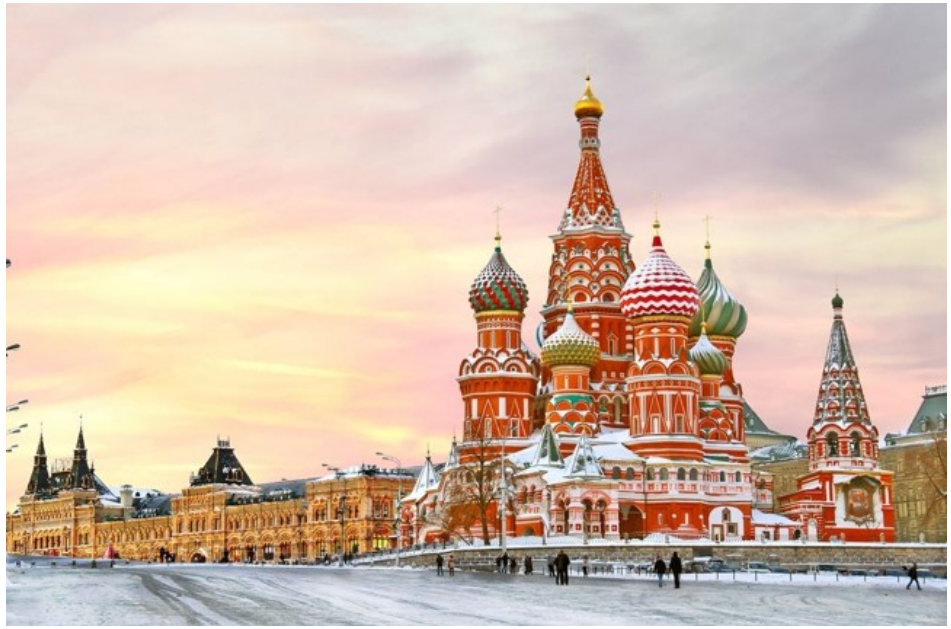
Authors' origin



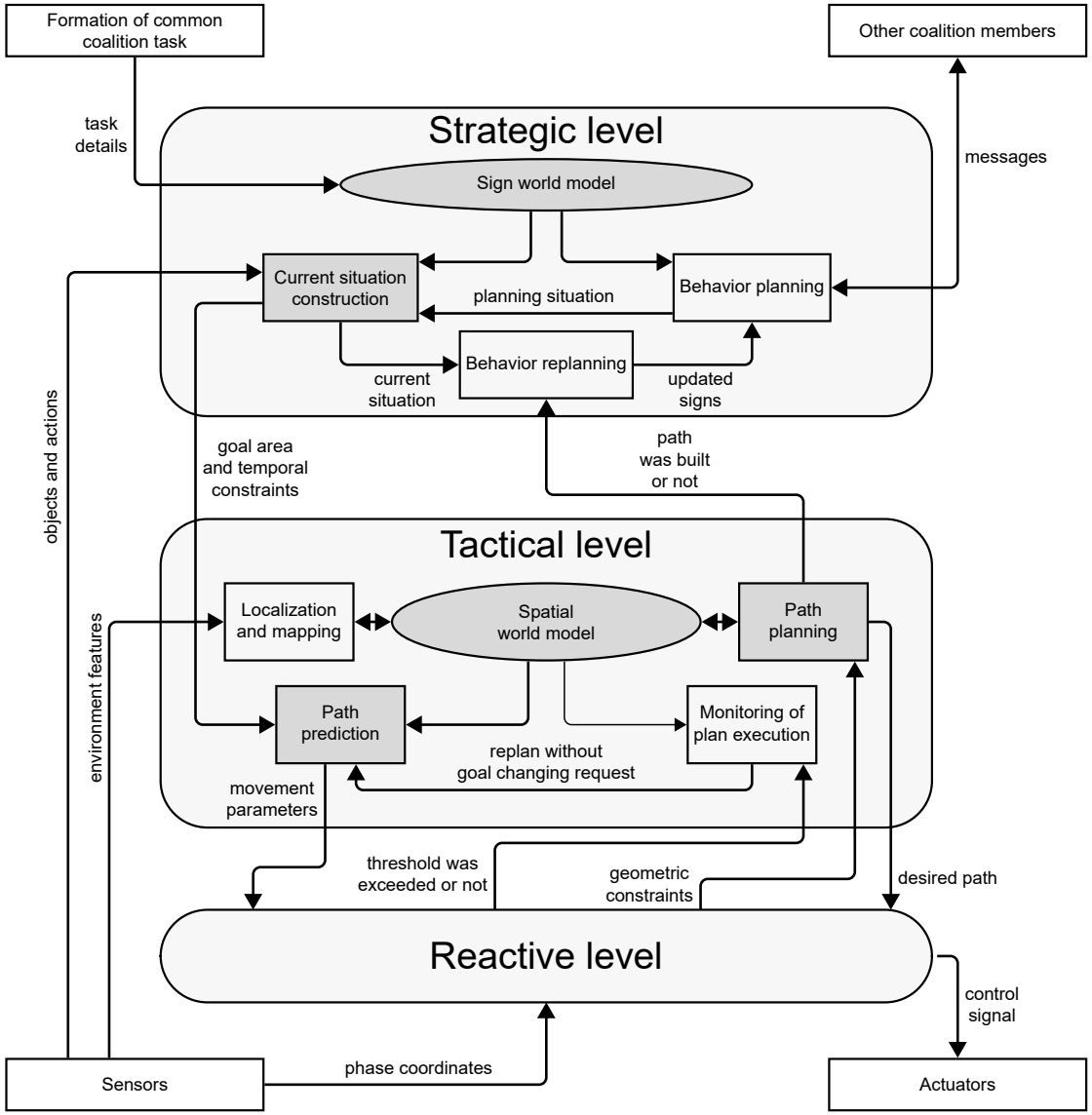
Authors' background

Federal Research Centre "Computer Science and Control" of **Russian Academy of Sciences**

Research interests: Artificial Intelligence, Cognitive Modeling, Semiotics, Task Planning, Heuristic Search, Path Planning, Robotics

Ongoing research: Multilayered cognitive architecture of the control system for intelligent agents (including mobile robots, UAVs, etc.) – **STRL architecture**

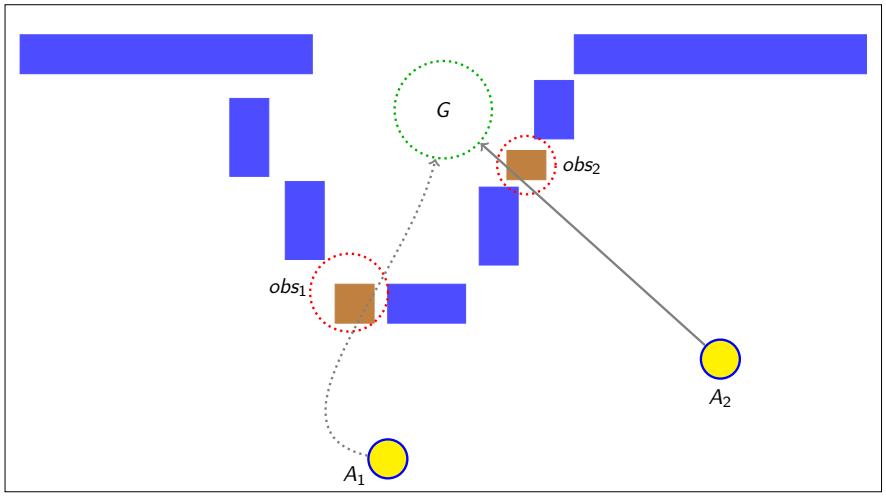
STRL architecture



3 levels of control:

- **Strategic**: Behavior planning (including inter-agent communication
- **Tactic**: Path planning (including prediction and monitoring)
- **Reactive**: Path following taking into account agent's dynamic

Smart Relocation Tasks (SRT)



Problem

Goal area can not be achieved by some agents on their own (using standalone task and path planning methods)

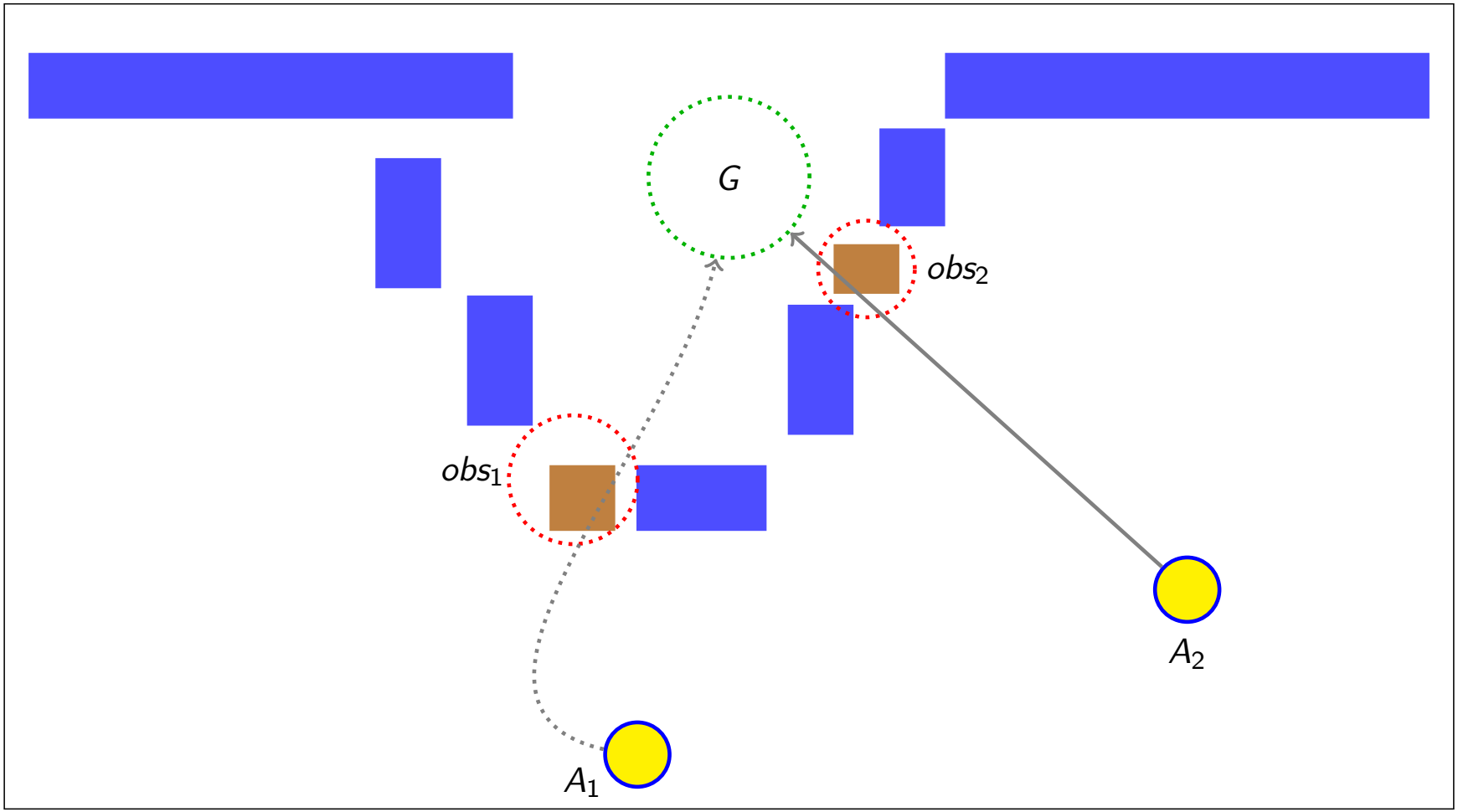
Solution

Agents must communicate and some agents must alter their "selfish" plans in order to construct coalition plan

3 levels of control:

- Transformable environment
- Different types of obstacles (some – can be destroyed)
- Agents with different capabilities (some agents can destroy obstacles, others – can not)
- Common spatial goal (ALL agents must reach this region in order goal to be achieved)

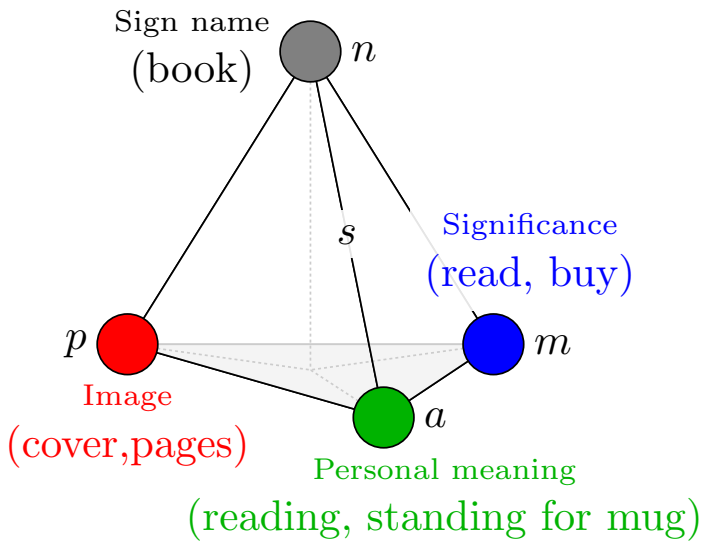
Plan execution

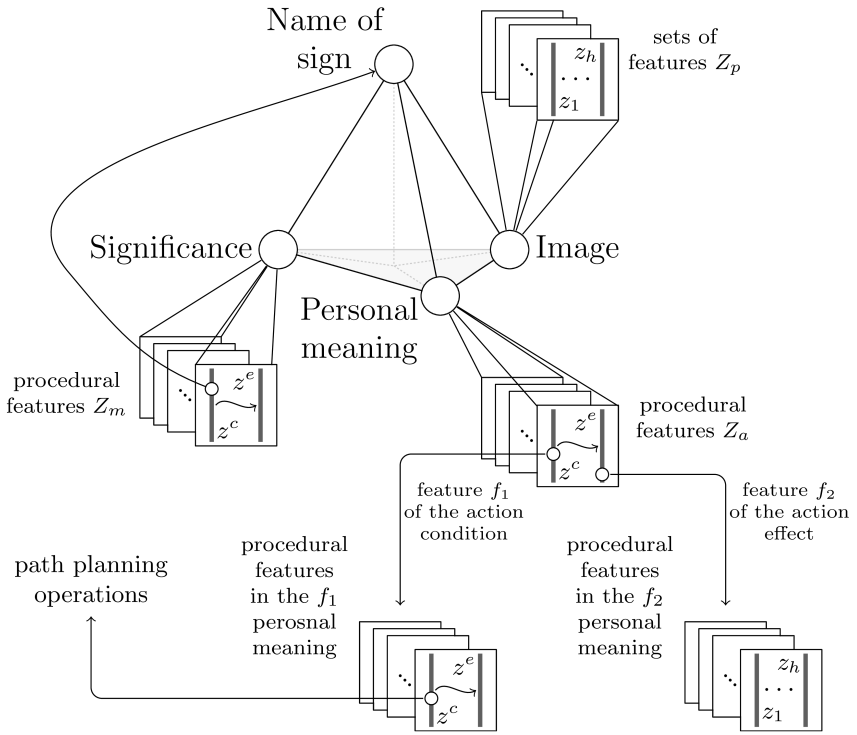


Sign knowledge representation

Sign as a component of knowledge:

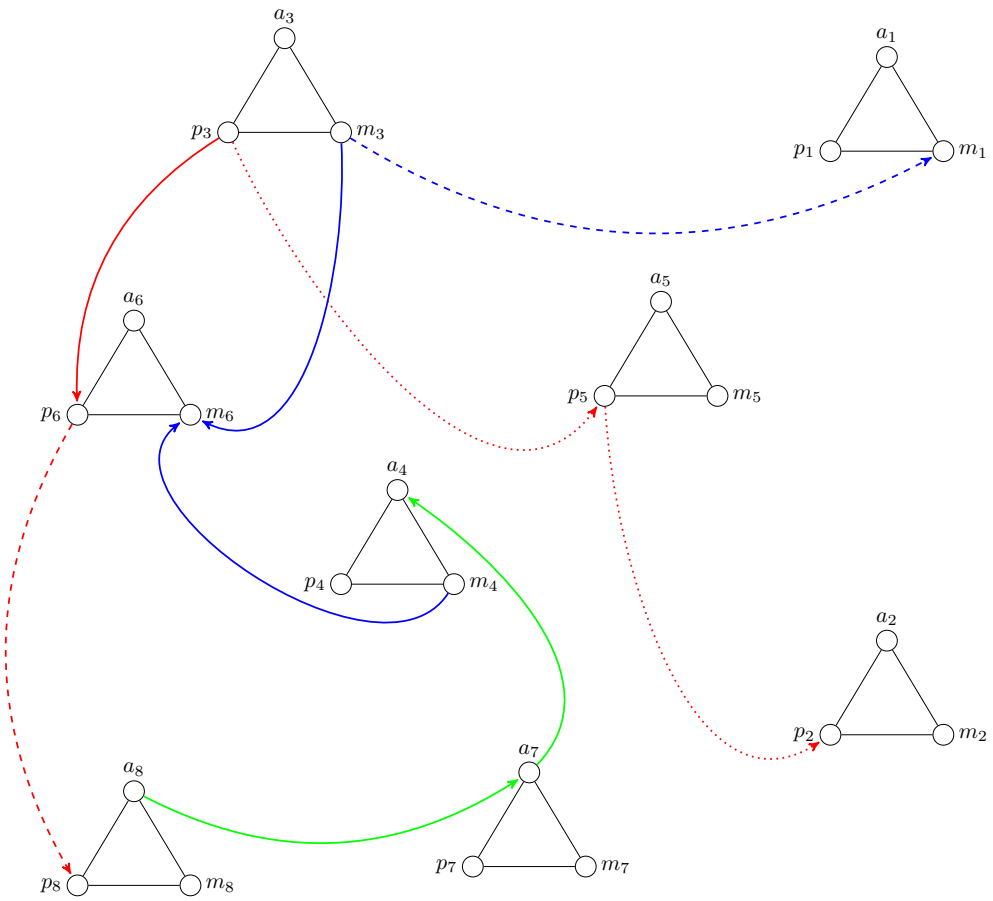
- cultural-historical approach of Vygotsky-Luria
- the theory of activity of Leontiev





This structure is supported by neuropsychological data (Edelmen, Ivanitsky, George, Hawkins etc.)

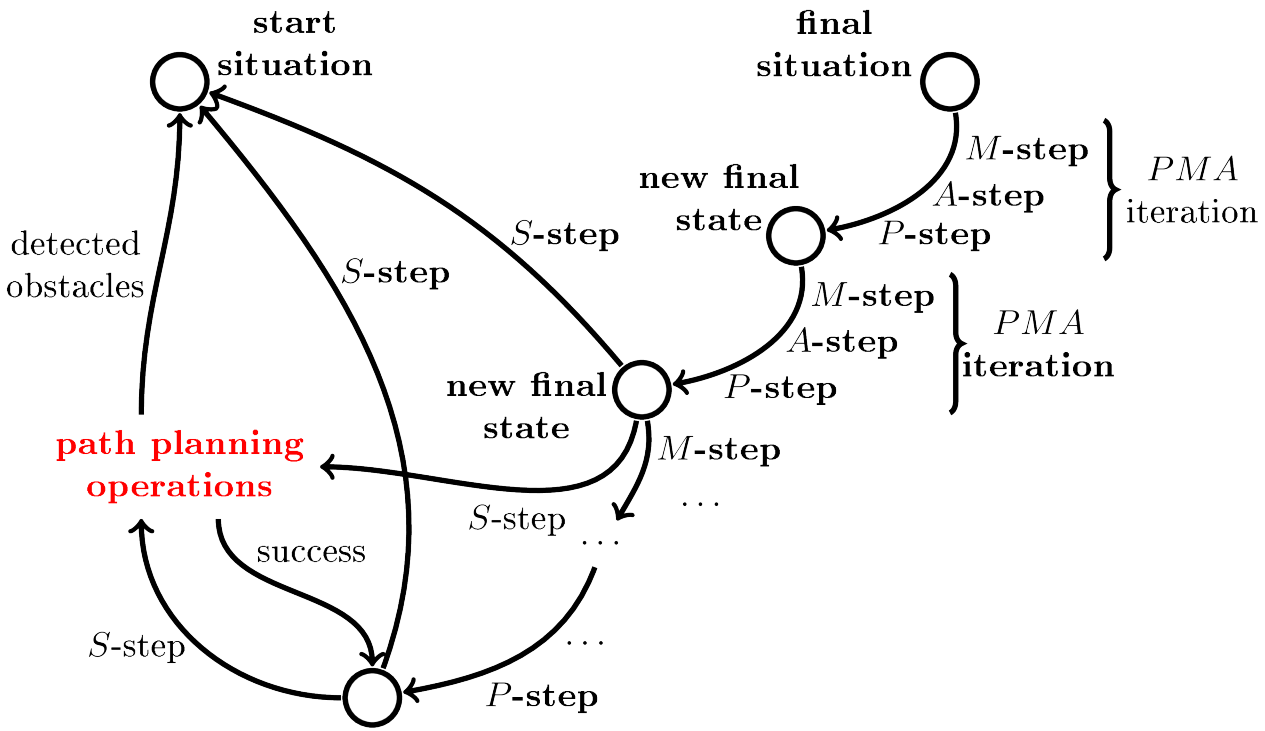
Sign world model



Semiotic network
$H = \langle H_P, H_A, H_M \rangle$ consisting of three semantic network:

- $H_P = \langle 2^P, \mathfrak{R}_P \rangle$ – semantic network on the set of sign images,
- $H_P = \langle 2^A, \mathfrak{R}_A \rangle$ – semantic network on the set of sign meanings,
- $H_P = \langle 2^M, \mathfrak{R}_M \rangle$ – semantic network on the set of sign significances.

Behavior planning algorithm

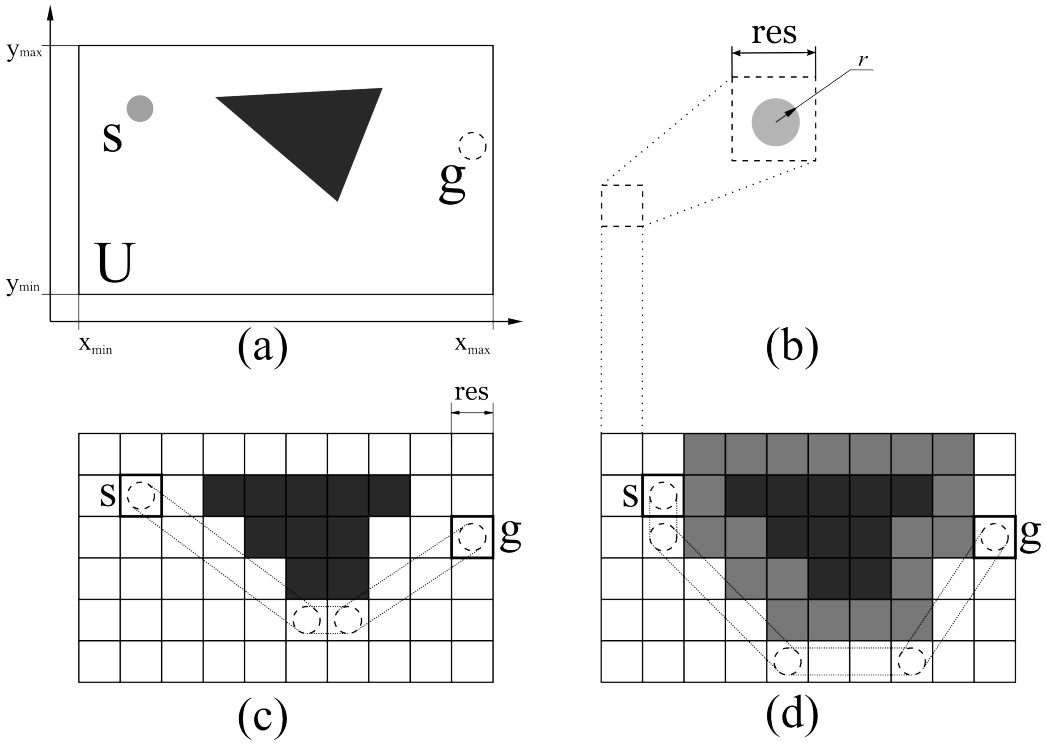


Planning starts from final situation and aims to meet start situation.

Main steps of algorithm (PMA iteration):

- *M-step* – search of relevant significances,
- *A-step* – choose a personal meaning from the set of personal meanings corresponding to the found significances,
- *P-step* – construct the new current situation using the set of features from the condition of performed action,
- *S-step* – send a message to other members of the coalition or perform the action corresponding to the chosen personal meaning or execute action hierarchy up to path planning operations.

Path planning as graph search



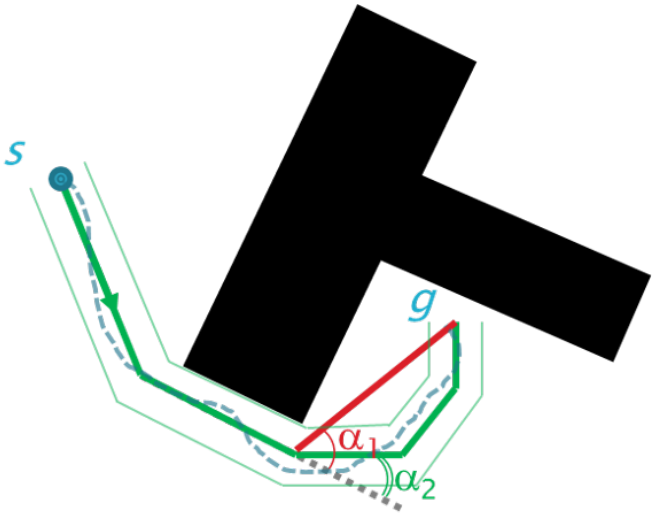
Regular square grid – simple, informative and **easy-to-construct** spatial graph model for 2D path planning

Elfes, A. 1989. Using occupancy grids for mobile robot perception and navigation. Computer, 22(6), 46-57.

Yap, P. 2002. Grid-based path-finding. In Proceedings of 15th Conference of the Canadian Society for Computational Studies of Intelligence, 44-55. Springer Berlin Heidelberg.

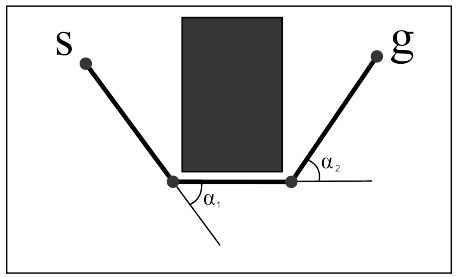
Tozour, P. 2004. Search space representations. In Rabin, S. (Ed.), AI Game Programming Wisdom 2, 85–102. Charles River Media.

Taking agent's dynamic constraints into account

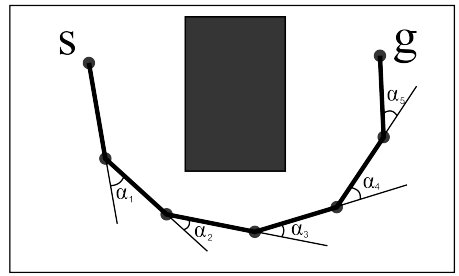


Angle-constrained path planning

Pure geometrical approach allows to state within compact, spatial-only search space (in contrary to "directly enhance the search-space with agent's dynamic constraints" approach)



$\alpha_i > \alpha_m$



$\alpha_i < \alpha_m$

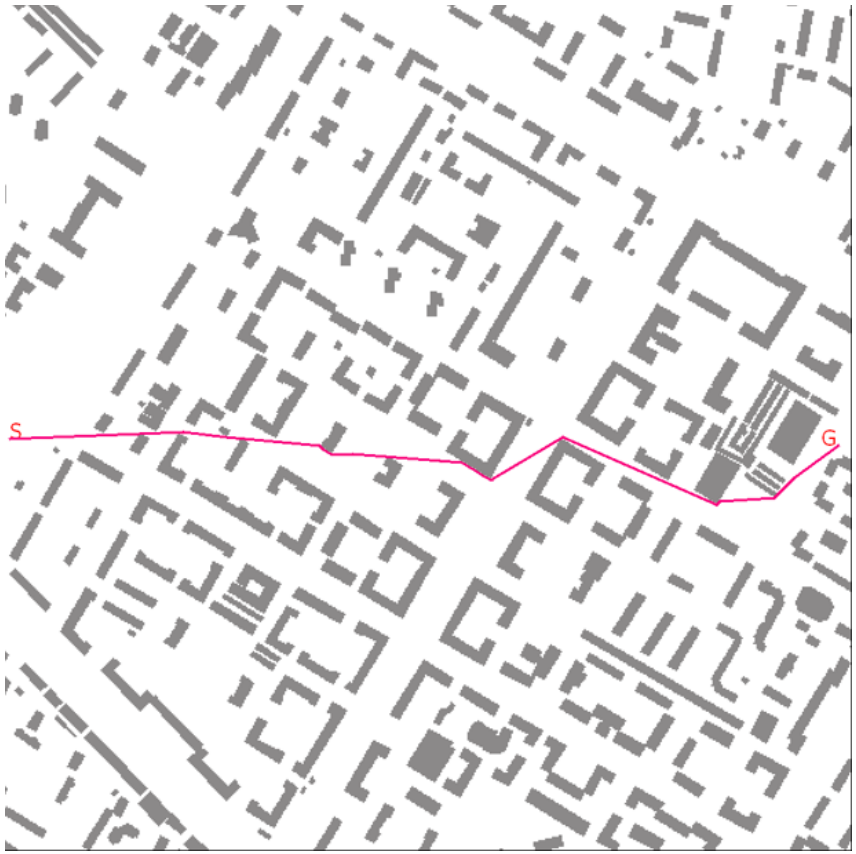
2 phases of path planning

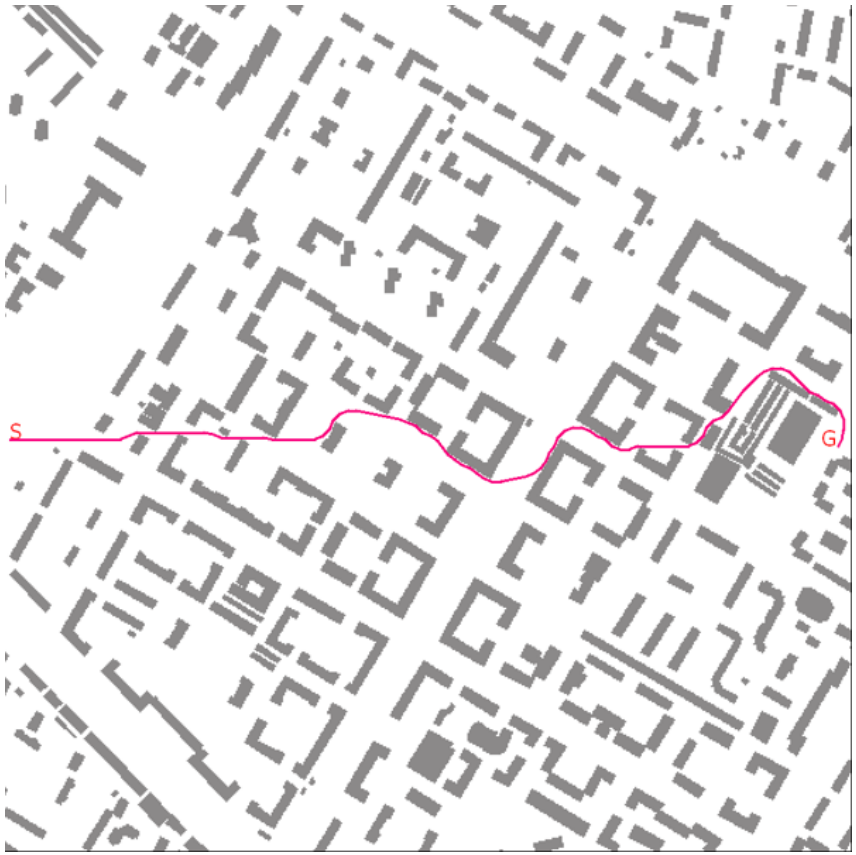
1. Path prediction (fast, no angle constraints)
   - Using Theta* to find a path
   - Use this path to calculate angle constraints (on reactive level)
2. Angle constrained path planning
   - Using LIAN to find a path
     - Not that fast
     - No path can exist under constraint given

Theta*: **Nash, A., Daniel, K., Koenig, S., Felner, A. 2007.** Theta*: Any-Angle Path Planning on Grids. In Proceedings of the National Conference on Artificial Intelligence (Vol. 22, No. 2, p. 1177). Menlo Park, Calif.: AAAI Press.

LIAN: **Yakovlev, K., Baskin, E., Hramoin, I. 2015.** Grid-based angle-constrained path planning. In Proceedings of 38th Annual German Conference on AI, Dresden, Germany, September 21-25, 2015 (pp. 208-221).

Theta* and LIAN

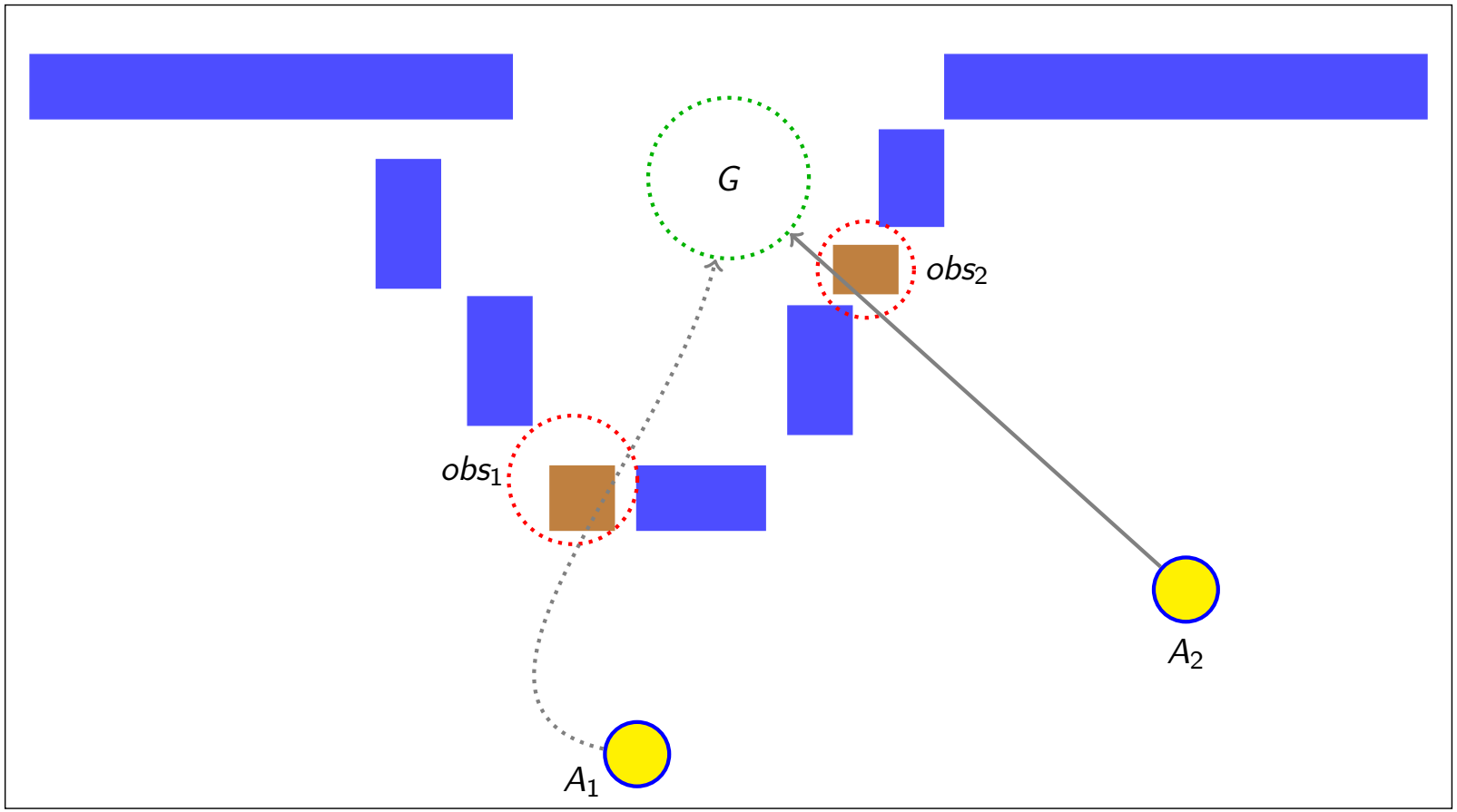




Interaction with Behavior planning

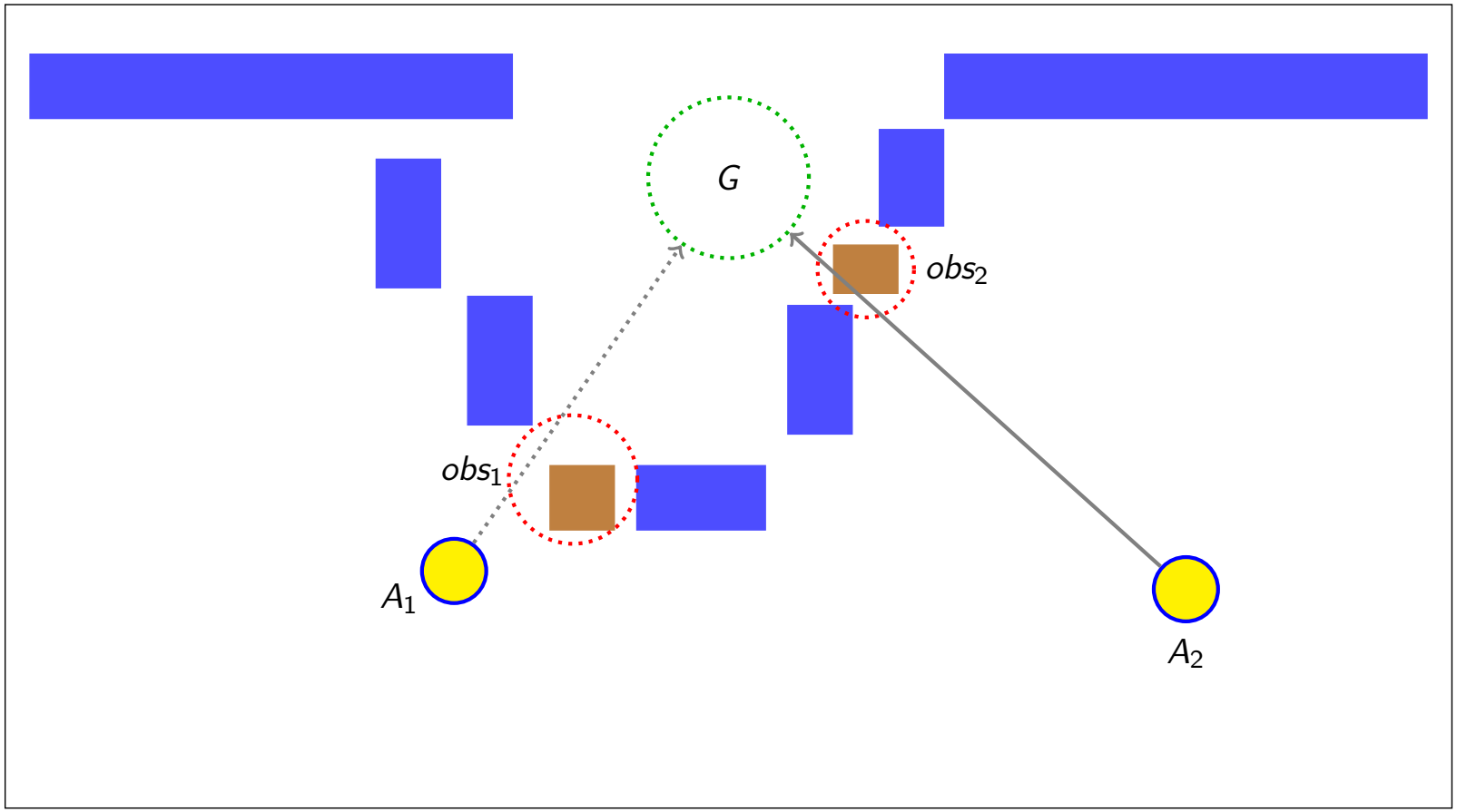
1. Non-angle-constrained path can not be found
   - It takes a while to come to that
   - Identify blocking obstacle
   - Pass id (or coordinates) of that obstacle to upper level of control
     - On upper level: messaging for help, altering the coalition plan
2. Non-angle-constrained path can is found but angle-constrained is not
   - Agent can not reach goal area under current constraints (time, speed etc.)
   - Inform upper level of control and ask for a task update (setting new time constraints for example)

Case study



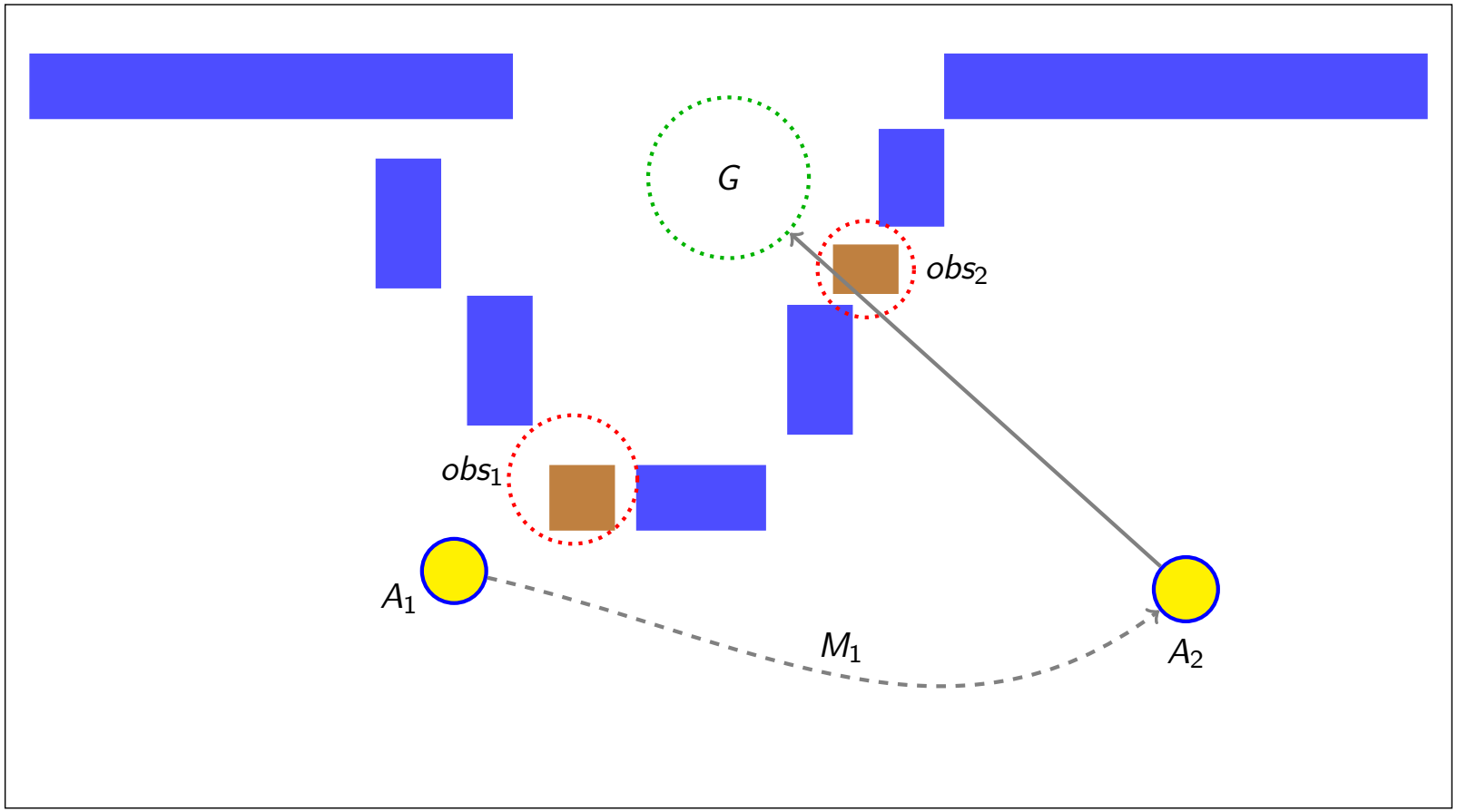
Activated signs for agent A_1: "place X_6", "far", "move 1" $\rightarrow$ path planning operations

Case study



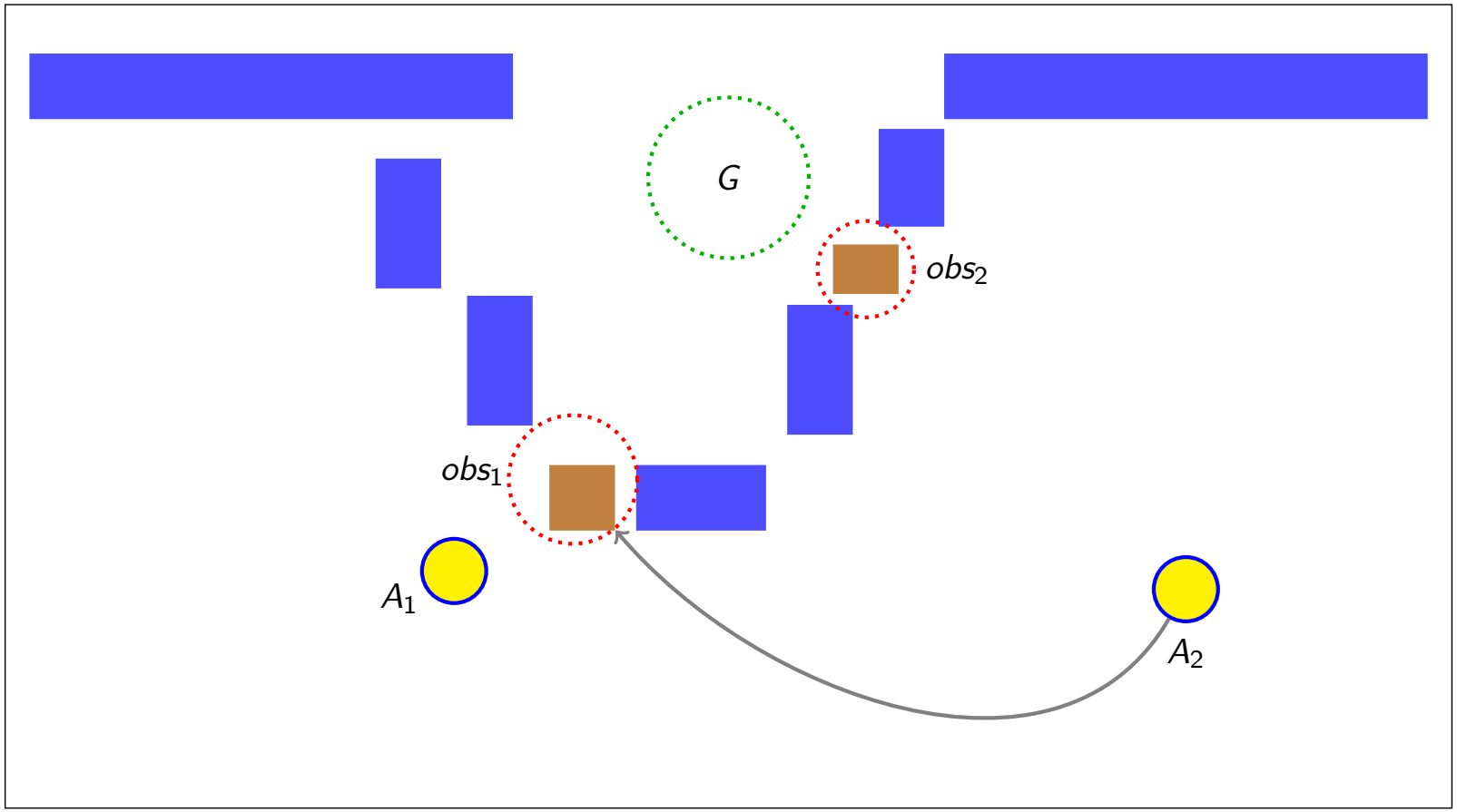
Activated signs for agent A_1: "obstacle 1", "near", "place X_6"

Case study



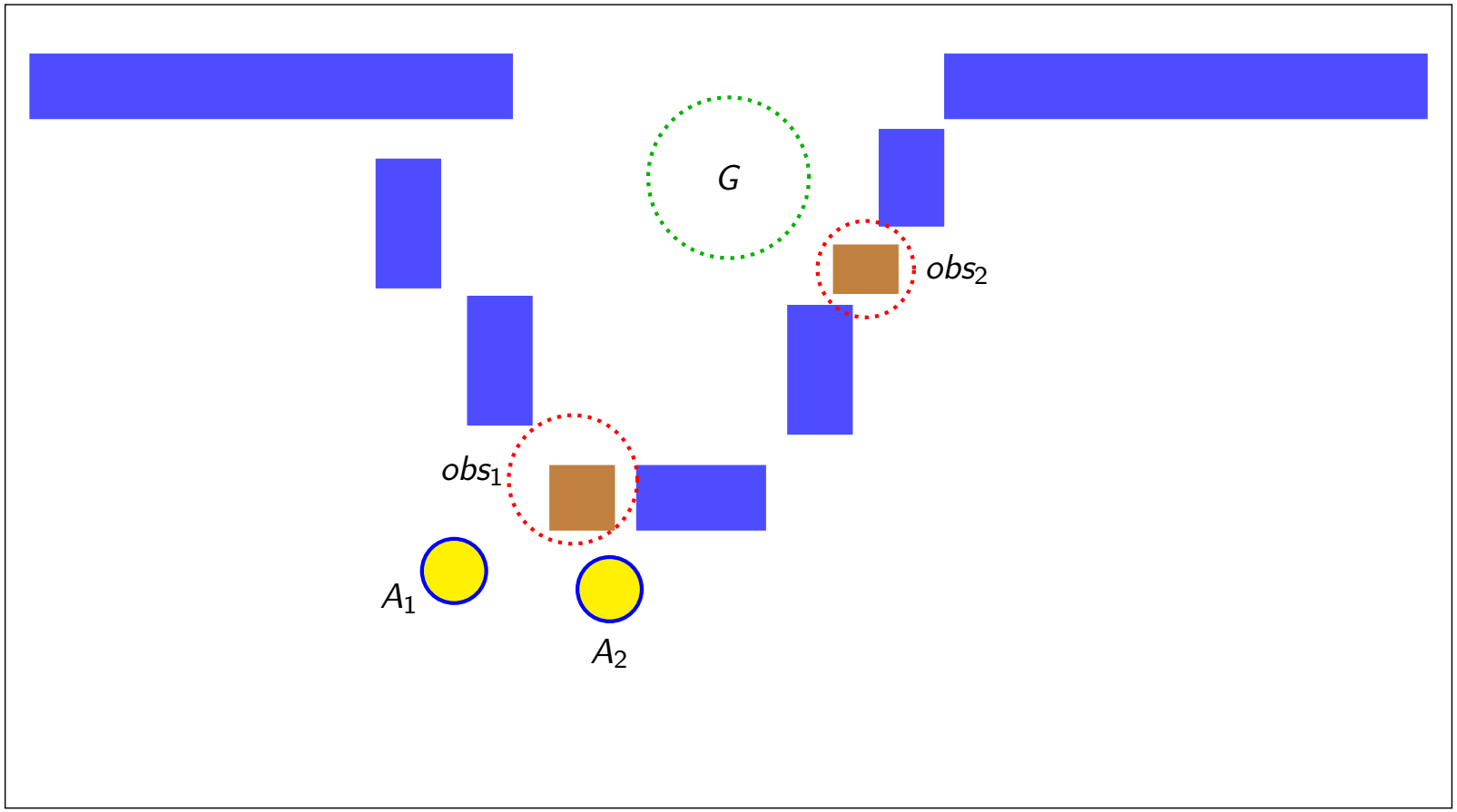
Activated signs for agent A_1: "send message", "agent A_2"

Case study



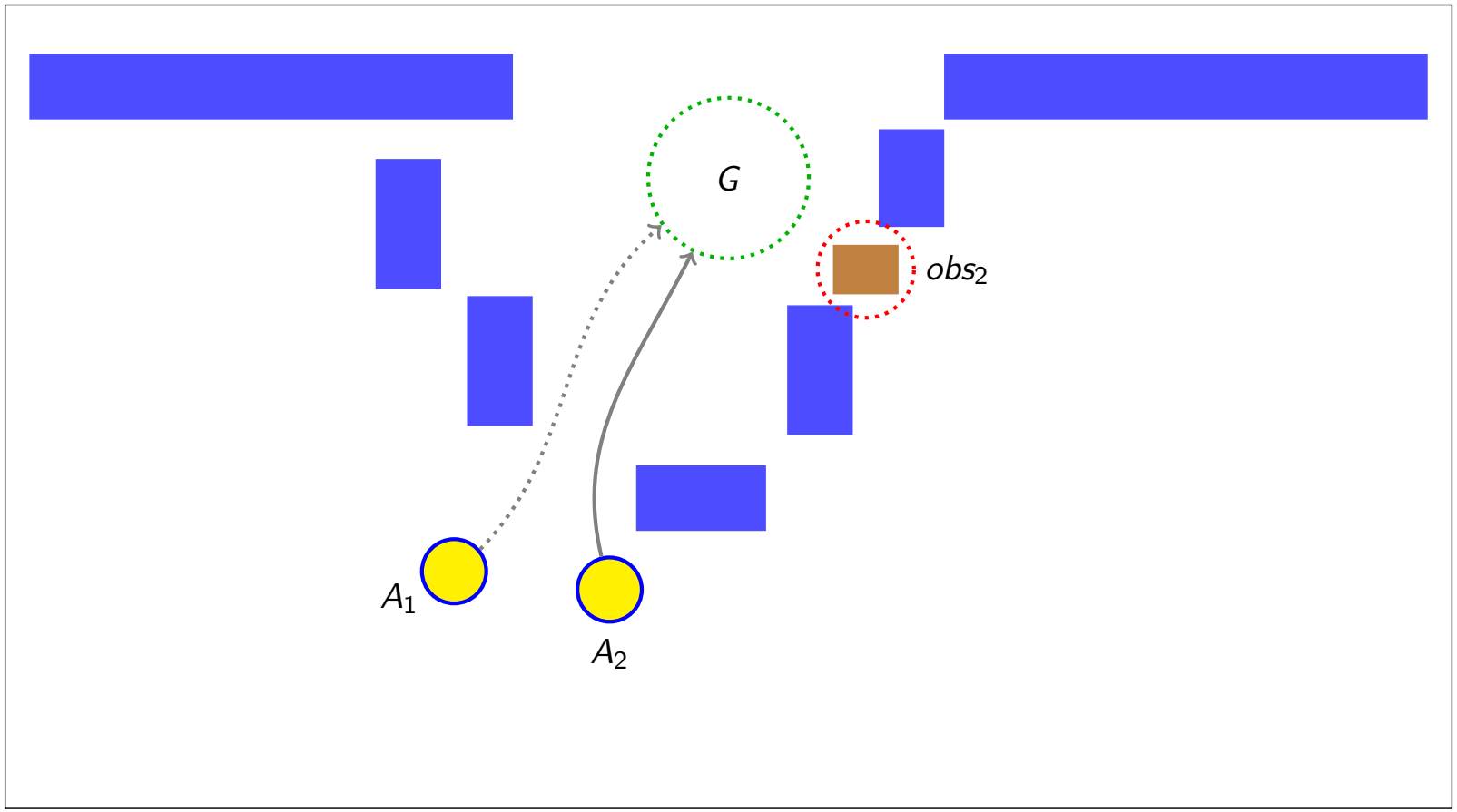
Activated signs for agent A_2: "place Y_3", "far", "move 2" $\rightarrow$ path planning operations

Case study



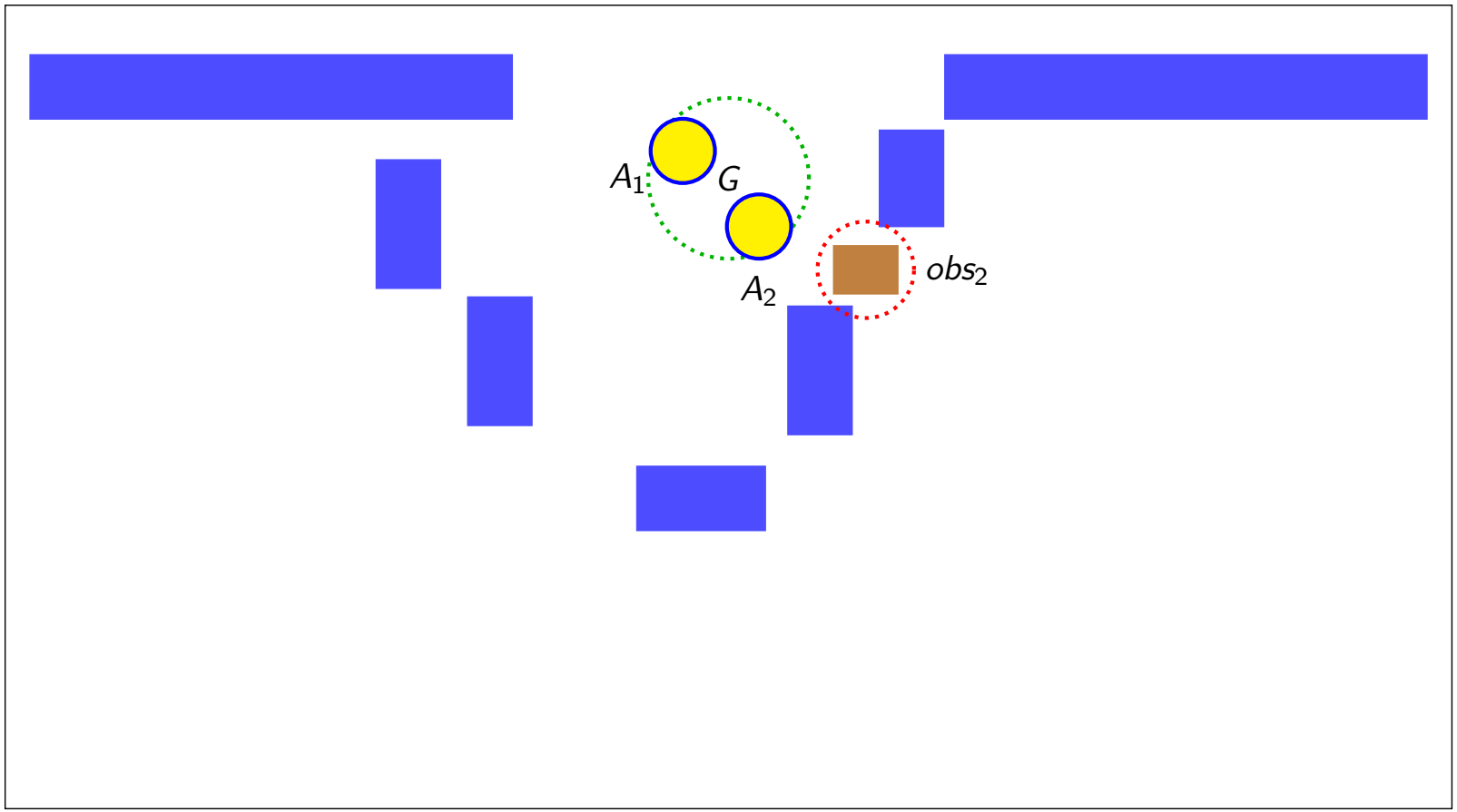
Activated signs for agent A_2: "place Y_1", "near", "obstacle 1", "destroy"

Case study



Activated signs for agents A_1 and A_2: "far", "move 3" $\rightarrow$ path planning operations

Case study



Activated signs for agents A_1 and A_2: goal state ("place G")

Summary

- Special type of navigation tasks (smart relocation tasks)
- New method for knowledge representation – sign world model based on psychological and neurophysiological data
- Top-level PMA planner (behavior planner) – iterative search procedure in semiotic network
- Path planner resides on the lowest level of behavior planner hierarchy
- 2 phase path planning: path prediction (fast) path planning taking into account agent's dynamic constraints (slow)

Future work

- Path planning
  - WHY we can not find a path (blocking obstacles, tough constraints etc)
- Behavior planning
  - Investigation of time and space special constraints

Questions?

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