Psychologically inspired planning method for smart relocation task

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Knowledge representation: sign world model

A component of knowledge representation is a sign:

- in sense of cultural-historical approach by L. Vygotsky,
- in sense of activity theory by A. Leontiev.

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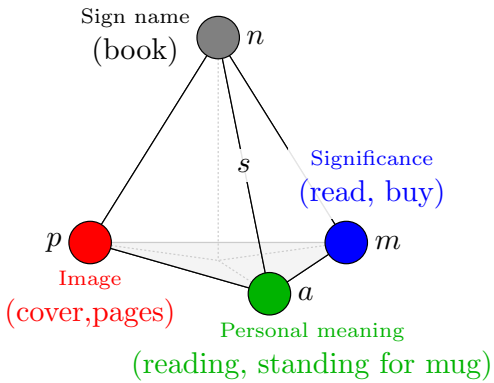

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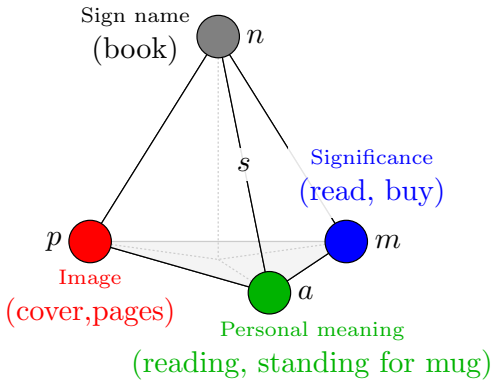
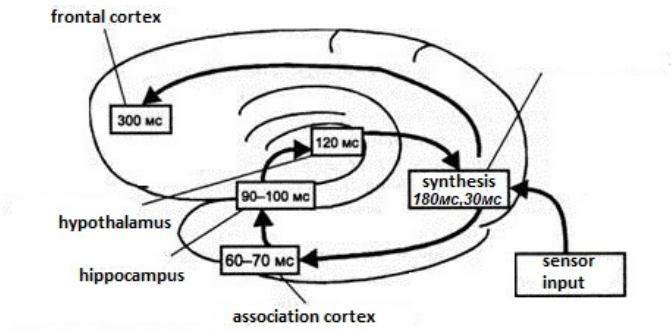




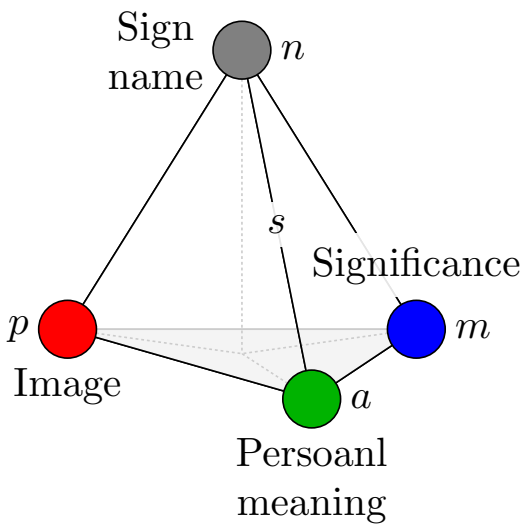
Supported ideas in psychology and biology:

- neurophysiological data (Edelman, Ivanitsky, Mountcastle etc.),
- two and three levels psychological theories (Stanovich, Kahneman).

Osipov, G. S., A. I. Panov, and N. V. Chudova. "Behavior Control as a Function of Consciousness. II. Synthesis of a Behavior Plan". *Journal of Computer and Systems Sciences International*. 2015.

— . "Behavior control as a function of consciousness. I. World model and goal setting". *Journal of Computer and Systems Sciences International*. 2014.

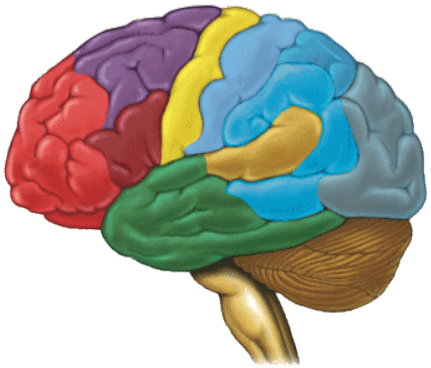
Three constituents of knowledge

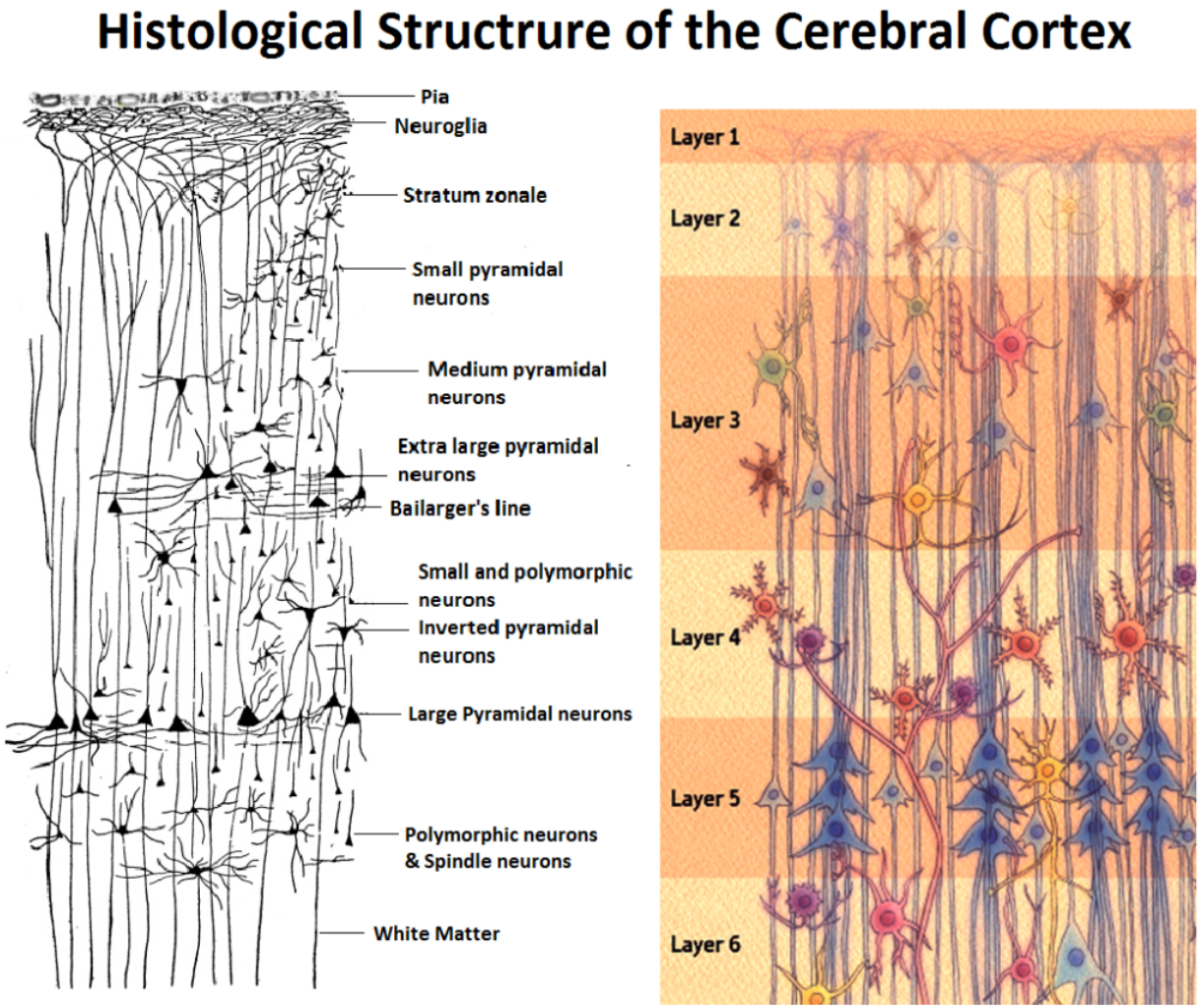


Mediated entity is represented with three causal structures:

- structure of image - knowledge about external causal relations in input data,
- structure of significance - abstract generalized knowledge accumulated in culture,
- structure of personal meaning - embodied knowledge including personal facilities, characteristics and motives.

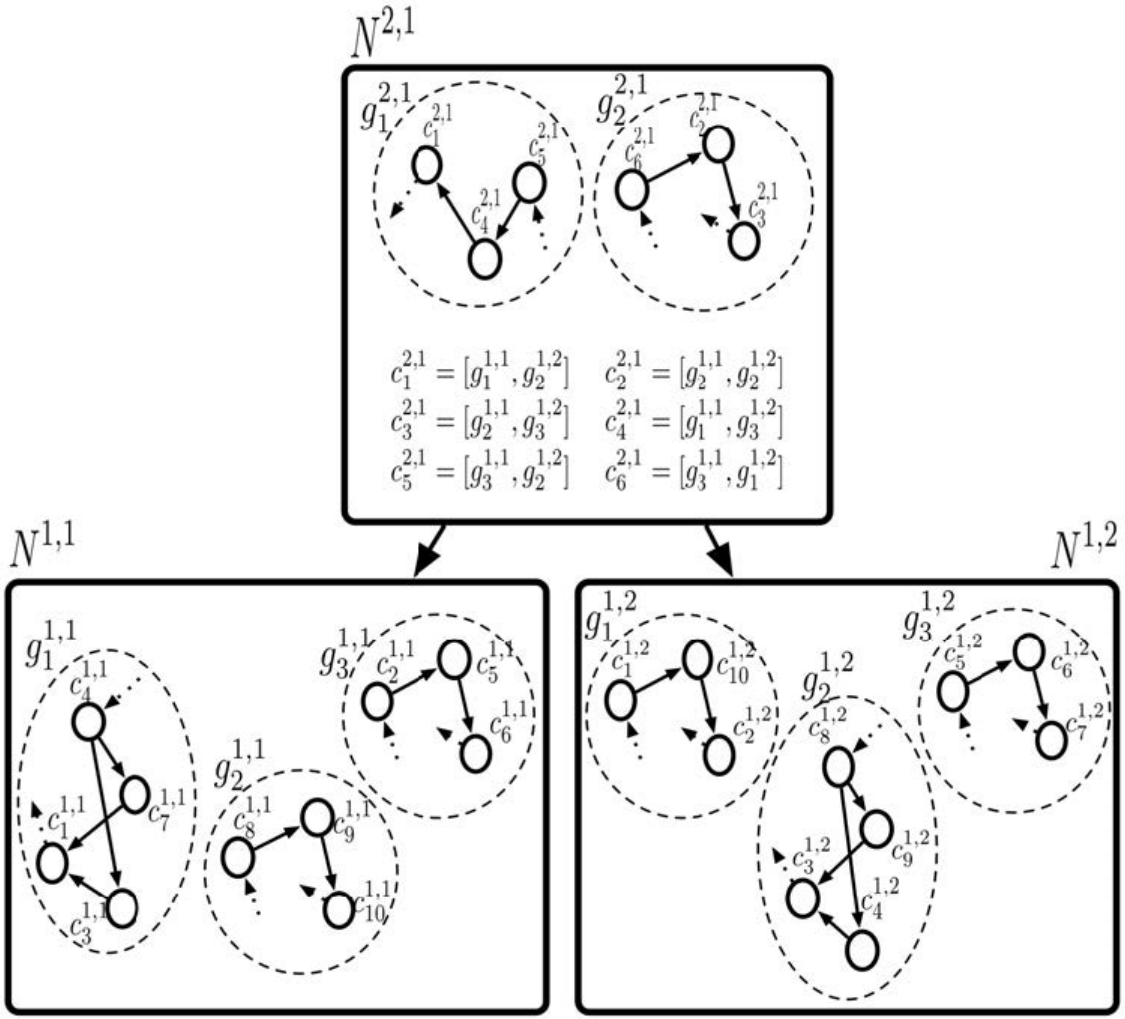
Neural substrate





Hierarchical model

Extended implementation of hierarchical temporal memory - **heterarchical causal framework**.



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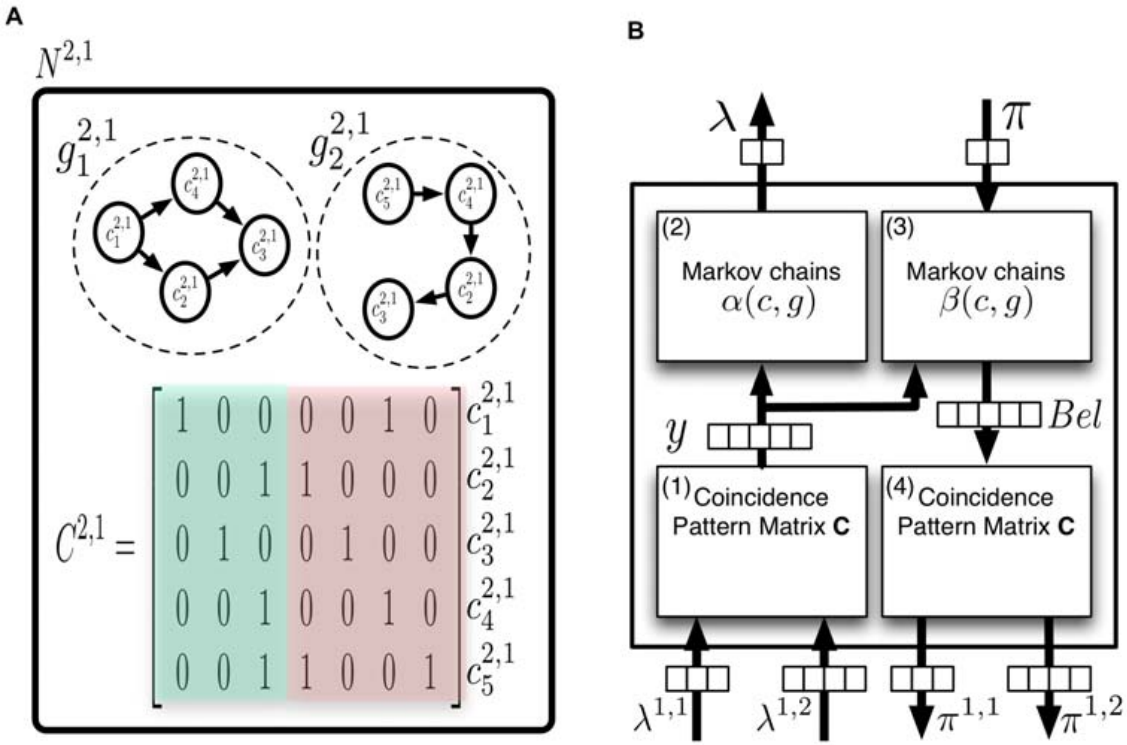
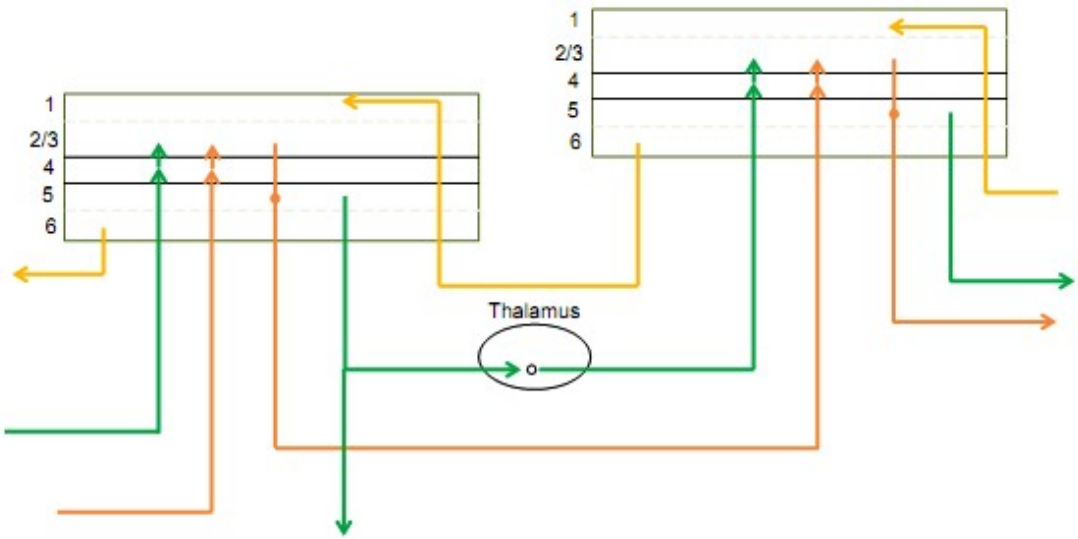
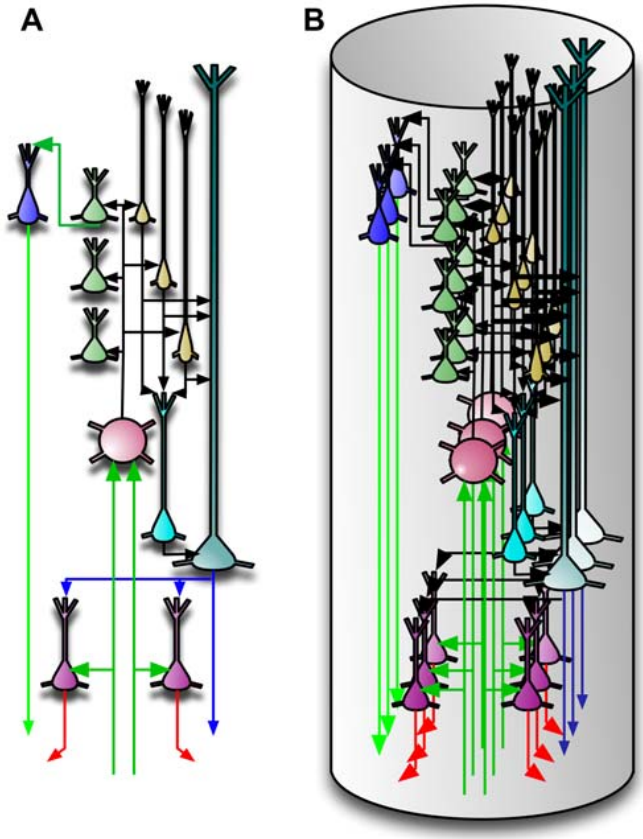
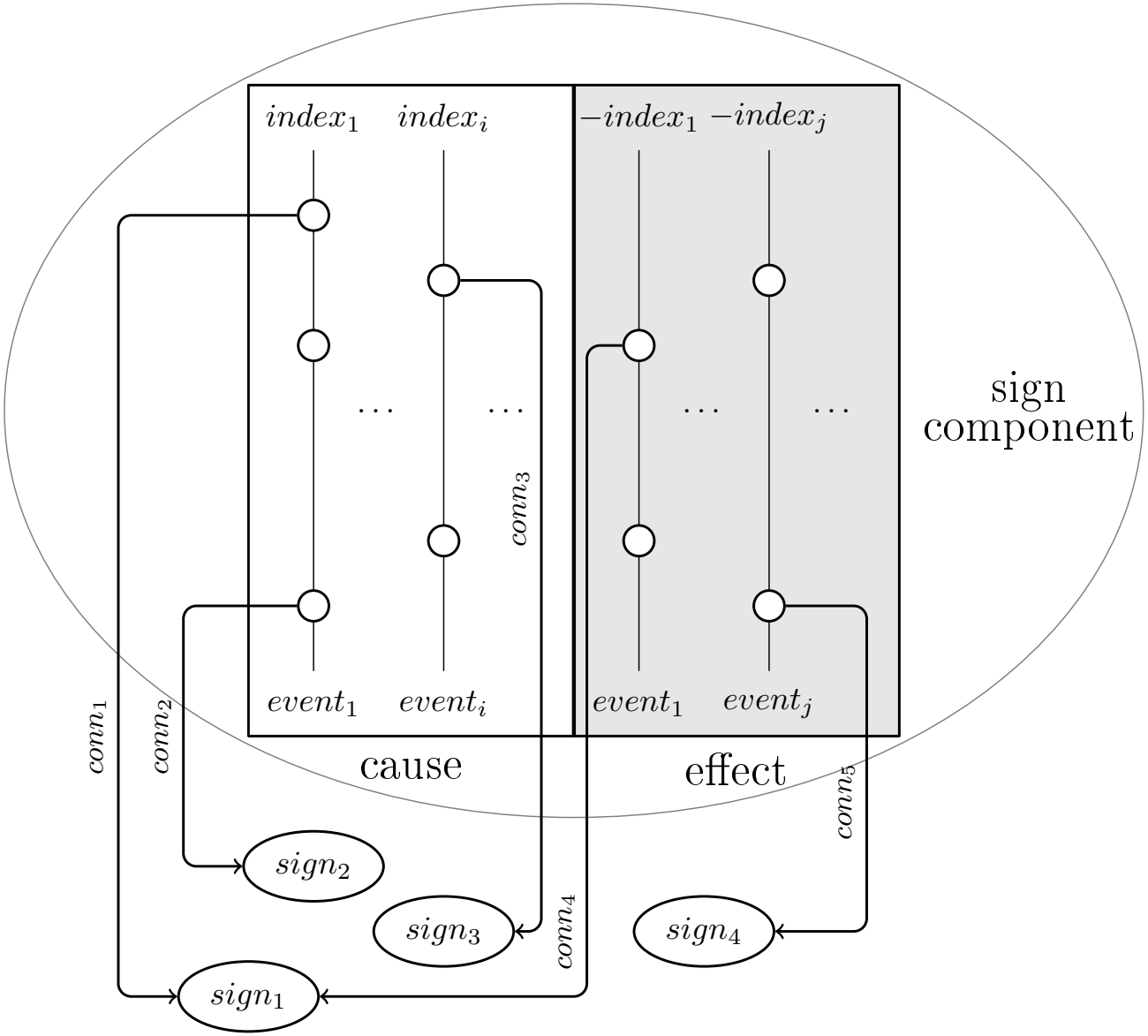


Neuronal organization





Causal matrix



Algorithm $\mathfrak{A}_{th}$ of sign component actualization

$\hat{f}_1, \hat{f}_2 \ldots, \hat{f}_k$

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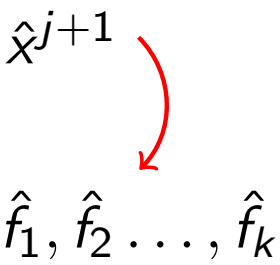

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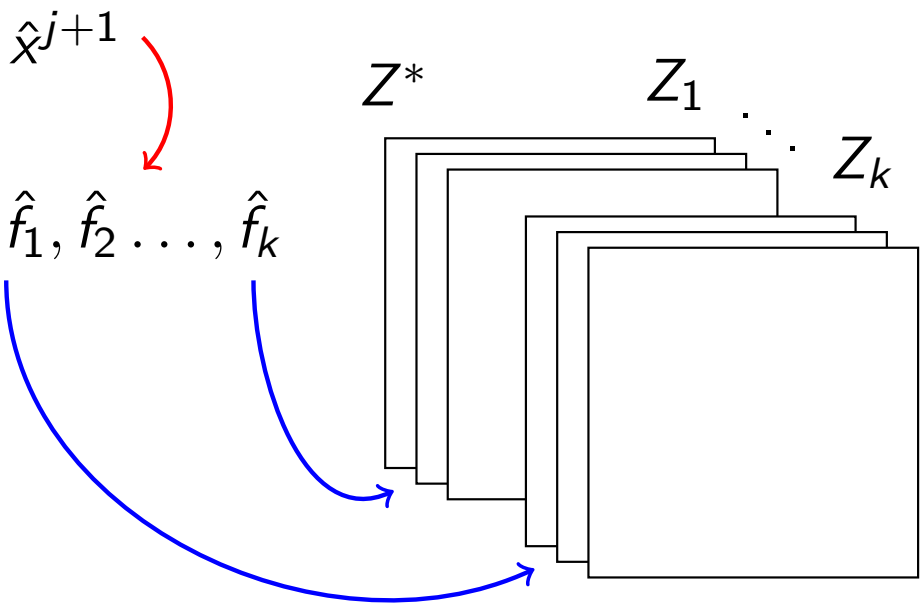

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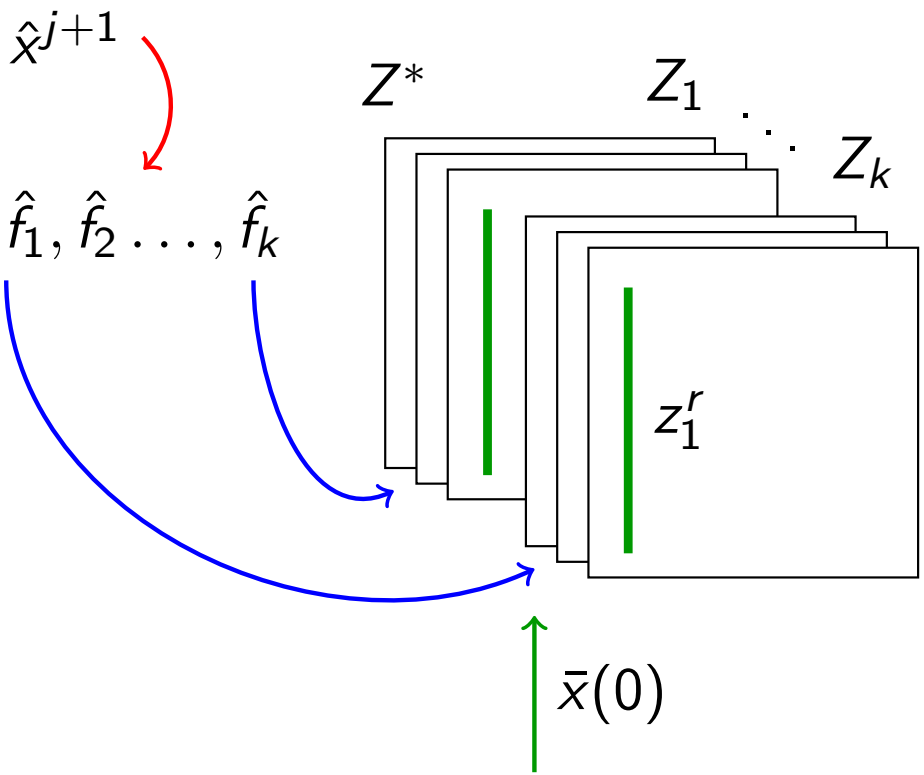

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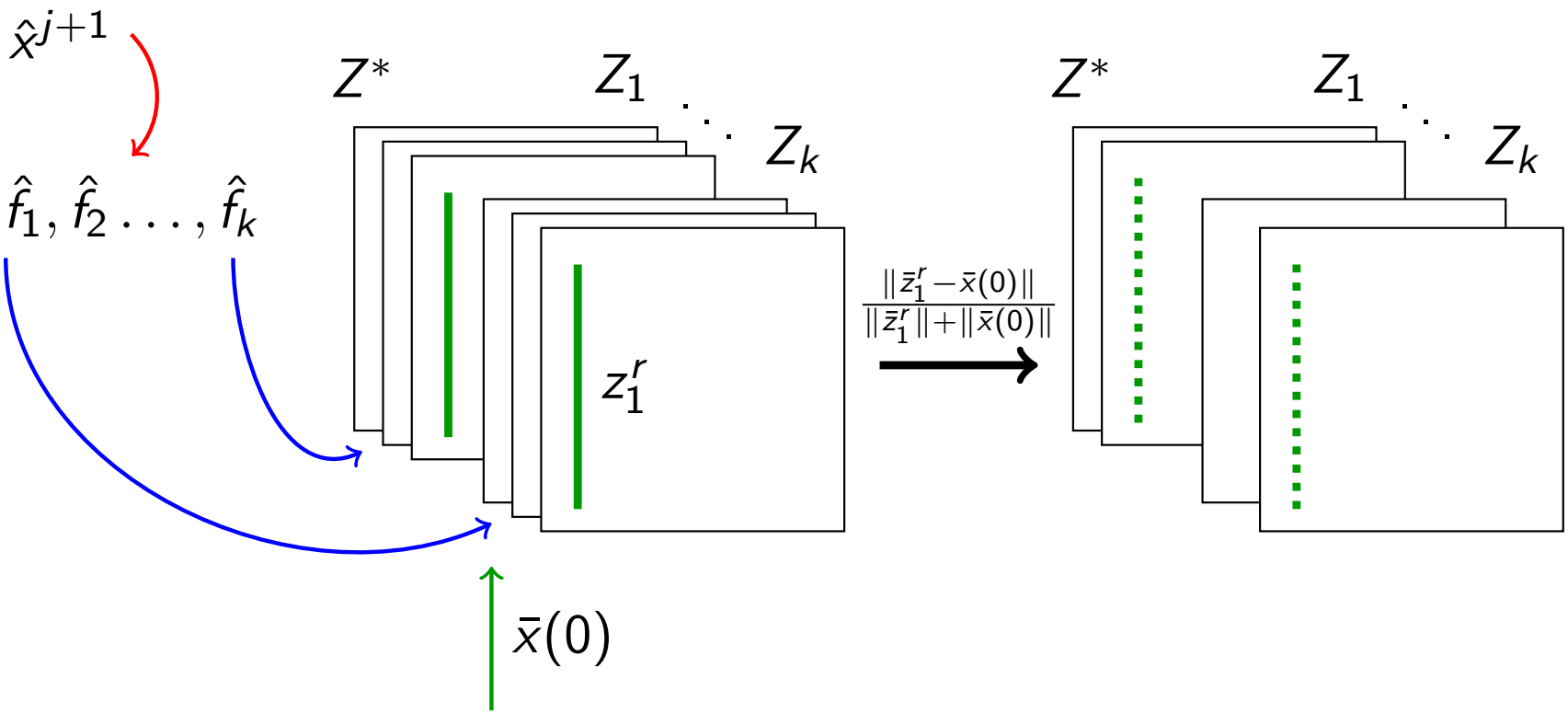

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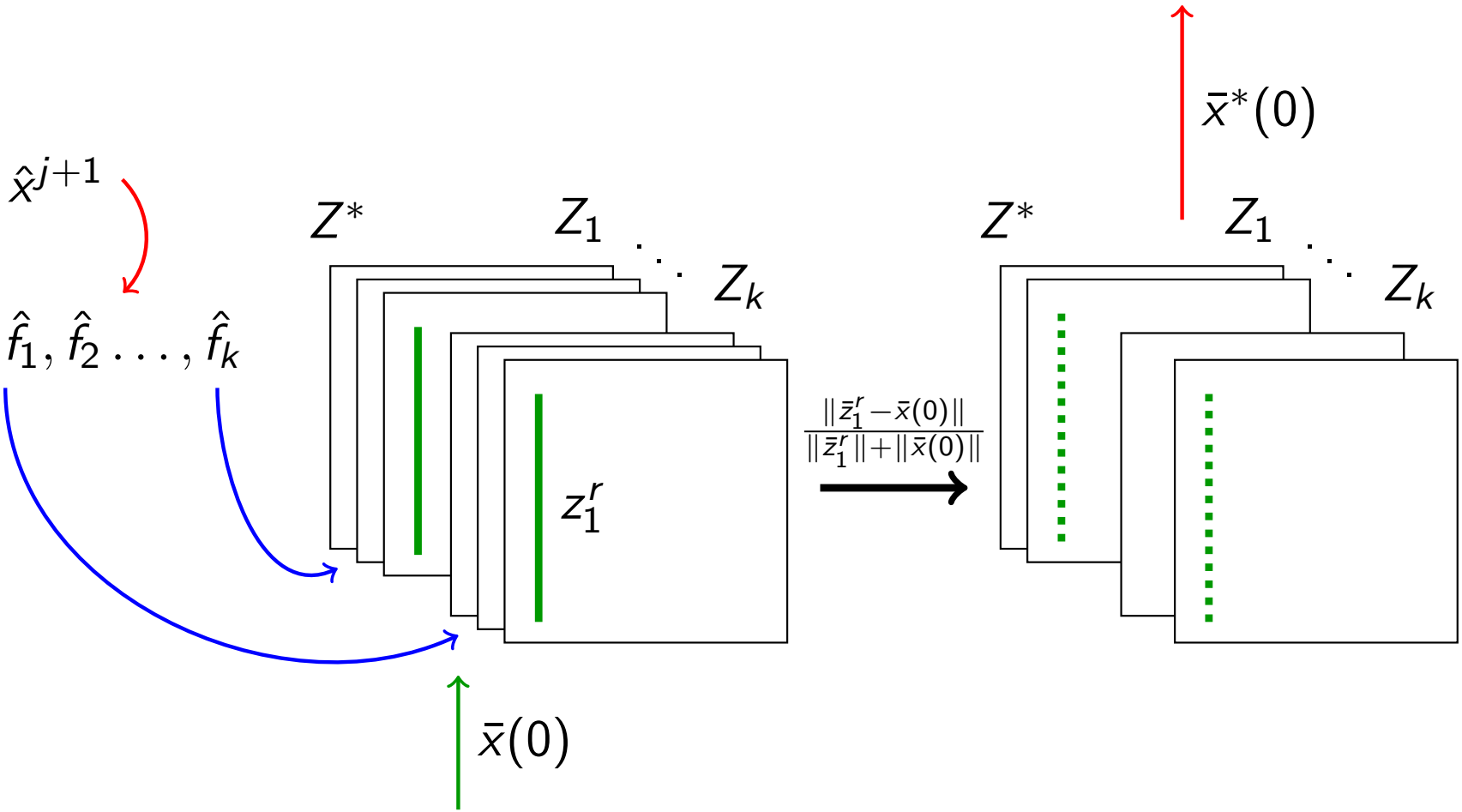

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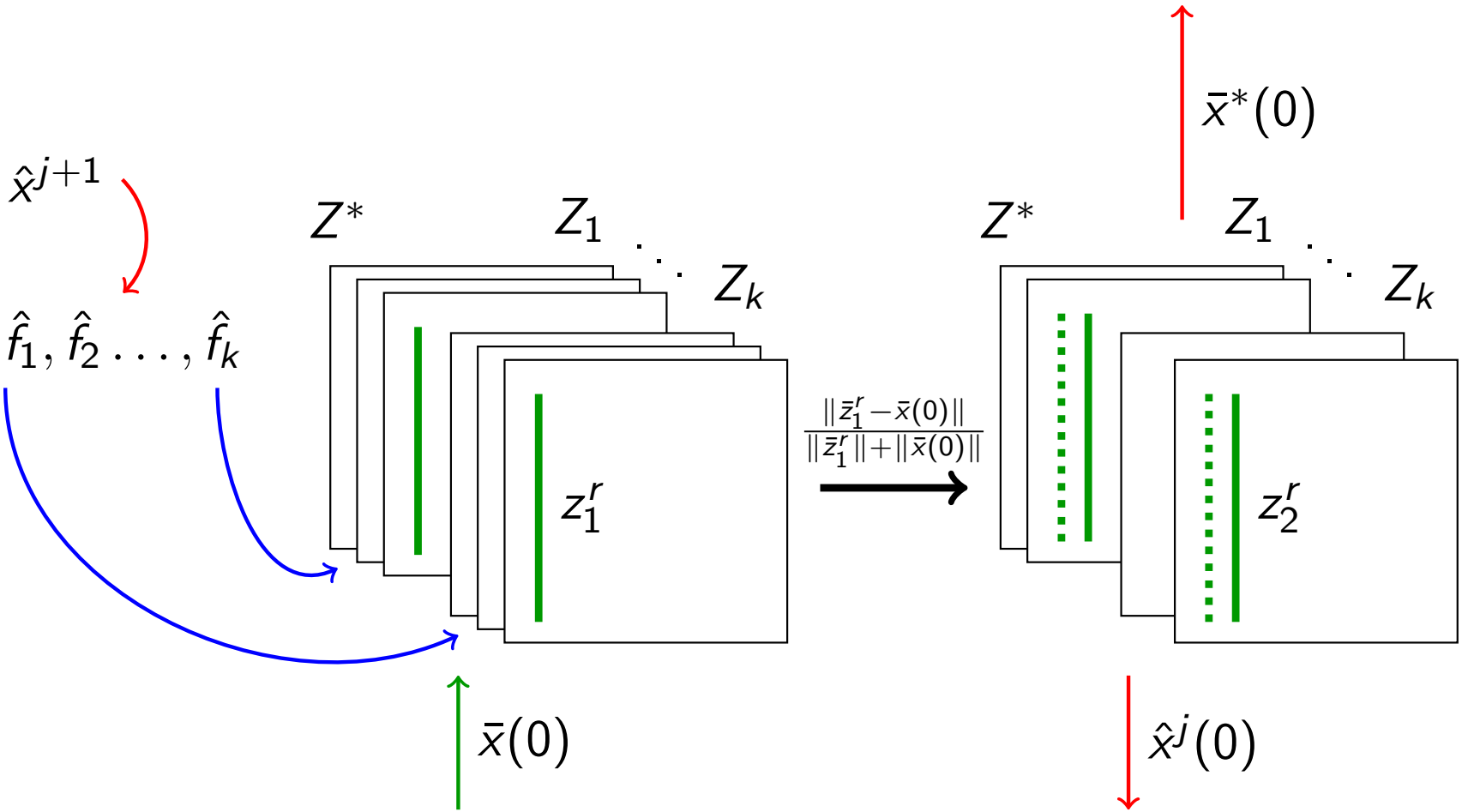

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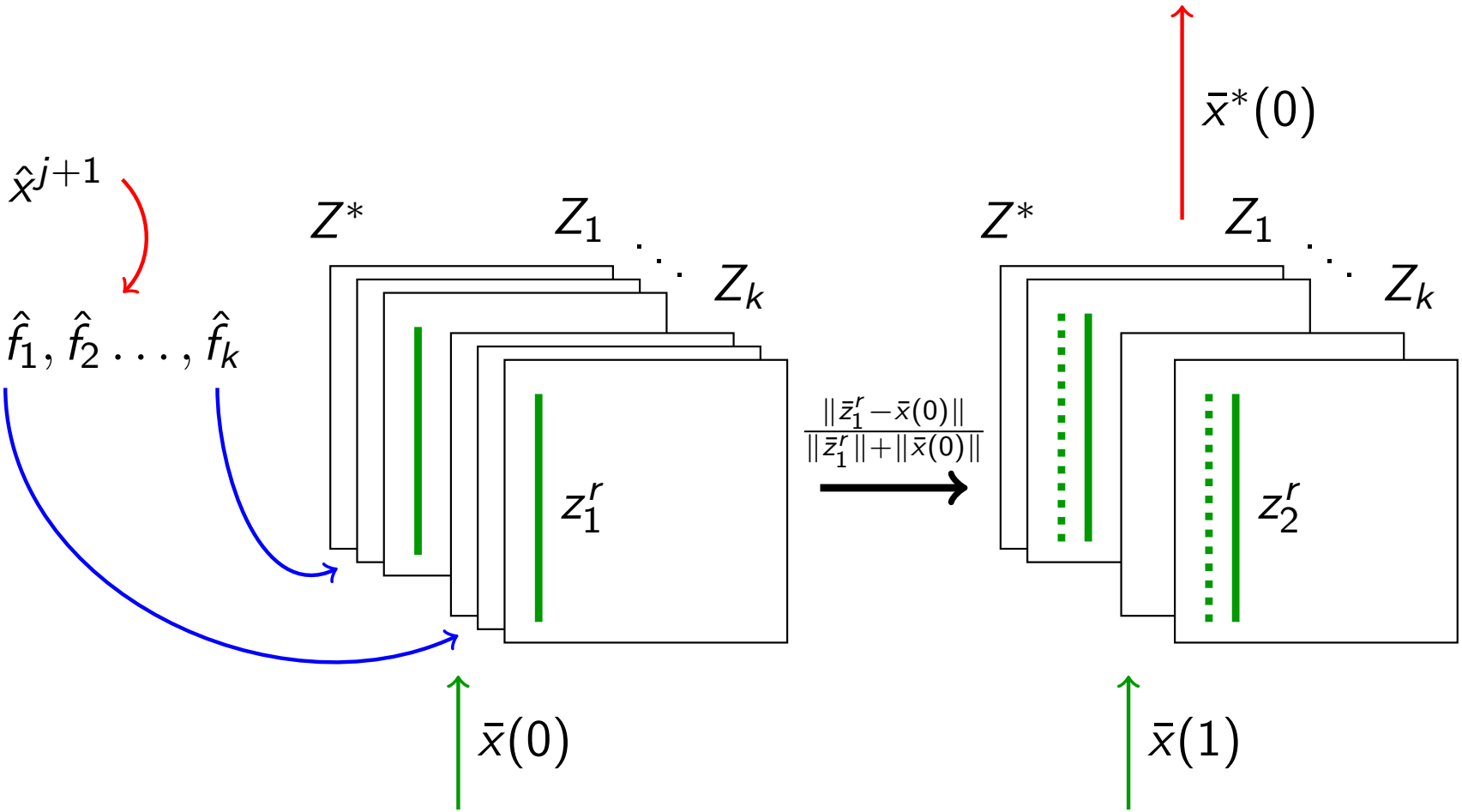

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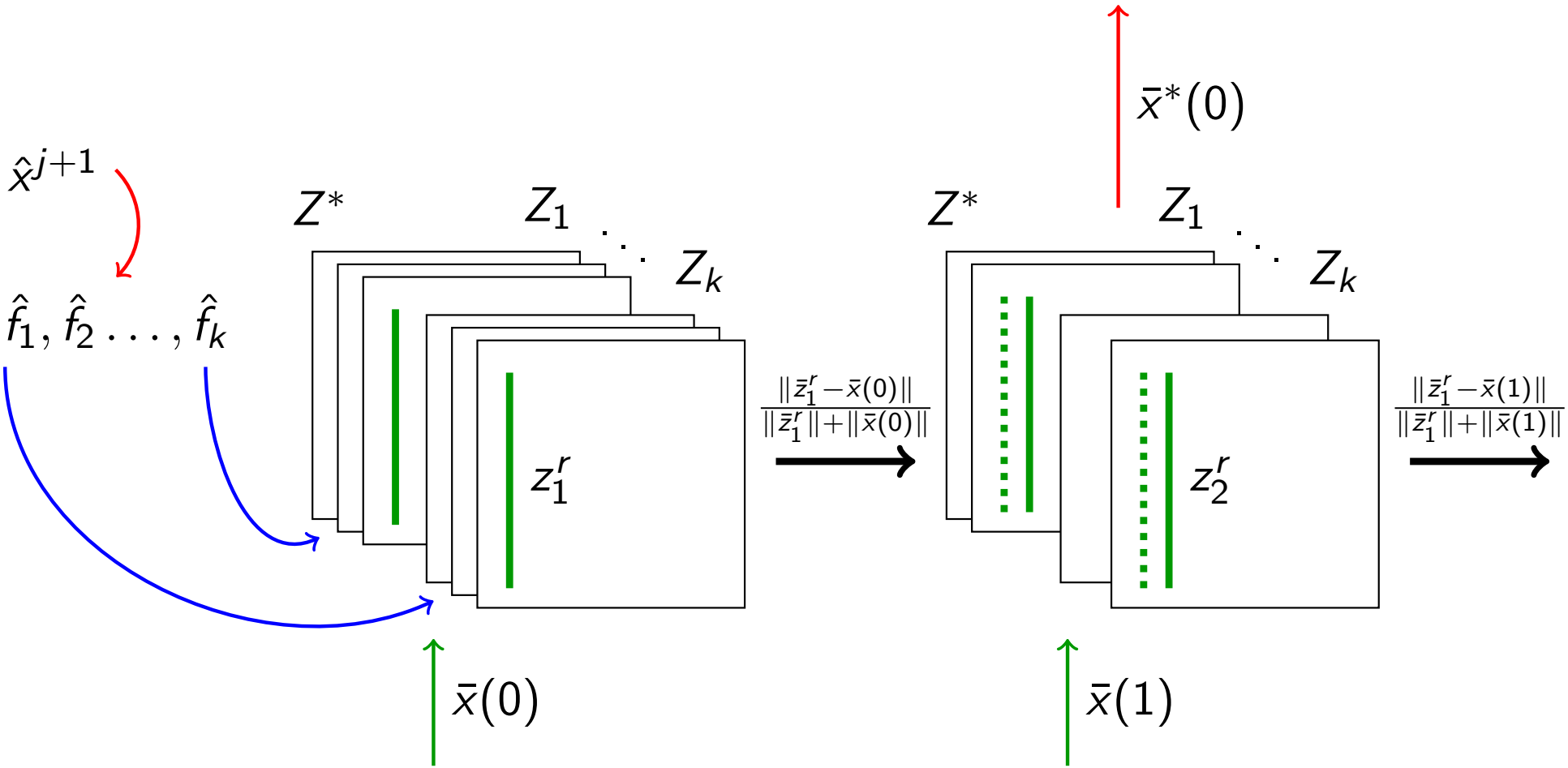
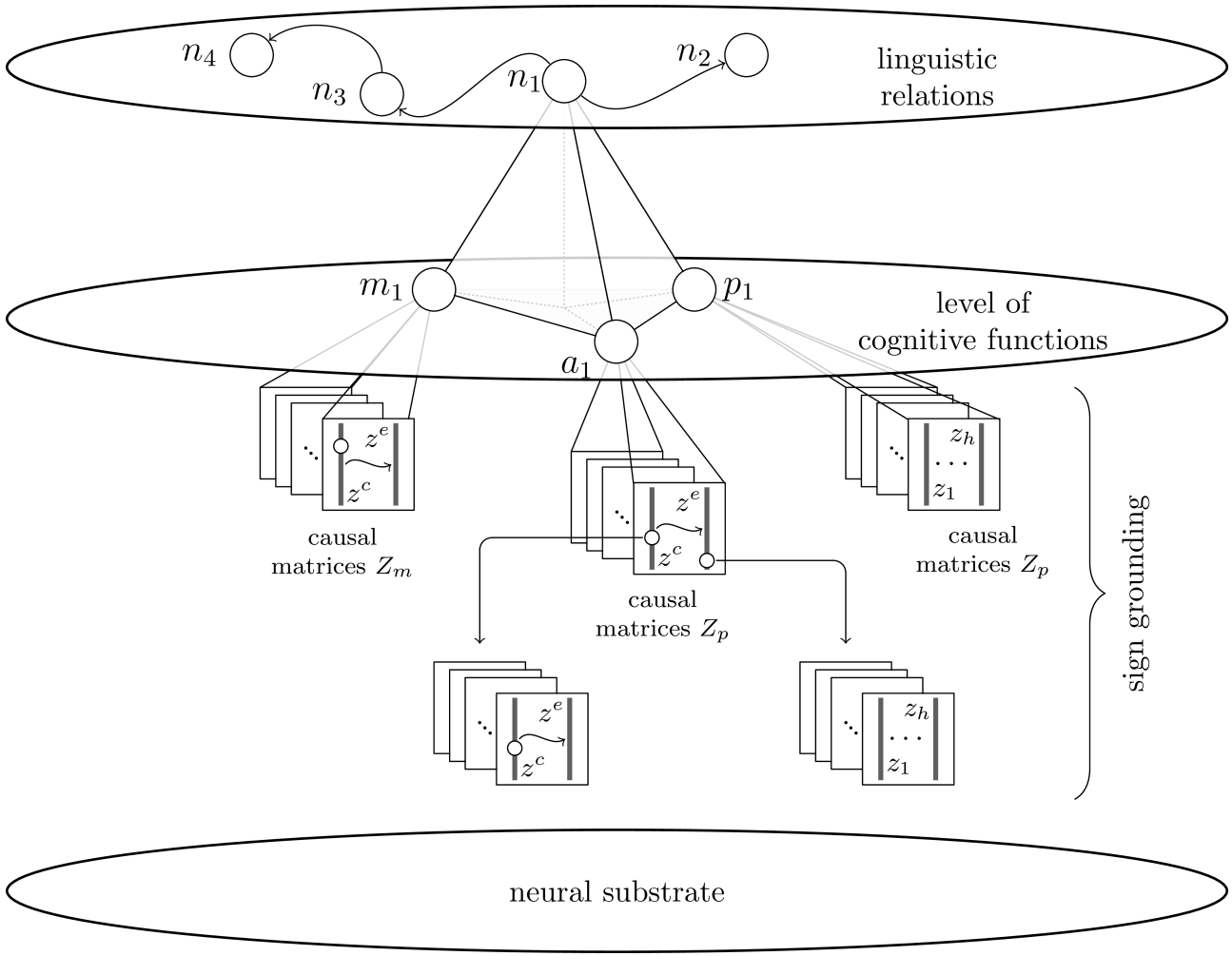
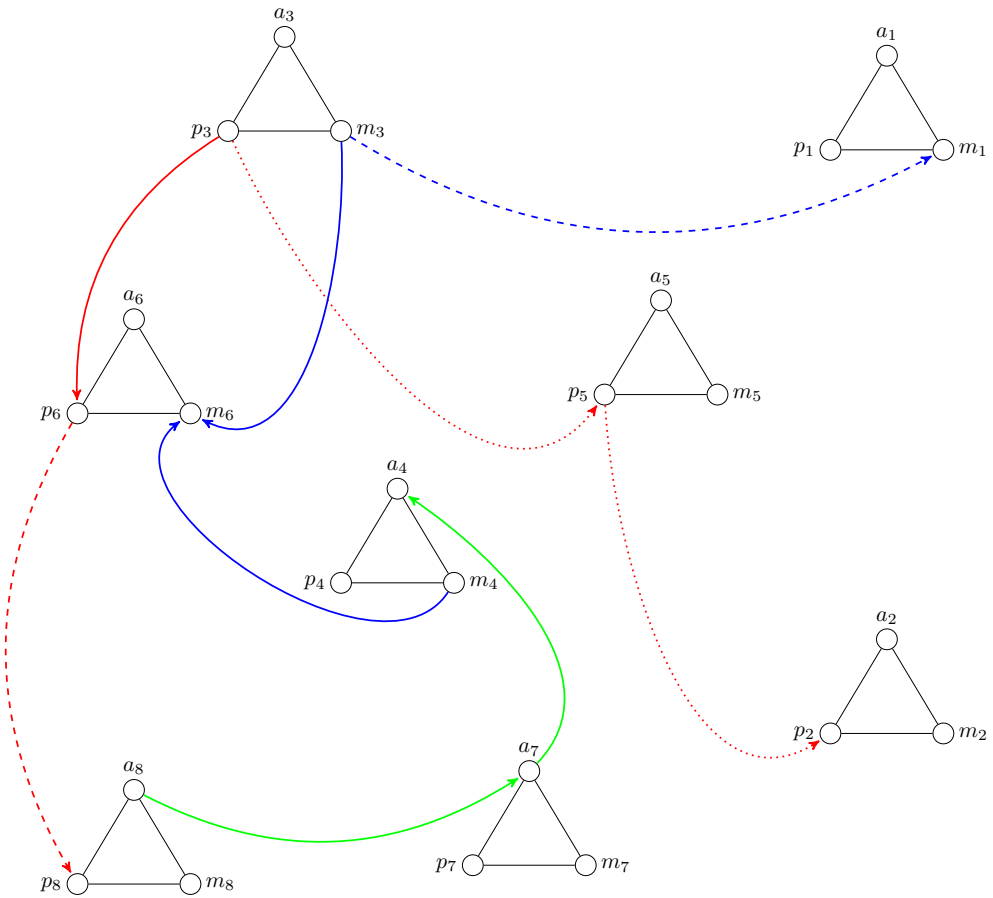


Representation levels



Sign world model

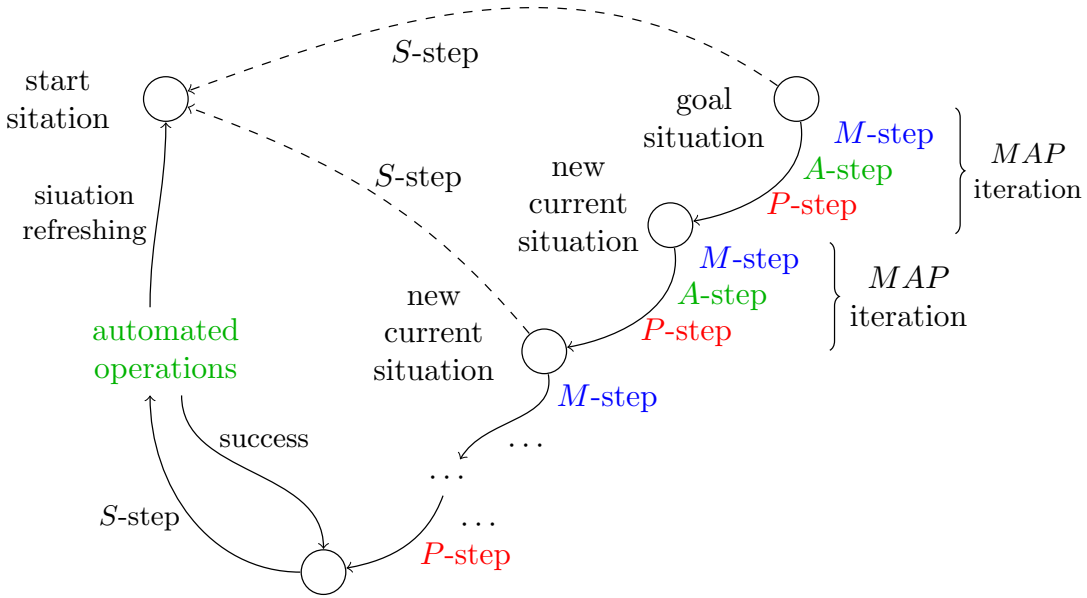


Semiotic network
$H = \langle H_P, H_A, H_M \rangle$ consisting of three semantic network:

- $H_P = \langle 2^P, \mathfrak{R}_P \rangle$ – 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.

Osipov, Gennady S. "Signs-Based vs. Symbolic Models". *Advances in Artificial Intelligence and Soft Computing*. 2015.

Behavior planning algorithm



Key features: hierarchical, online learning, meta-reasoning (heuristic generation), coalition support.

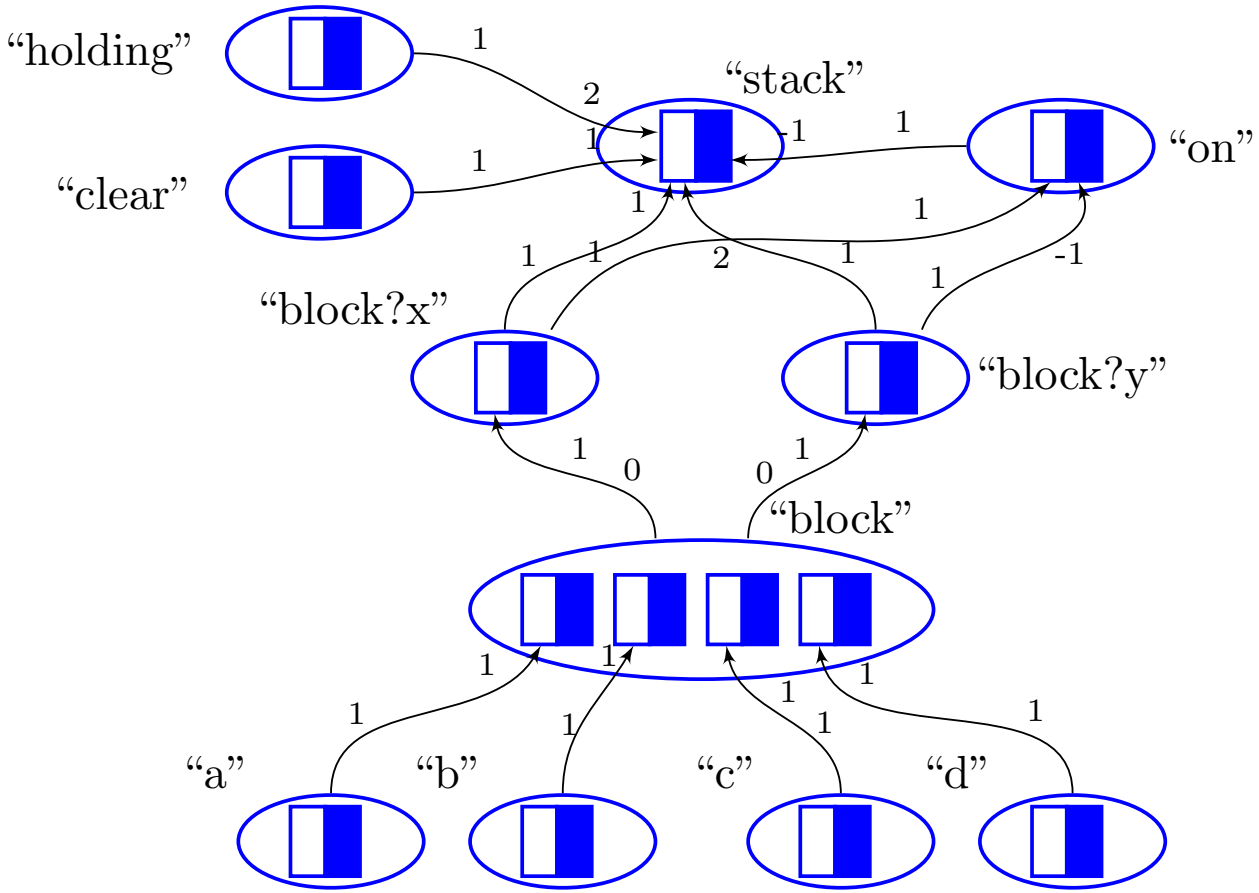
Panov, A. I. and K. S. Yakovlev. "Behavior and path planning for the coalition of cognitive robots in smart relocation tasks". *Robot Intelligence Technology and Applications 4*. 2016.

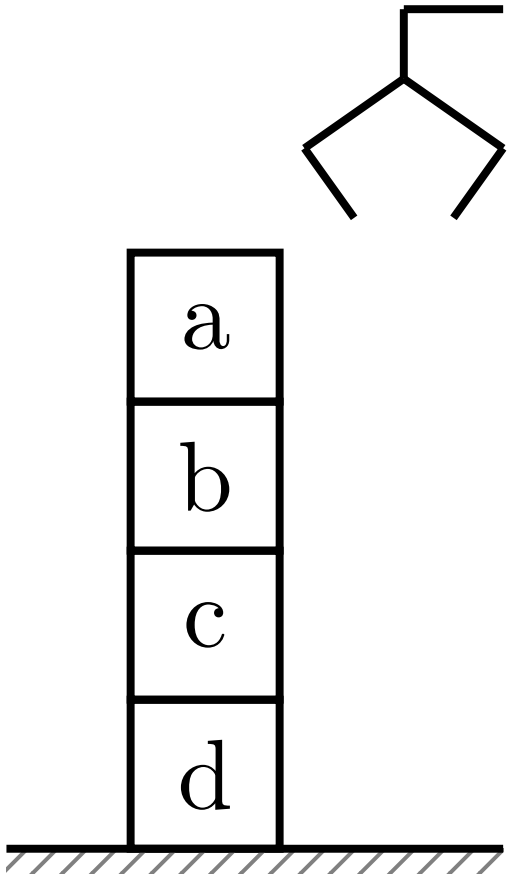
Planning starts from final situation and aims to meet start situation.

MAP iteration:

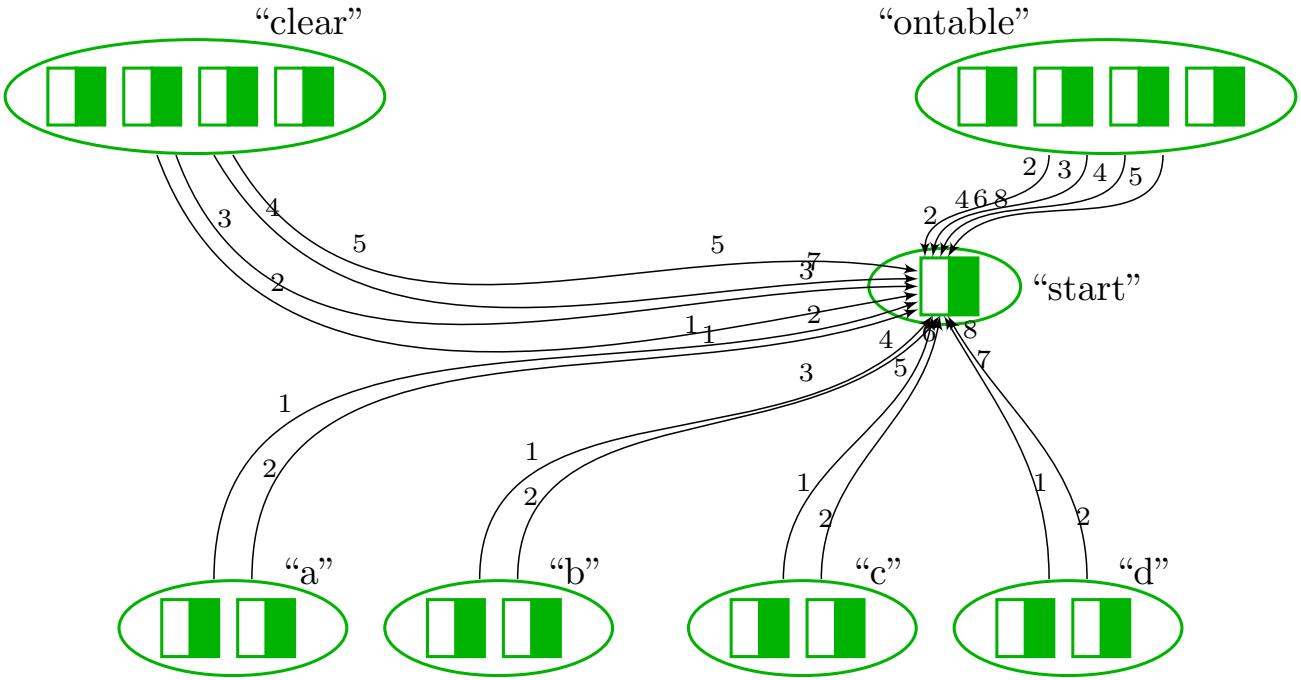
- *M-step* – search of relevant significances,
- *A-step* – choose a personal meaning from the set of personal meanings corresponding to the found significances,
- *P-step* – construct the new current situation using the set of features from the condition of performed action,
- *S-step* – send a message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

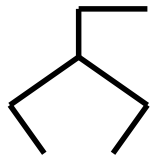
Example: fragment of network on significances

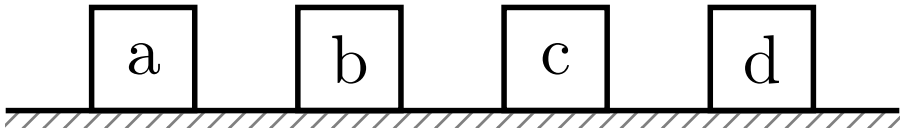




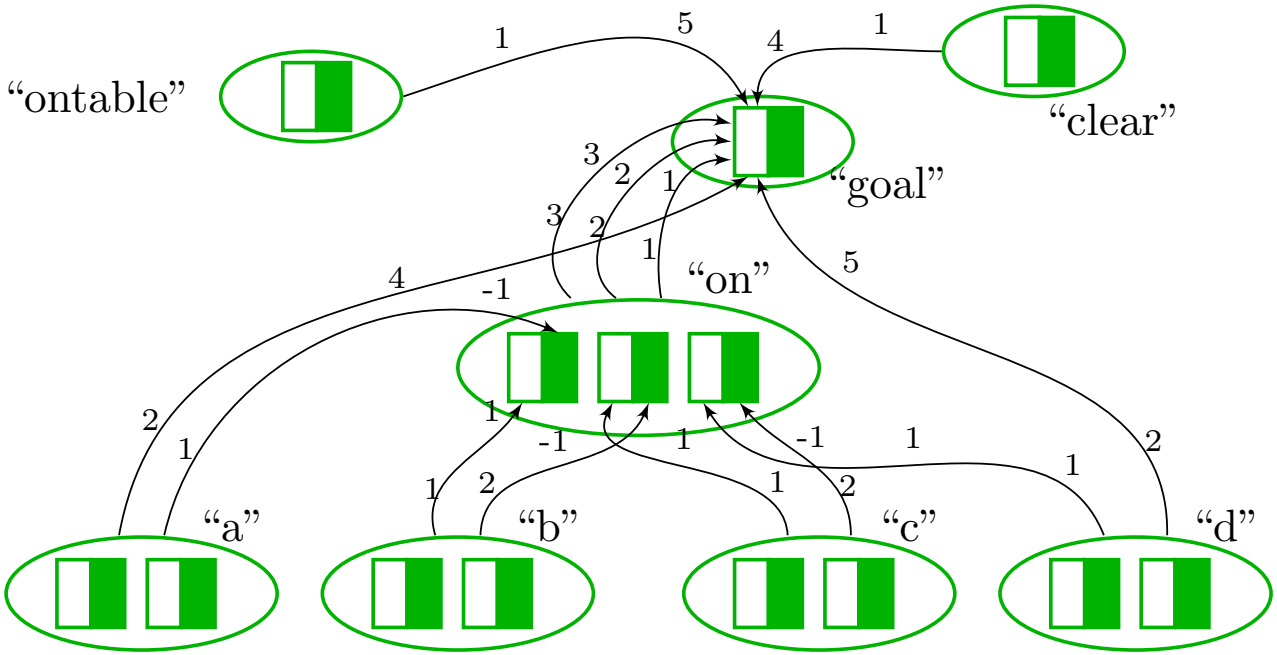
Example: network on meanings - start situation

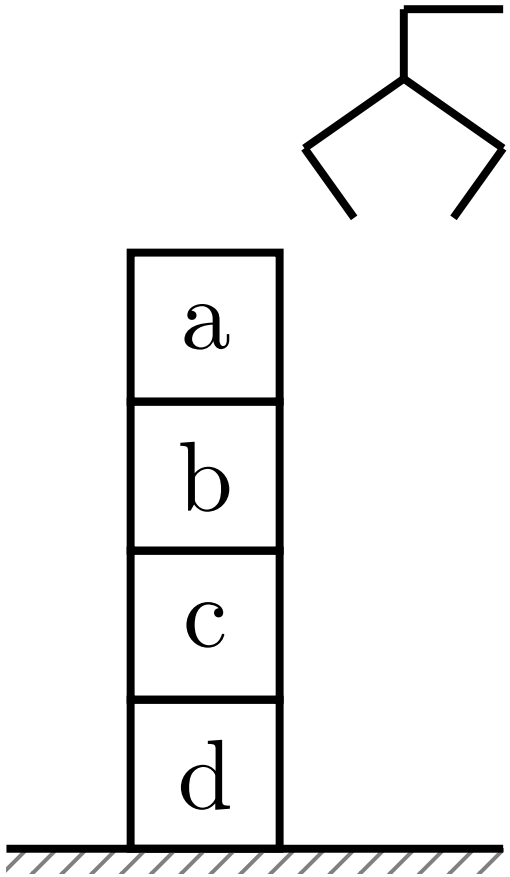






Example: network on meanings - goal situation





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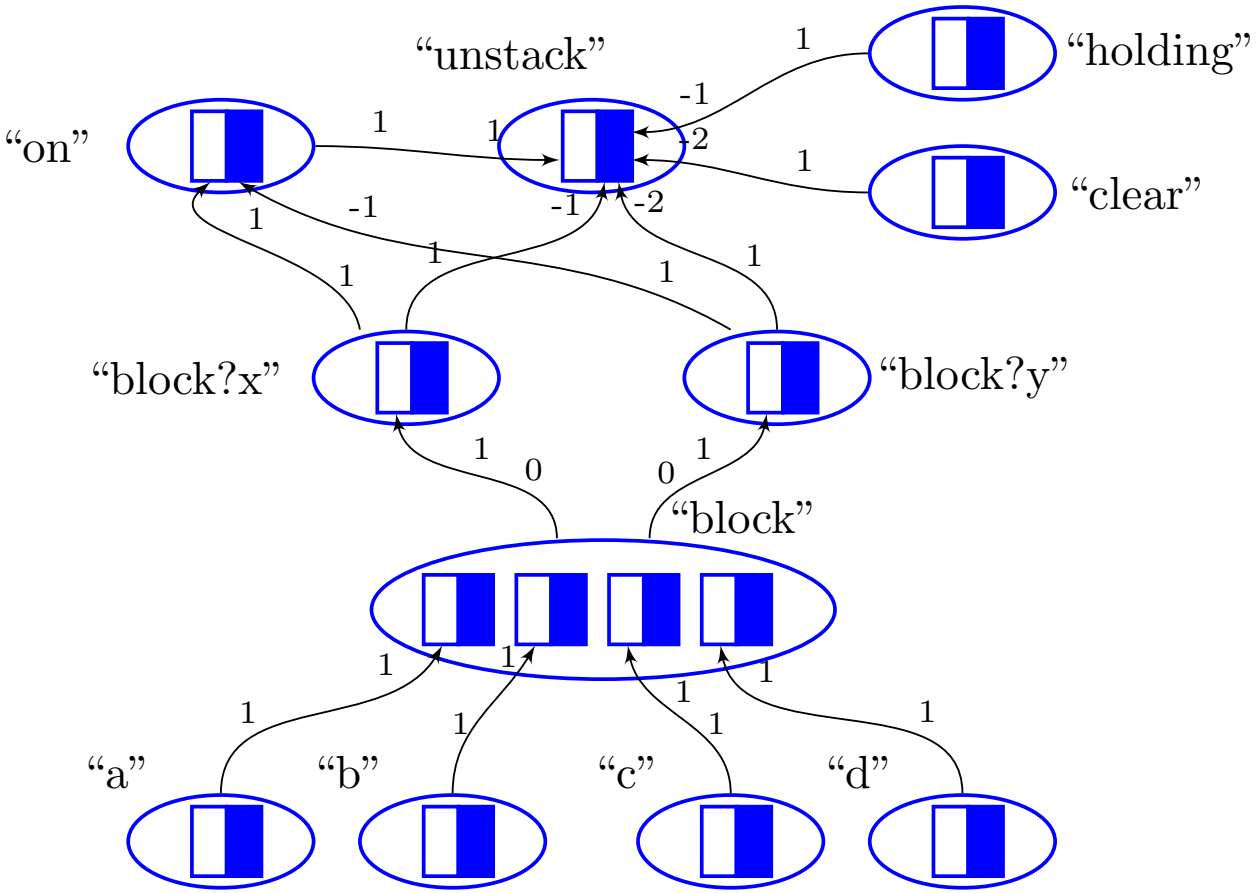
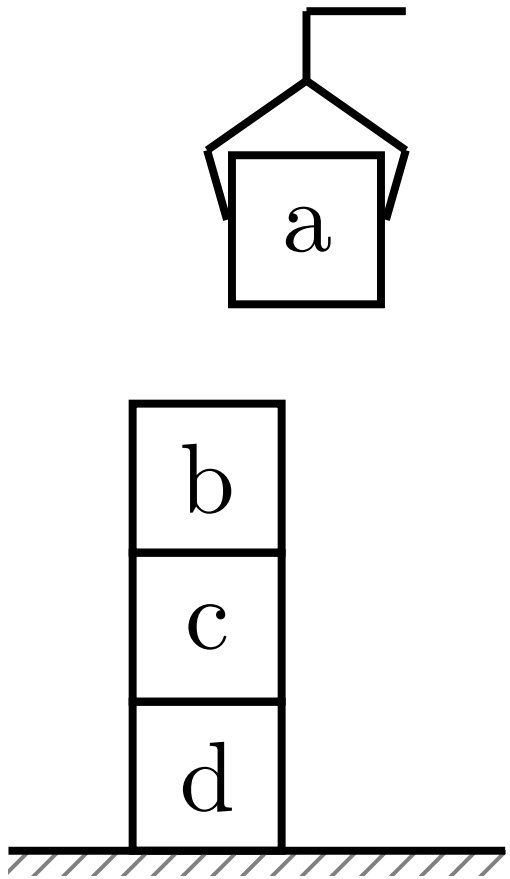
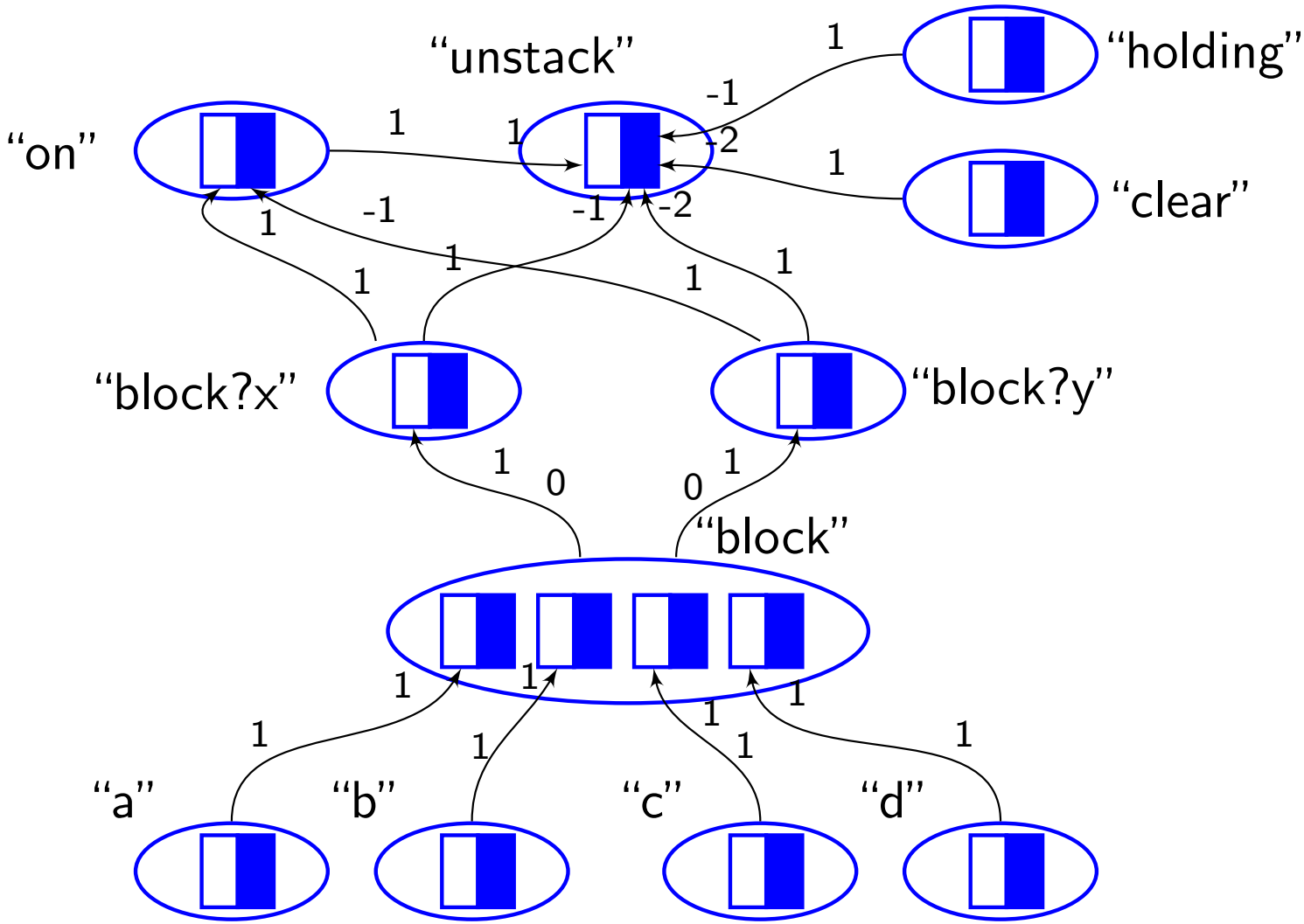




Example: generation of meanings



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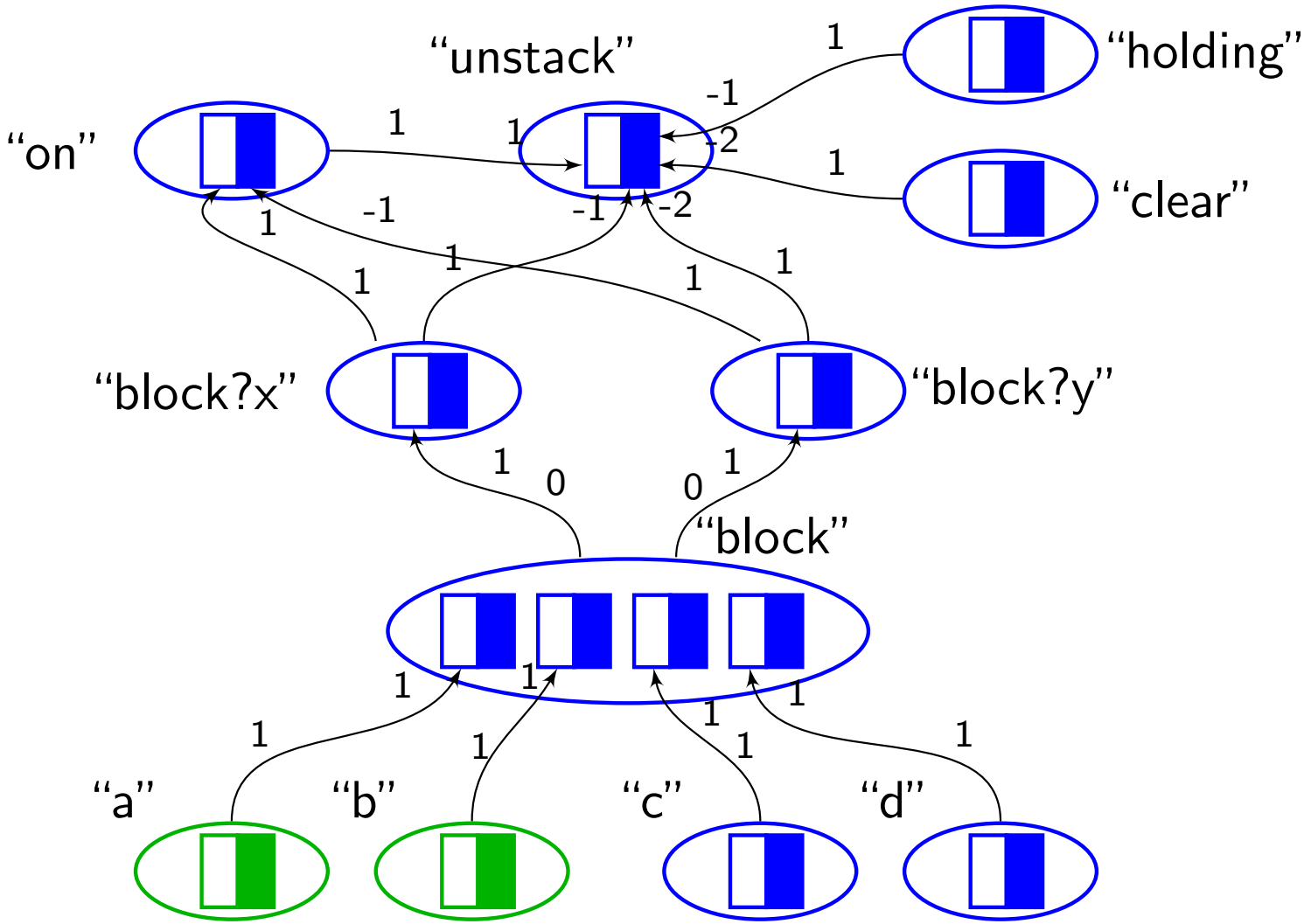

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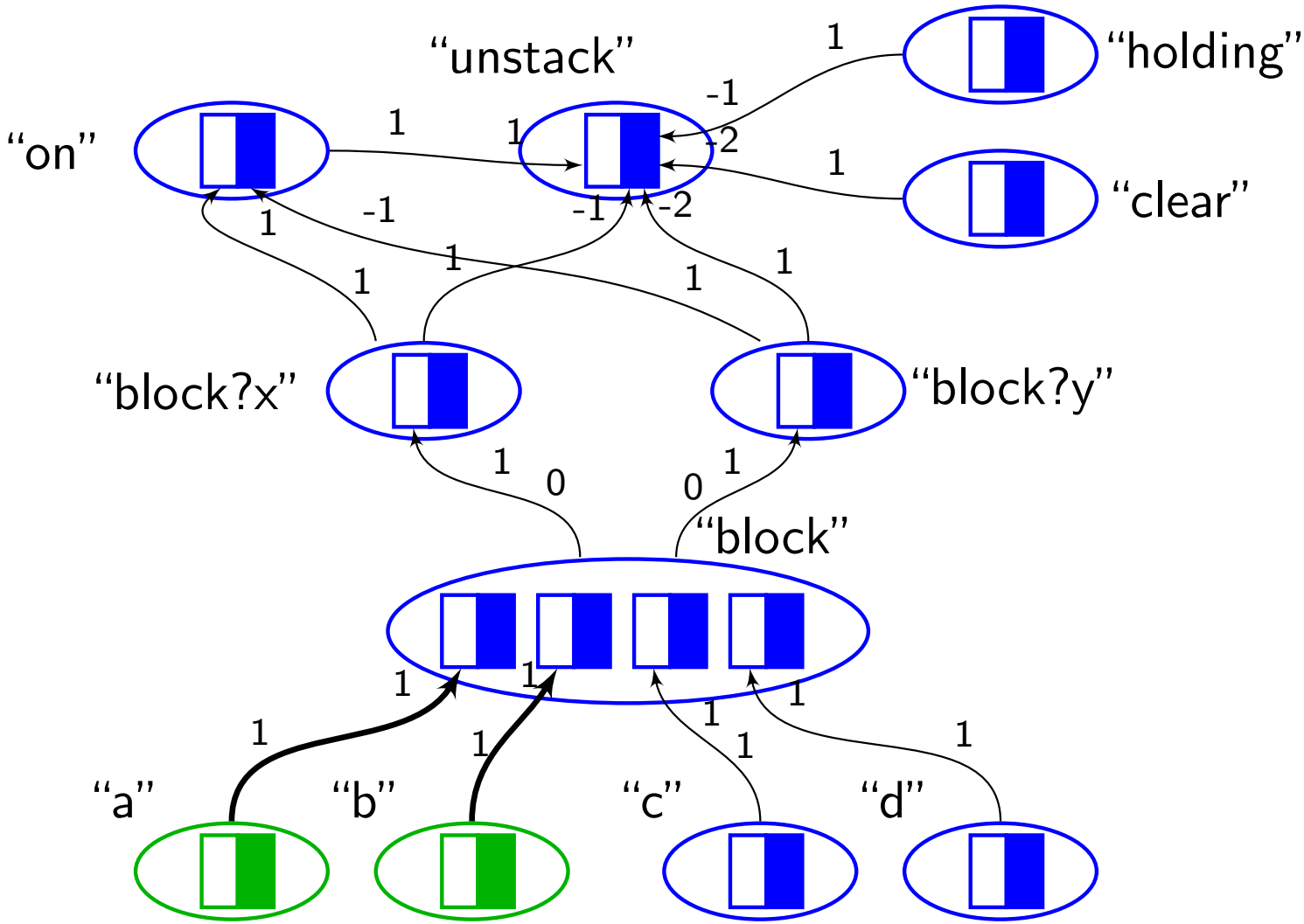

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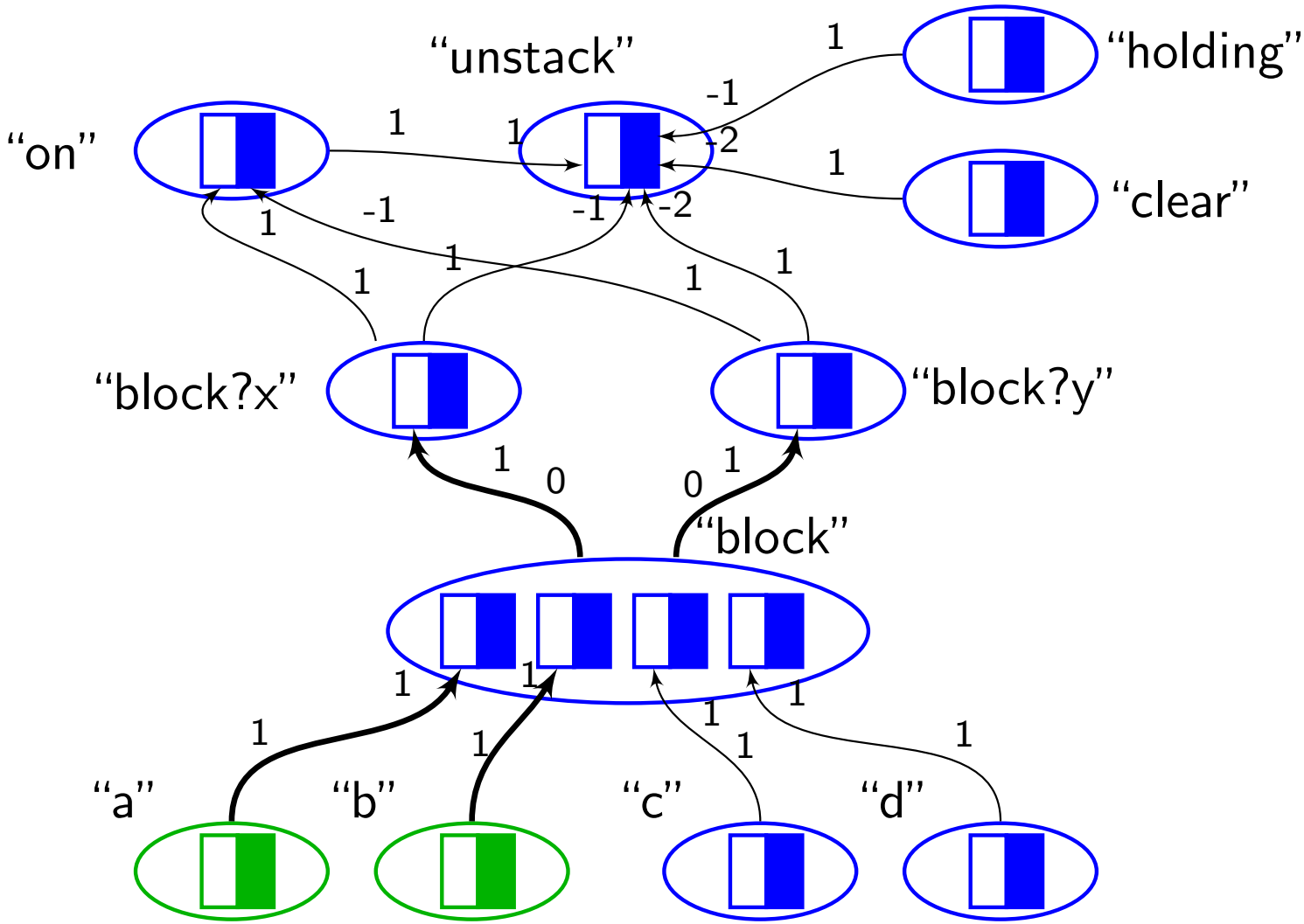

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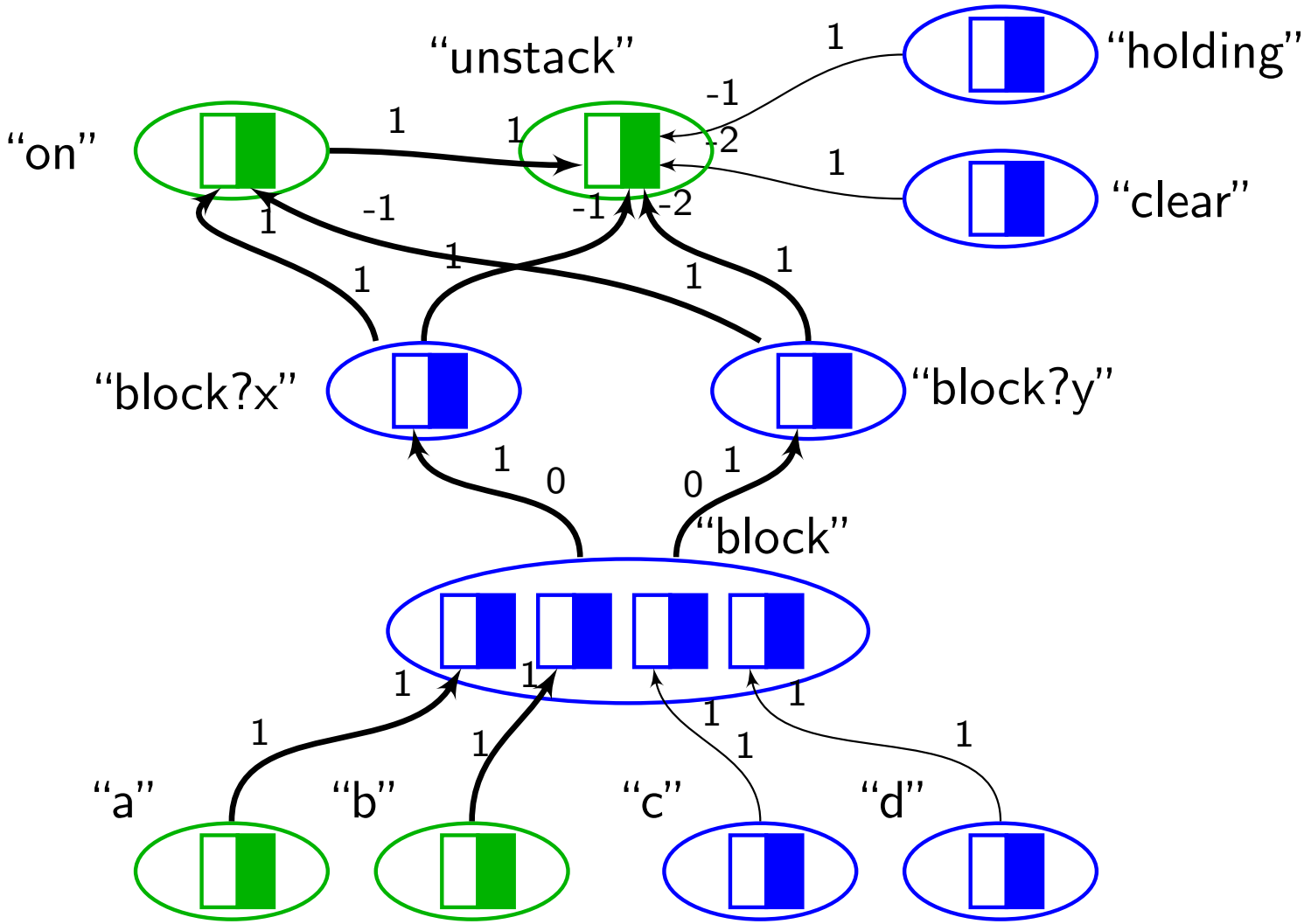

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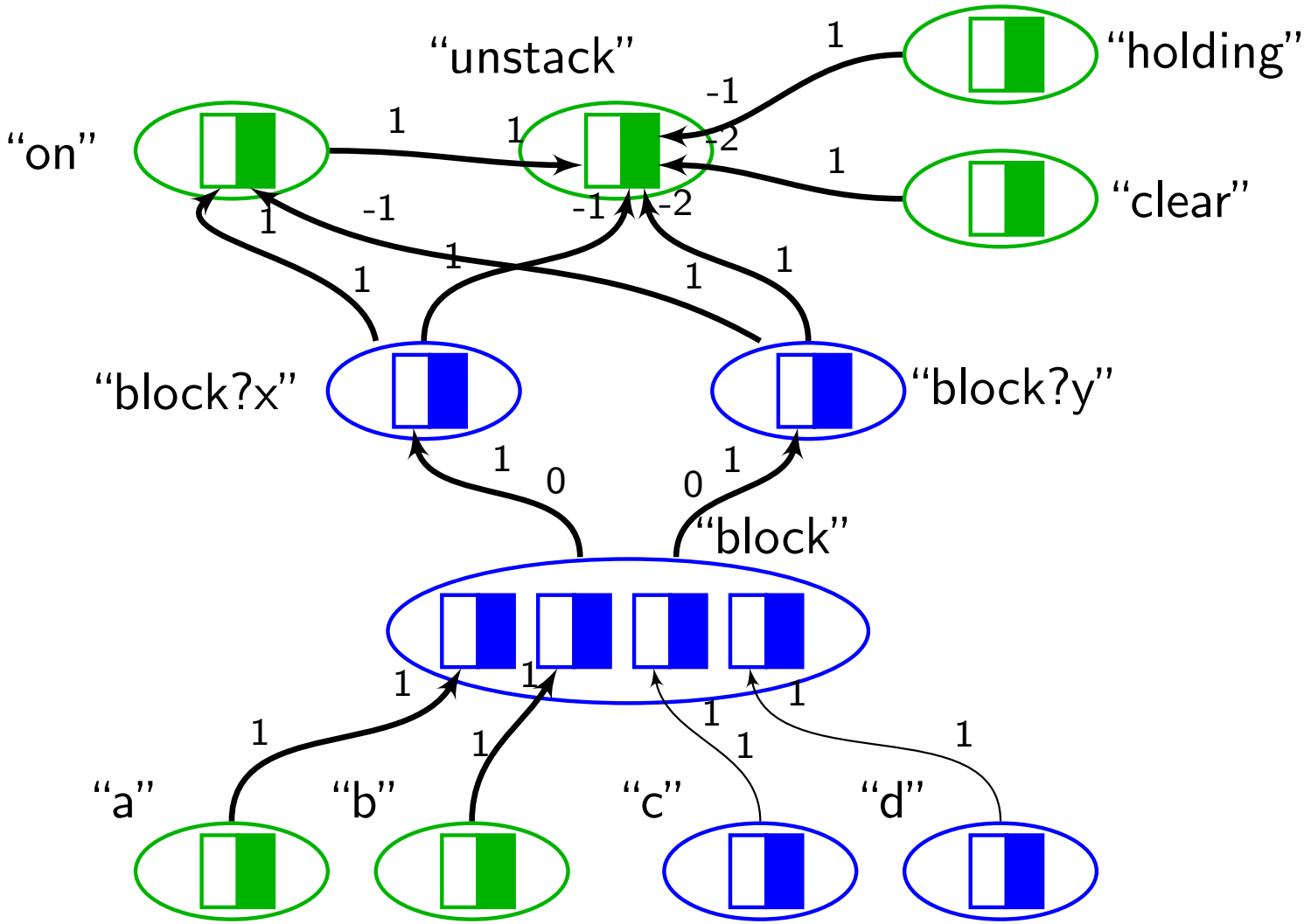

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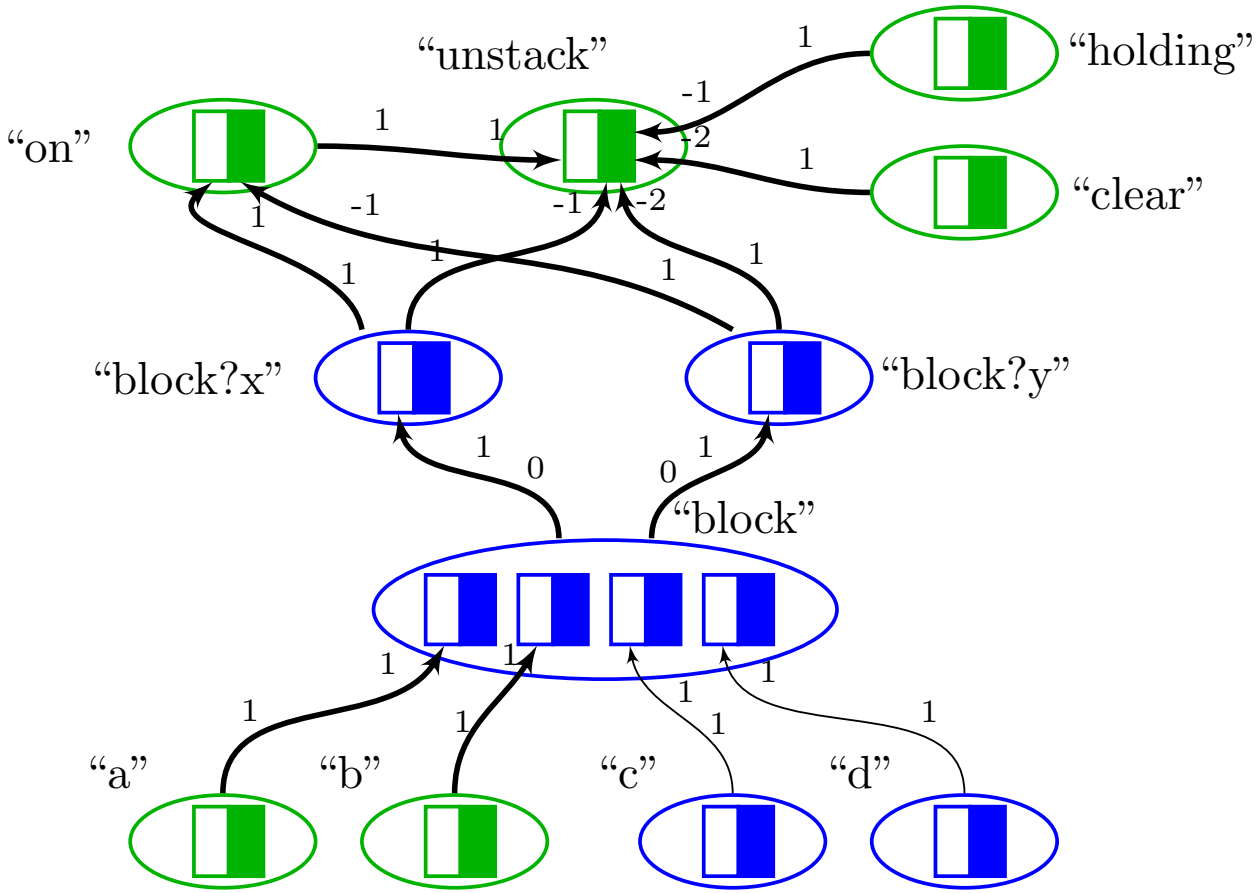
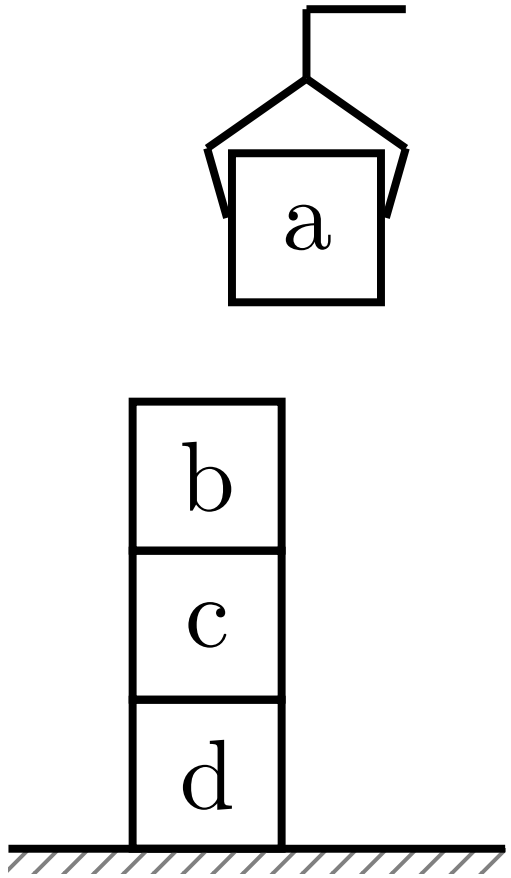
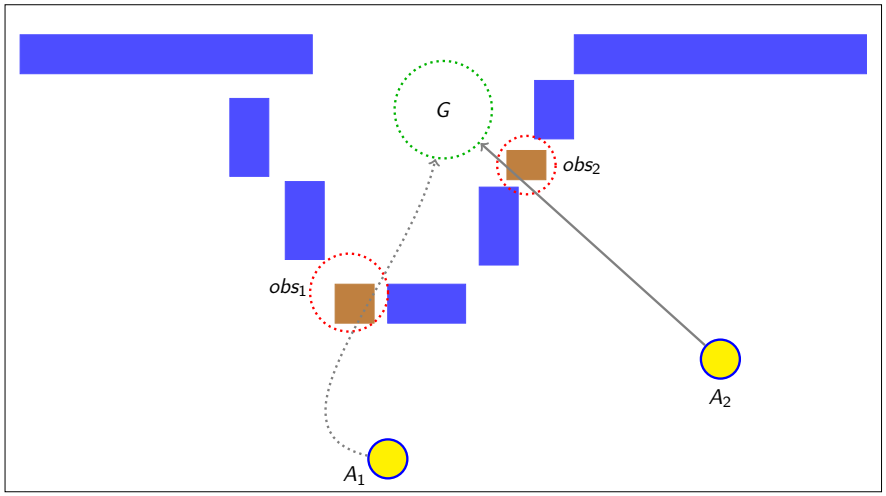




Smart Relocation Tasks (SRT)



Problem

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

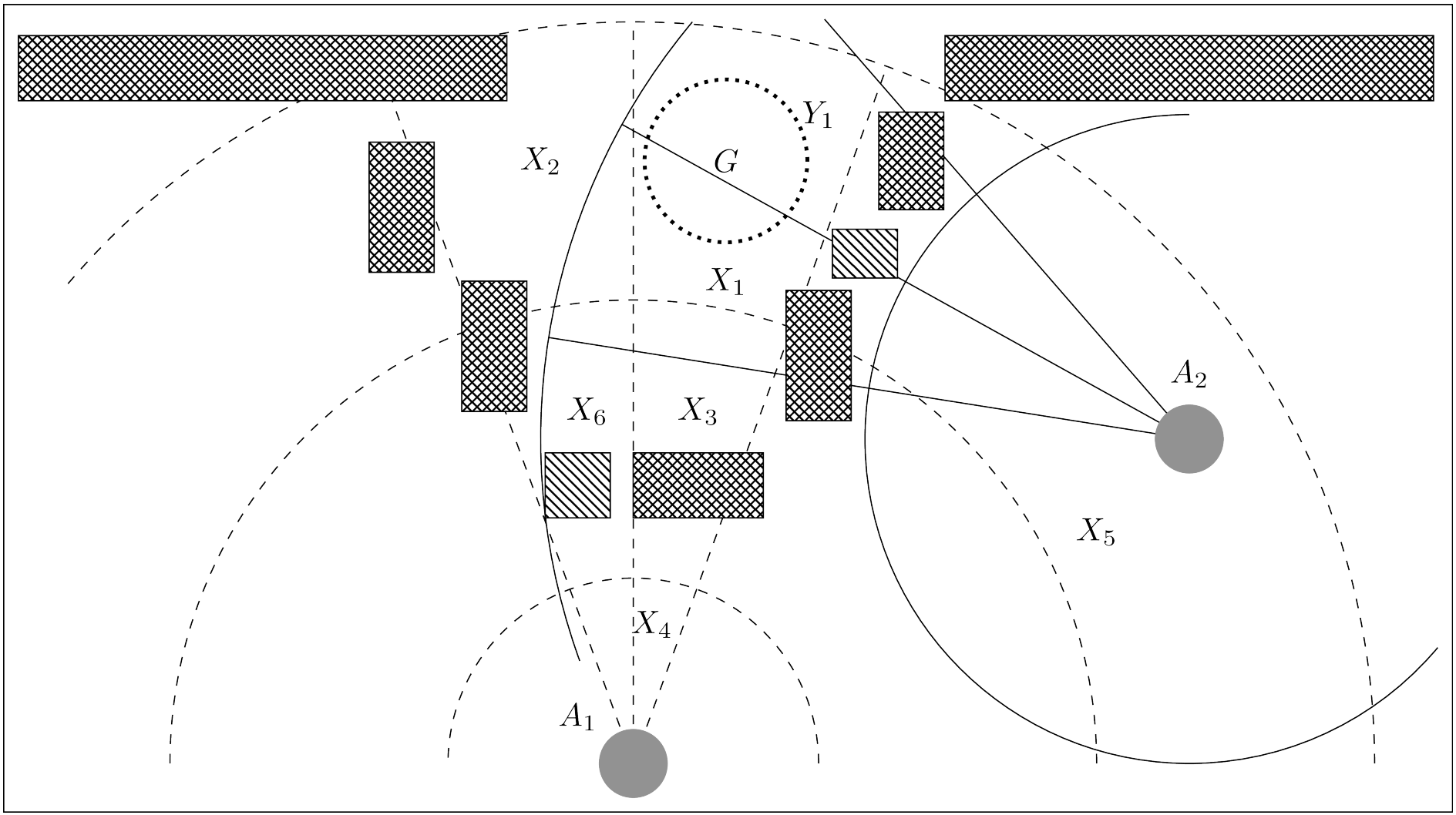
Solution

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)

Model task



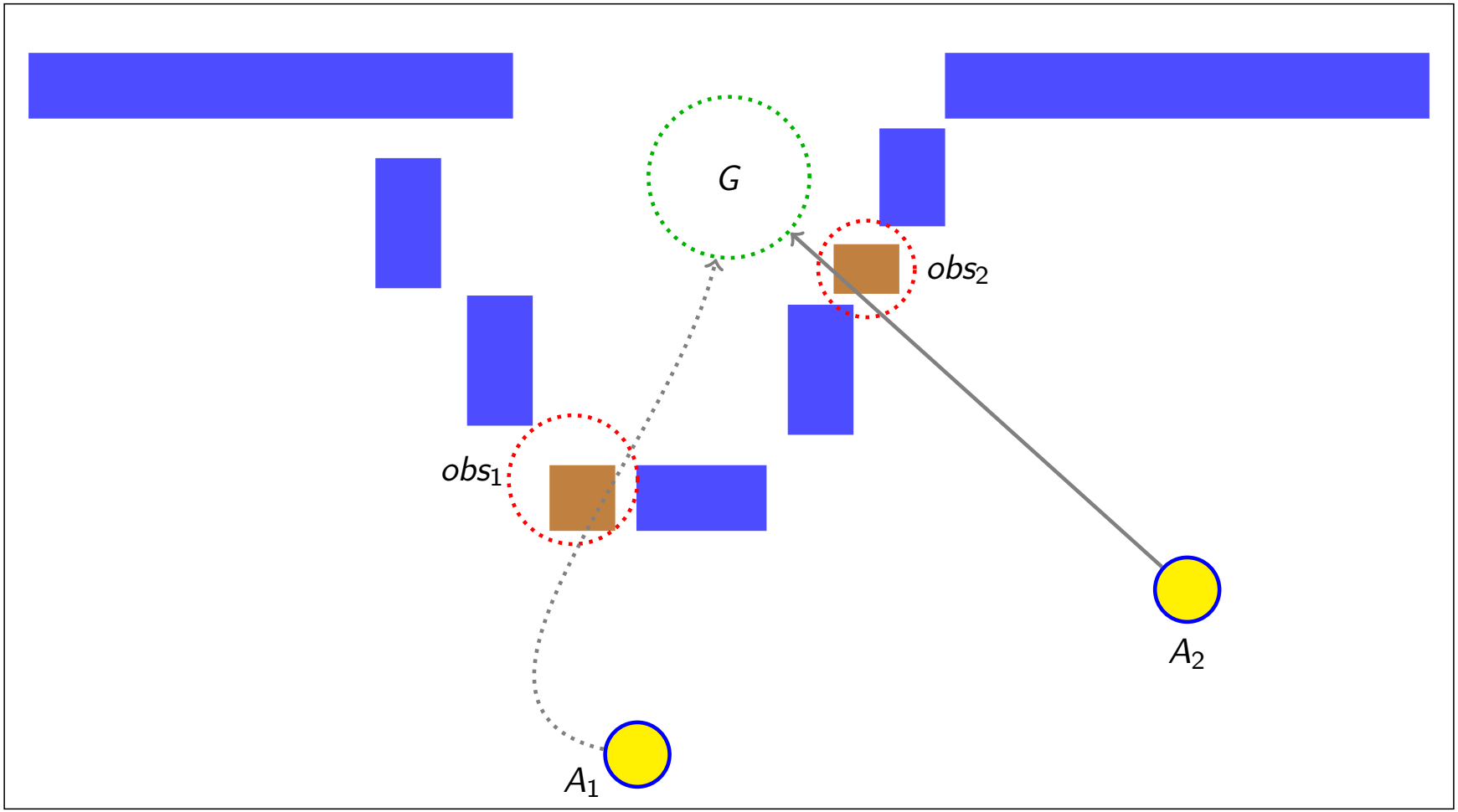
Spatial knowledge representation

Relocation actions — signs s_t (features f_t, t — relocation type), with corresponding prediction matrices Z_t consist of 3 columns:

$$z_1 = (l_x, l), z_2 = (l_y, d_u, E), z_3 = (l_y, l, t_v),$$

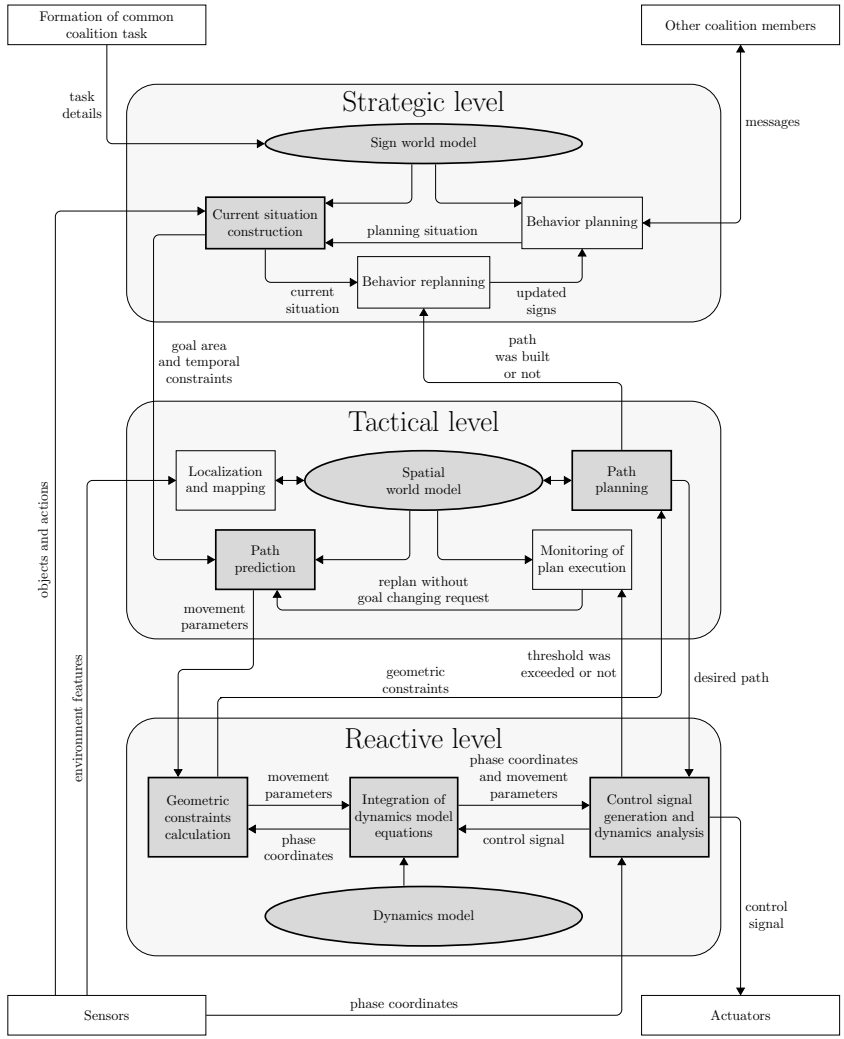
- l_x, l_y — features represented category of distance in a spatial logic (e.g., "far", "closely" etc.),
- d_u — features represented category of direction in a spatial logic (e.g., "left", "straight" etc.),
- t_v — features represented category of time in temporal logic (e.g., "soon", "not soon" etc.),
- l — feature of agent presence,
- E — feature of obstacle absence.

Model task



Conclusions

- We propose psychologically inspired knowledge representation (sign world model) supported by neurophysiological data
- Sign world model is used to construct models of cognitive functions
- Sign world model is used in STRL cognitive architecture as an implementation of strategic level of control



Thank you for attention!

FRC CSC RAS

pan@isa.ru

`https://github.com/cog-isa/map-planner.git`