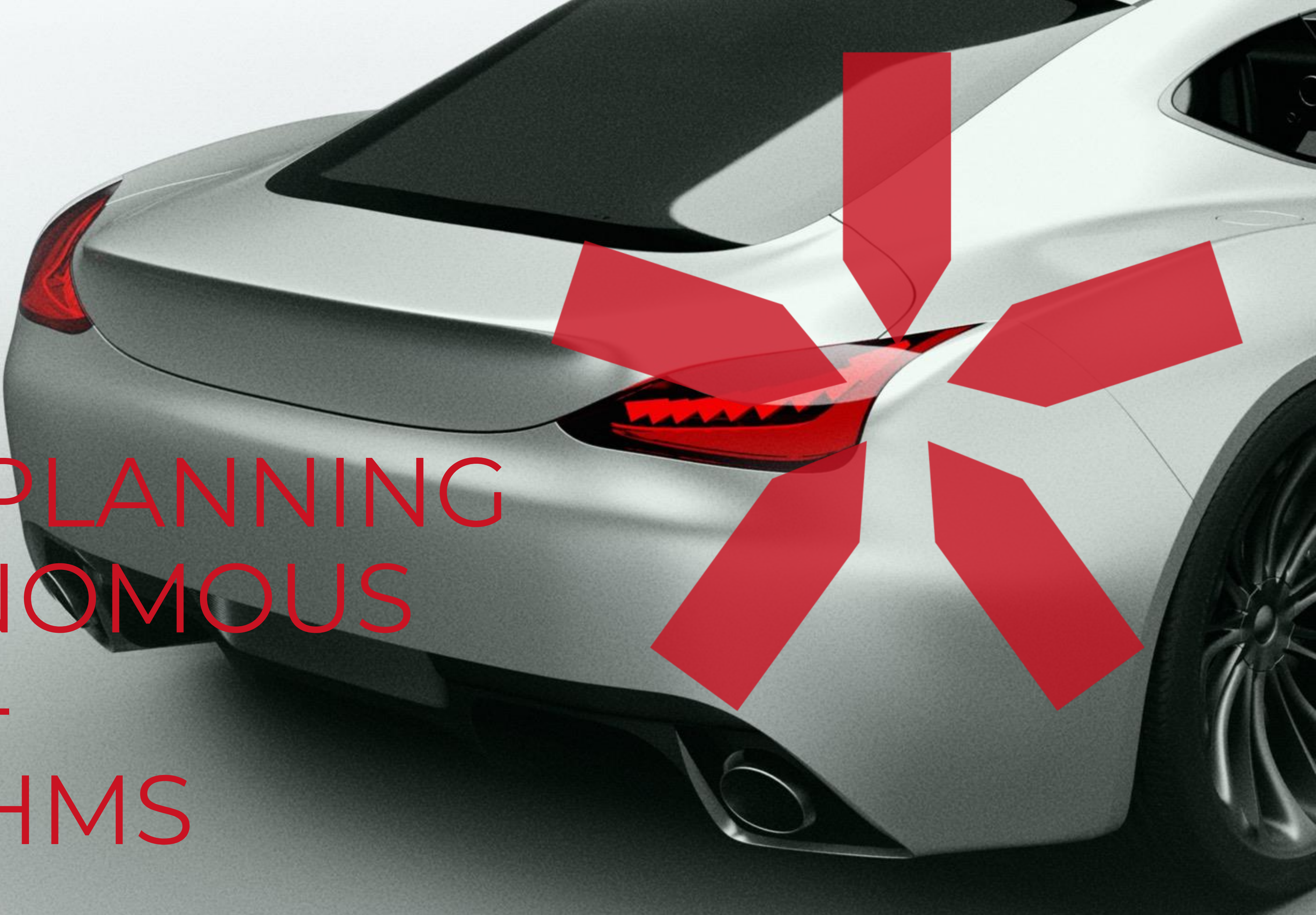
MOTION PLANNING IN AUTONOMOUS DRIVING - ALGORITHMS



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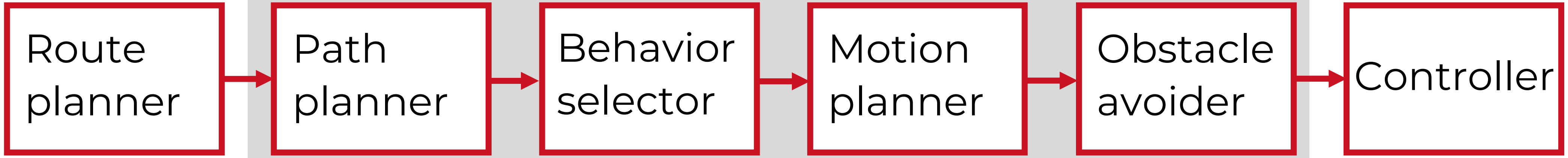
ALGORITHM CLASSIFICATION

1. Space configuration
2. Pathfinding algorithms
3. Attractive and repulsive forces
4. Parametric and semi-parametric curves
5. Artificial intelligence
6. Numerical optimization



CLASSIFICATION

More details in Claussmann et al., 2019, available here:

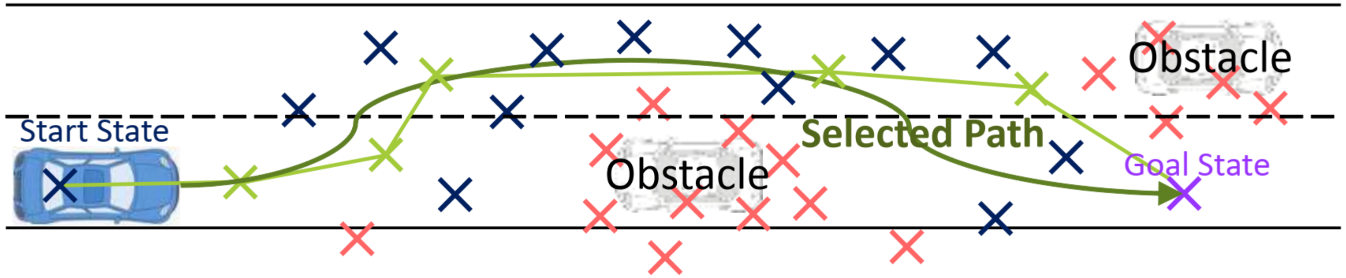
https://www.researchgate.net/publication/333124691_A_Review_of_Motion_Planning_for_Highway_Autonomous_Driving

1. SPACE CONFIGURATION

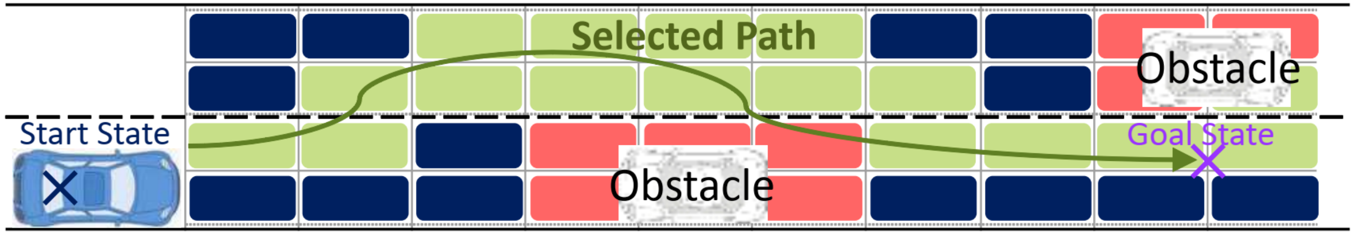
- Geometric methods
- Challenge is to find the right space configuration parameters

1. SPACE CONFIGURATION

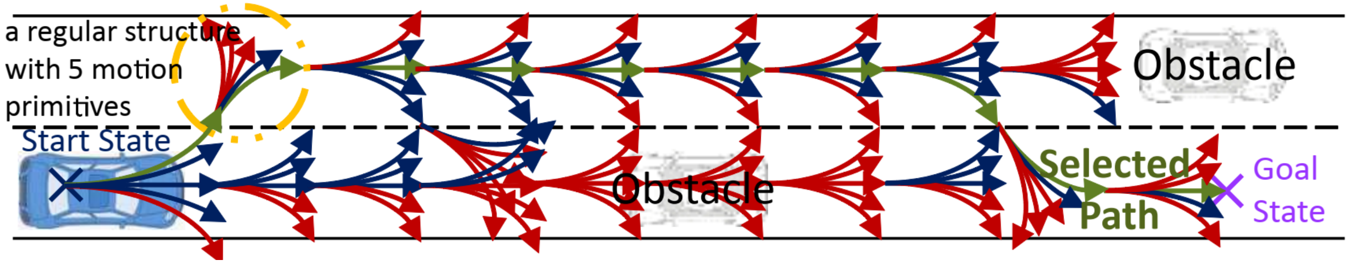
Sampling-based



Connected cells



Lattice

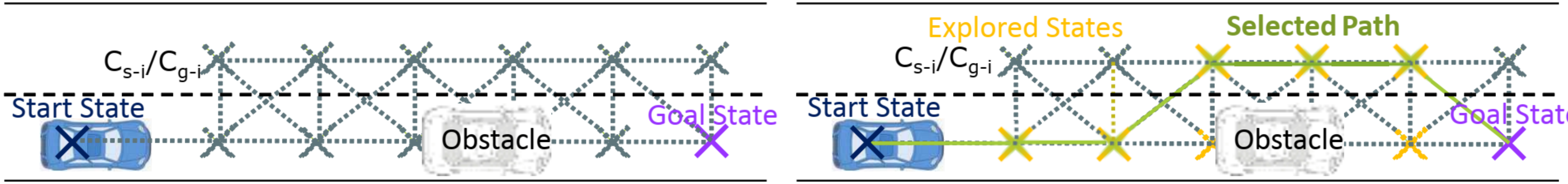


2. PATHFINDING ALGORITHMS

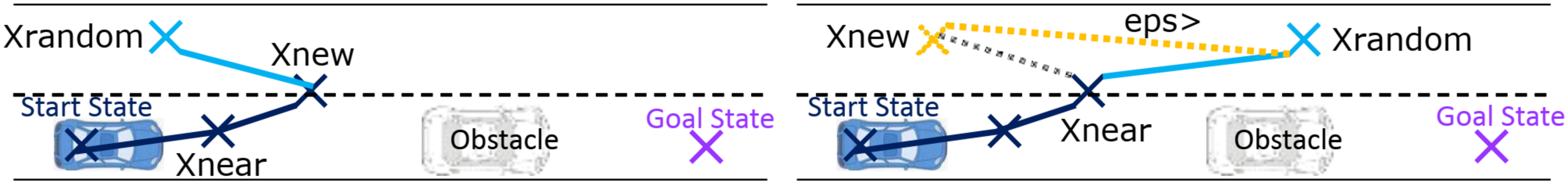
- Find a path in a graph to optimize a cost function
- Mainly used for route and local planning

2. PATHFINDING ALGORITHMS

Dijkstra or A*



Rapidly-exploring Random Trees (RRT)



3. ATTRACTIVE AND REPULSIVE FORCES

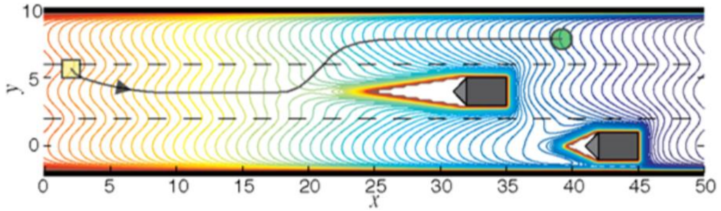
- Evolution space as attractive forces (for desired motion) and repulsive forces (for undesirable motion)

- Motion of vehicle guided by the resultant force vectors – no space decomposition

- Works with continuous space

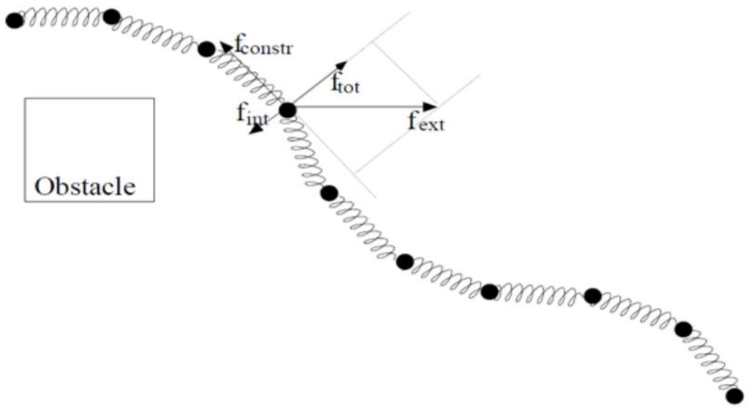
3. ATTRACTIVE AND REPULSIVE FORCES

Artificial potential field



ieeexplore.ieee.org/document/4543783

Elastic band model



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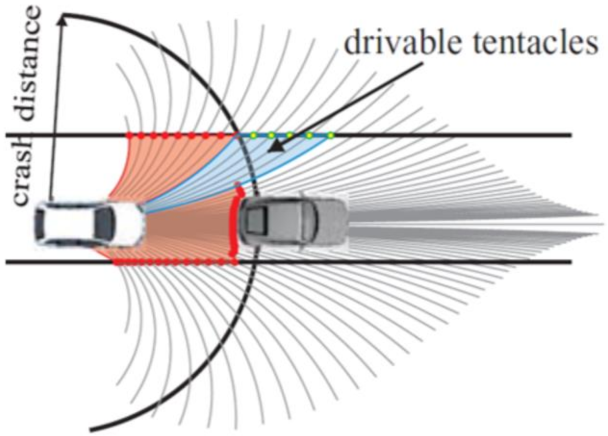
4. PARAMETRIC AND SEMI-PARAMETRIC CURVES

- Geometric methods
- Particularly suited for highway driving
- Curve-based algorithms can implicitly take into account kinematic constraints

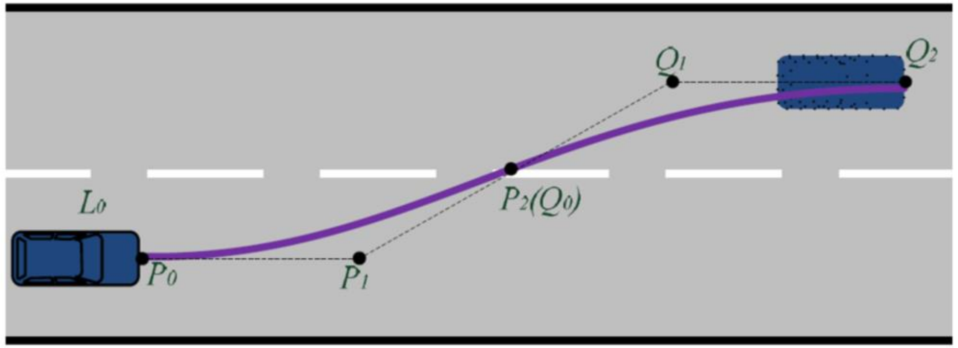
4. PARAMETRIC AND SEMI-PARAMETRIC CURVES

Point free
(e.g. Tentacle scheme)



onlinelibrary.wiley.com/doi/abs/10.1002/rob.20256

Point based
(e.g. Bézier curves)



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5. ARTIFICIAL INTELLIGENCE

- Try to simulate human reasoning and learning
- Generic and flexible
- Mostly used for predictive planning

5. ARTIFICIAL INTELLIGENCE

Human-like
- Risk estimators
- Taxonomic models
- Game theoretical

Heuristic
- Support vector machines
- Evolutionary methods

Approximate reasoning
- Fuzzy logic
- Artificial neural networks
- Reinforcement learning

Logic-based
- Rule-based
- Decision trees
- Finite state machines

6. NUMERICAL OPTIMIZATION

- Minimization of a cost function
- Well-defined mathematical models
- Easily handle constraints

6. NUMERICAL OPTIMIZATION

- Model predictive control is highly popular
- Requires the solution of a nonlinear programming problem
- Dynamic programming better for finding global solutions

6. NUMERICAL OPTIMIZATION

$$\begin{aligned}
\text{minimize} \quad & \sum_{k=1}^{N-1} f_k(z_k, p_k) && \longleftarrow \text{Objective function} \\
\text{subject to} \quad & z_1(\mathcal{I}) = z_{\text{init}} && \longleftarrow \text{Measurement or estimate of the system states} \\
& E_k z_{k+1} = c_k(z_k, p_k) && \longleftarrow \text{Equality constraints (system dynamics)} \\
& z_N(\mathcal{N}) = z_{\text{final}} && \longleftarrow \text{Final equality constraints} \\
& \underline{z}_k \leq z_k \leq \bar{z}_k && \longleftarrow \text{Upper and lower bounds on inputs and states} \\
& F_k z_k \in [\underline{z}_k, \bar{z}_k] \cap \mathbb{Z} && \longleftarrow \text{Integer variables} \\
& \underline{h}_k \leq h_k(z_k, p_k) \leq \bar{h}_k && \longleftarrow \text{Nonlinear constraints}
\end{aligned}$$

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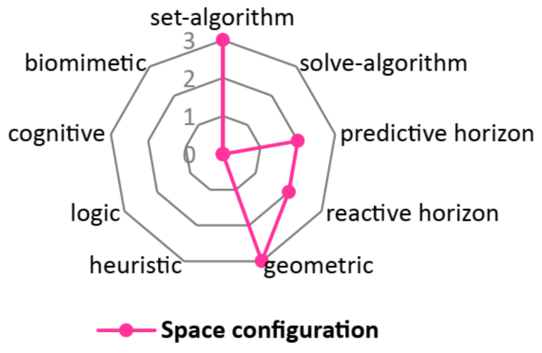
TAKE AWAY POINTS

- A classification of algorithms for motion planning
- Focus on structured environment (highways)
- Help to make sense of the huge literature in the area

TAKE AWAY POINTS



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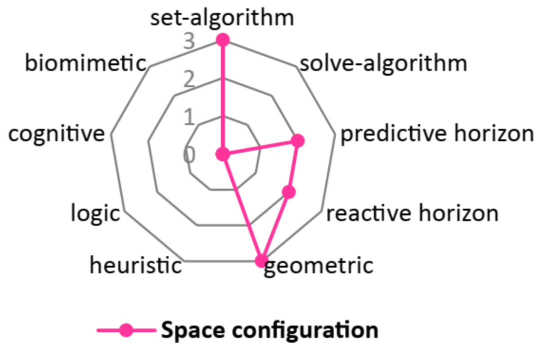

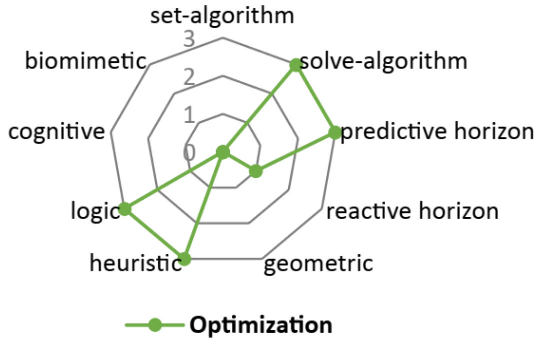

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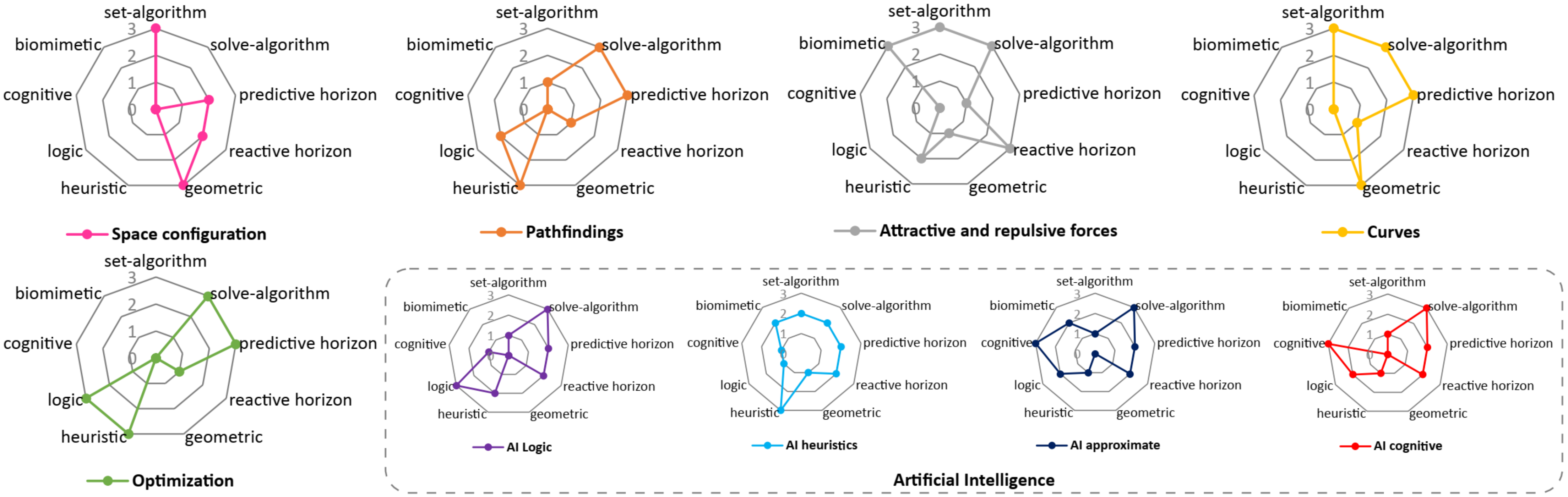

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