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# Distributed Model Predictive Control for Multi-Agent Systems

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## MOTIVATION

- **Multi-Agent Systems (MAS)** plays critical role in robotics applications<sup>1</sup>
- **Distributed Model Predictive Control (DMPC)** enables parallel optimization-based decision<sup>2</sup>
- **Challenge:** Existing DMPC methods are commonly formulated as a single-stage optimization problem<sup>3</sup>
- **Proposed Solution:** **Two-Stage DMPC**
- **Impact:** Improved feasibility and travel times for real time performance

### APPLICATION OF MAS



Autonomous exploration and environmental monitoring

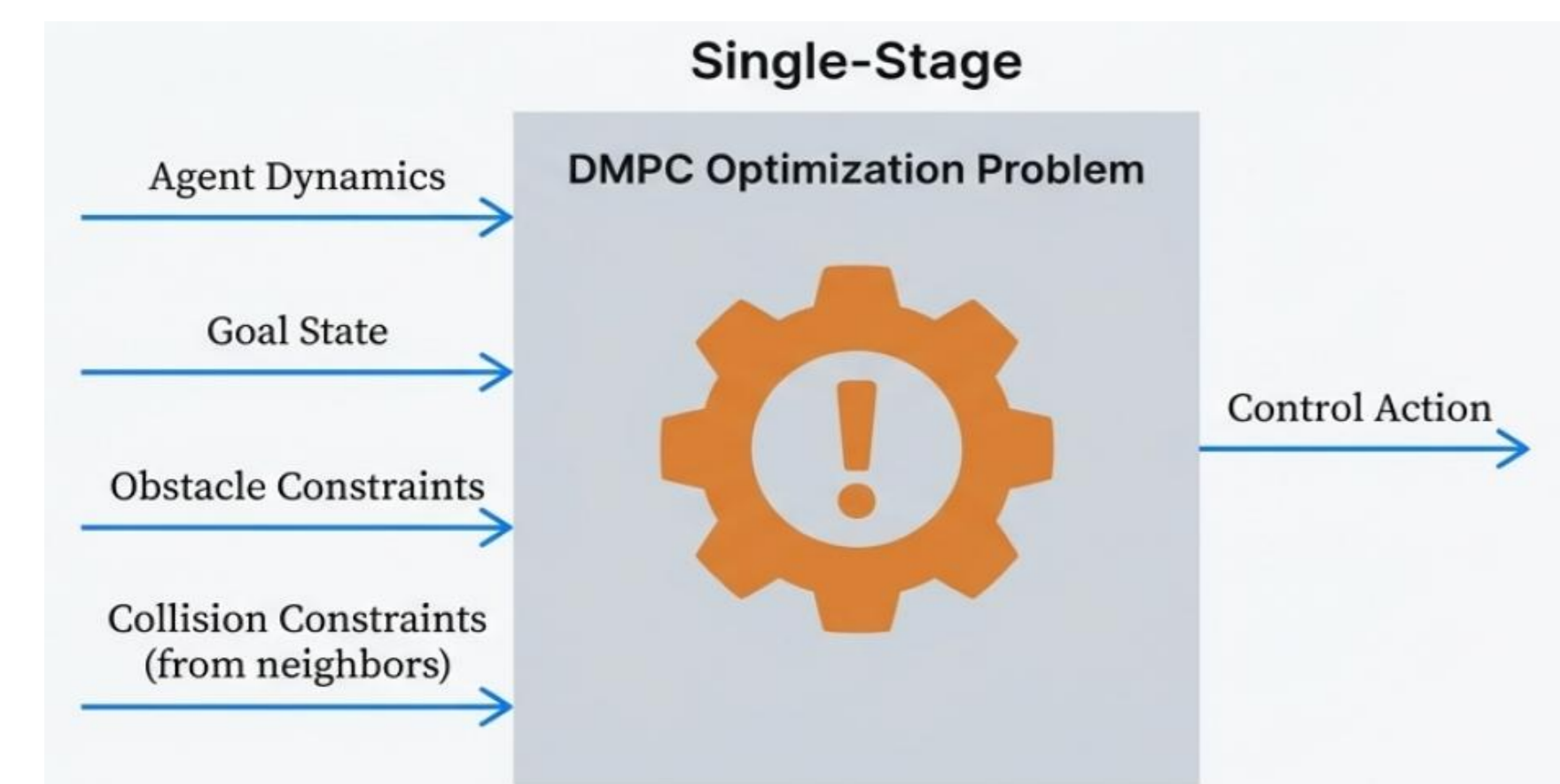


Inspection of hazardous industrial regions



Logistics and activities in remote or inaccessible areas

### EXISTING DMPC METHODS

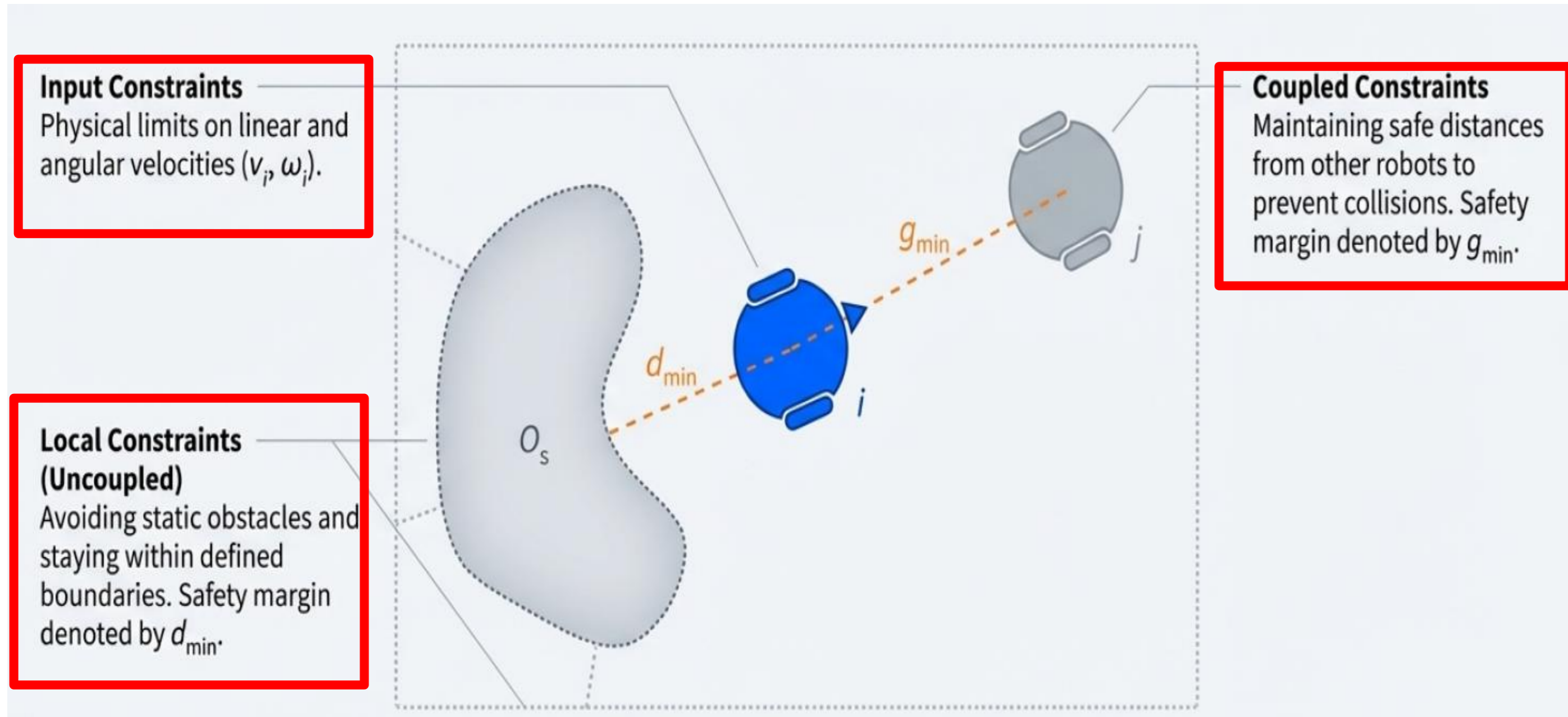


### BOTTLENECKS?

- Network Congestion
- Potential Infeasibility
- Inefficient Real Time Performance
- Long travel times

## PROBLEM DESCRIPTION

### ➤ CONSTRAINTS IN A MULTI-ROBOT SYSTEMS COORDINATION



### ➤ MATHEMATICAL REPRESENTATION

$$J_i^*(x_i(k)) = \min_{u_0, \dots, u_{N-1}} \sum_{k=0}^N \|x(k) - x_{ref}\|_Q^2 + \|u(k)\|_R^2$$

Subject to:

$$x(k+1) = f(x(k), u(k)), \quad h(x_i) \leq 0, \quad c_{i,r}(x_i, x_{j \in \mathcal{N}_{i,r}}) \leq 0 \quad r = 1, \dots, R_i$$

Non-Coupled Constraints:

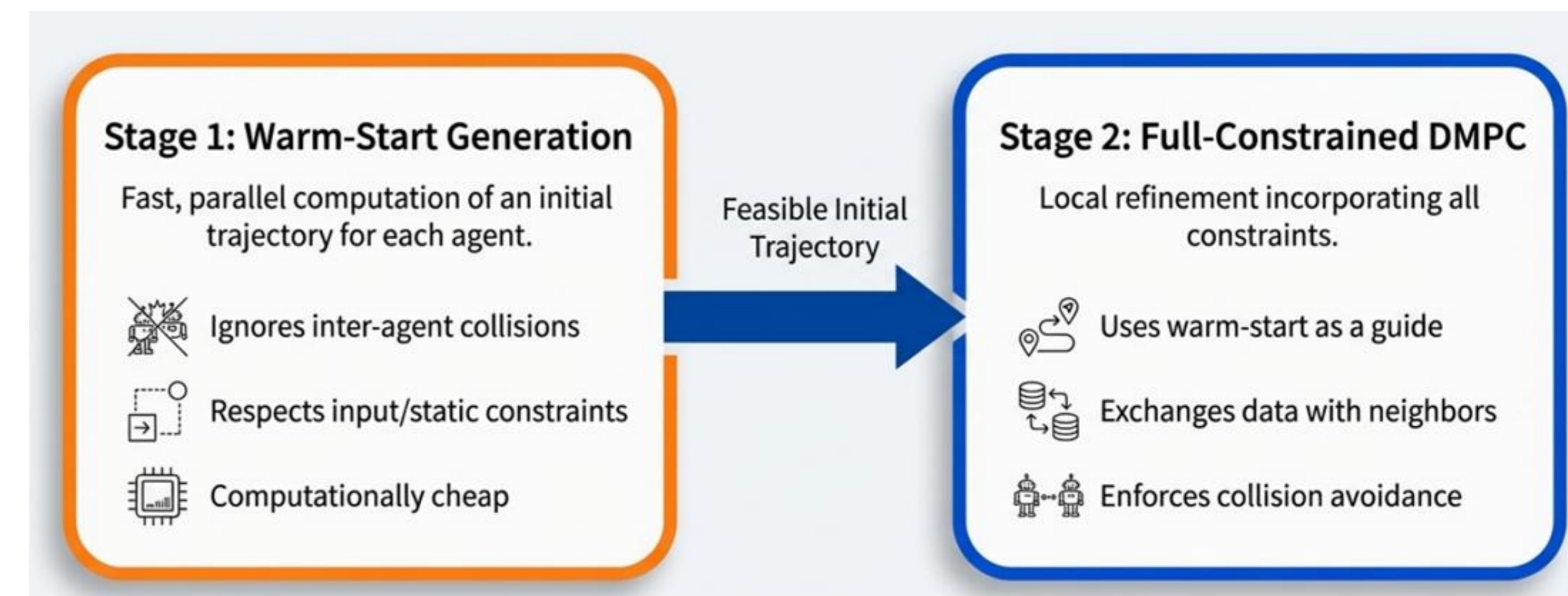
$$h(x_i) = \begin{cases} x_i \in \mathcal{X}_i & \text{(state bounds)} \\ u_i \in \mathcal{U}_i & \text{(input bounds)} \\ x_i \notin \mathcal{O}_i & \text{(fixed obstacle avoidance)} \end{cases}$$

Coupled Constraints (Collision Avoidance):

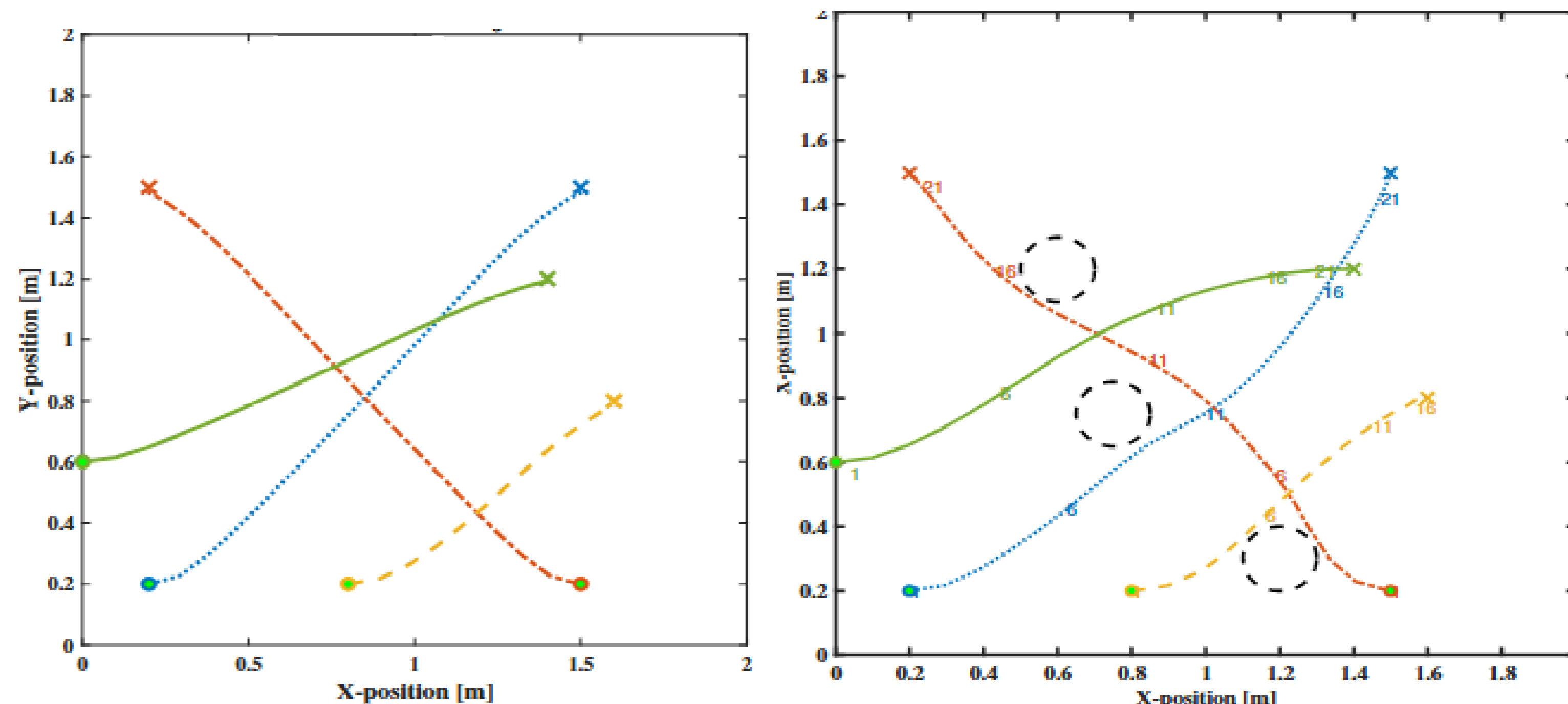
$$c_{i,r}(x_i, x_{j \in \mathcal{N}_{i,r}}) = \|x_i - x_j\|^2 - d_{min}^2 \geq 0, \quad \forall j \in \mathcal{N}_{i,r}$$

## METHODOLOGY

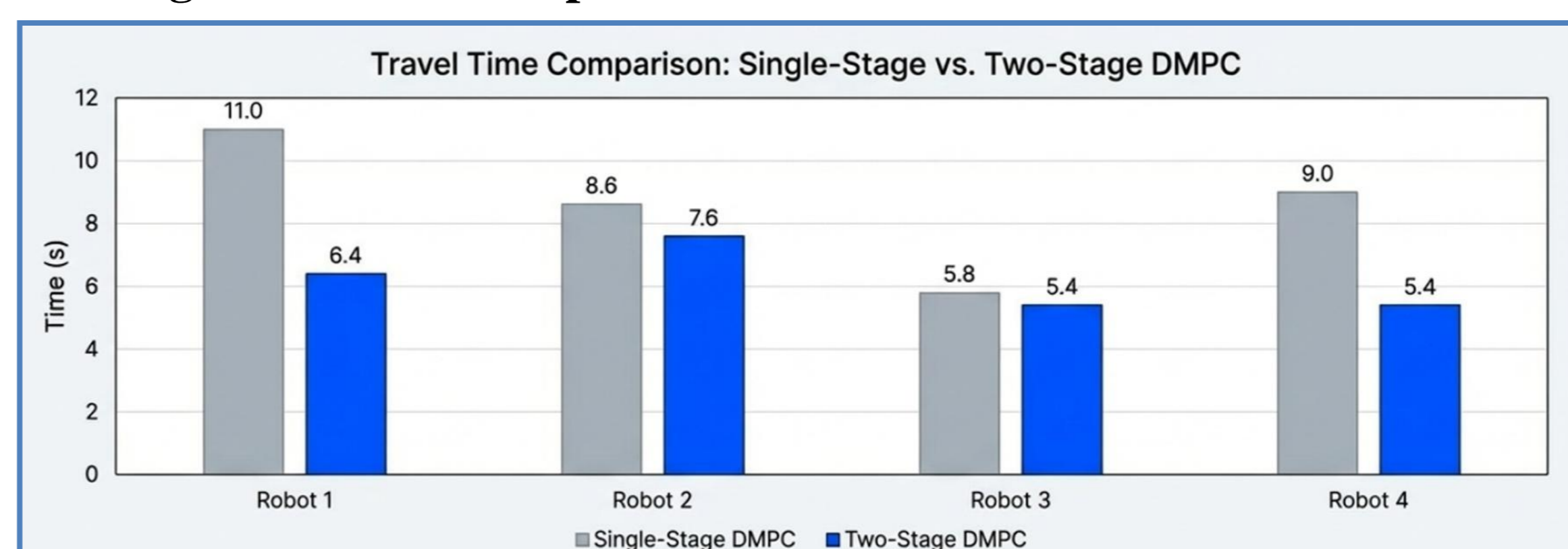
### ➤ TWO – STAGE DMPC ARCHITECTURE<sup>4</sup>



## RESULTS



Average of 10 – 15 % improvement in travel times



SCAN TO WATCH

## CONCLUSION

- A two-stage DMPC scheme for multi-agent system coordination with non-coupled and coupled constraints, and input constraint was developed.
- Theoretical guarantees of the approach were established.
- The effectiveness was demonstrated through simulations and experiments.
- Future work will focus on integrating **Disturbance Rejection Observer** to the scheme.

## REFERENCES

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