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An Integrated Framework to Prevent Unsafe Proximity Hazards in Construction by Optimizing Spatio-Temporal Constrains

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Outline

1.	Introduction
2.	Motivation and objectives
3.	Methodology
4.	Potential contributions
5.	Concluding remarks

❑ Resources

Moving resources

Stationary resources/facilities

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Introduction

Contact collisions

- Close proximity between resources

Path/Trajectory planning

- Proper routing of resources in the planning stage
- Time-optimal and collision-free paths

Safety risks reduction

- Optimize trajectories of construction resources in time integrated 2D space
- Manage project cost and schedule

Increases Safety

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Motivations

- Not take the **planning stage** into account
- Neglected the **time factor** in both analysis and visualization
- Neglected **direction/heading** of the entities' movement

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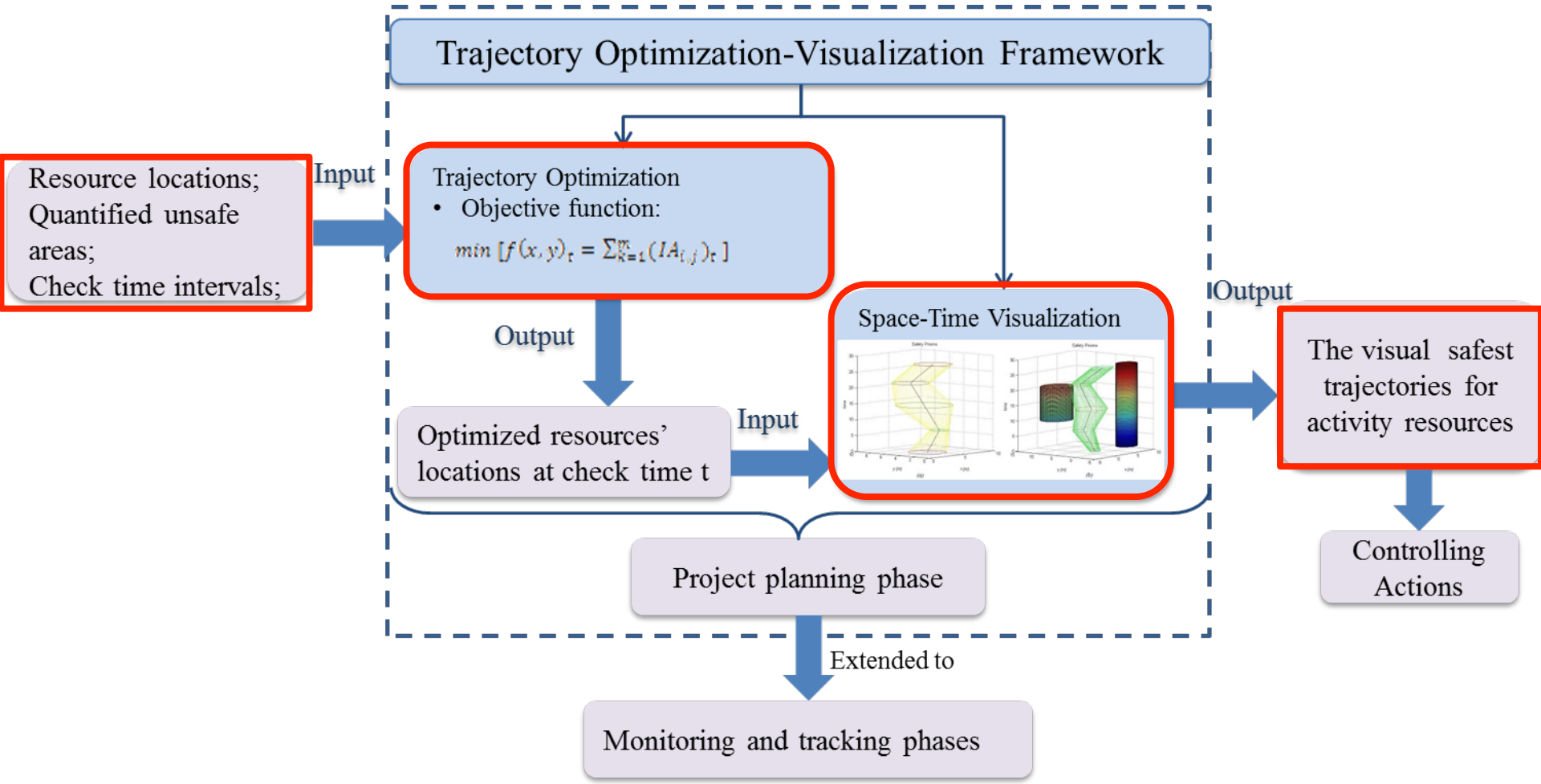
Objectives

Unsafe Proximity Avoidance Model

- **Decrease resources congestions, predict and optimize motion trajectories**
- **Visualize optimized trajectories in time-integrated 2D space**

Methodology



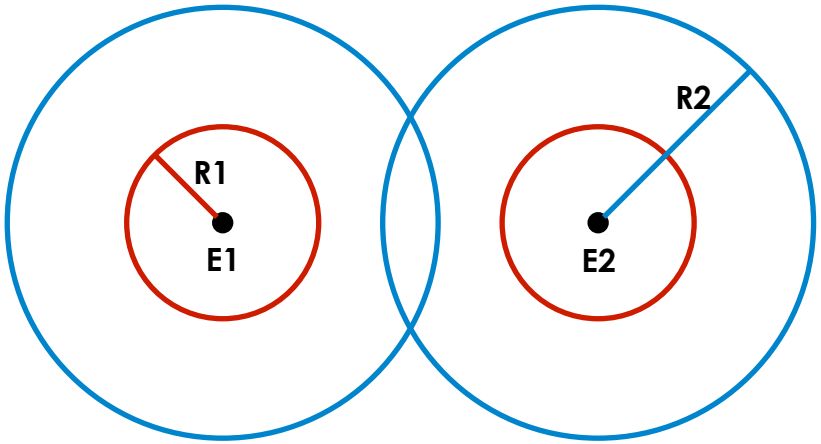
❑ Safety Areas

- **R1: alert distance**

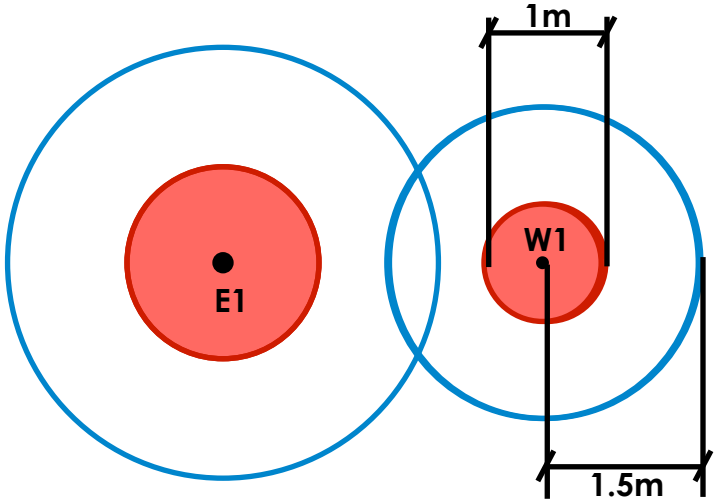
  → regardless of its static or moving state

- **R2: warning distance**

  → equipment reaction distance + braking distance



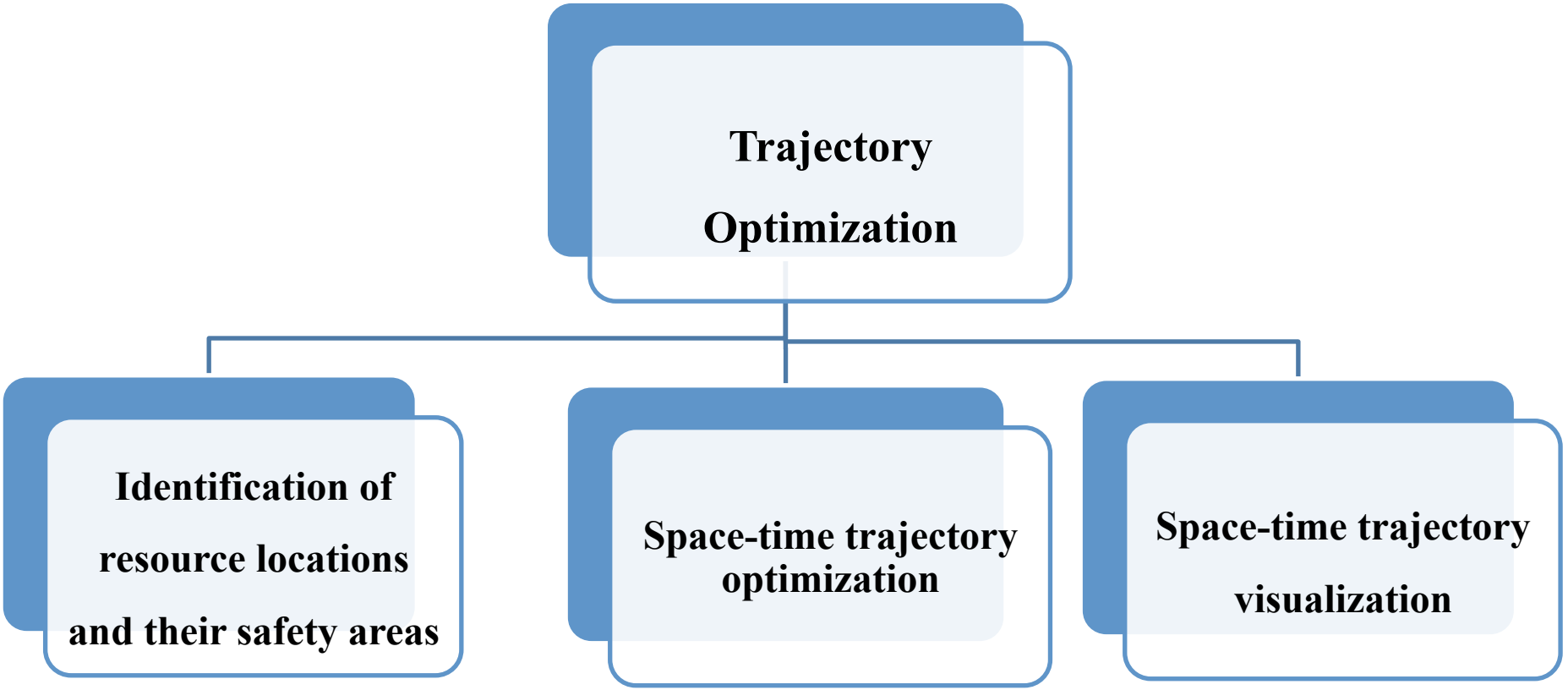
Two pieces of equipment



Equipment and worker-on-foot

Methodology

❑ Trajectory Optimization



❑ Resource Locations and Safety Areas

Expected location of each resource:

→ Pre-set time intervals to optimize the trajectory step by step

→ The nature and the schedule of activities for each resource

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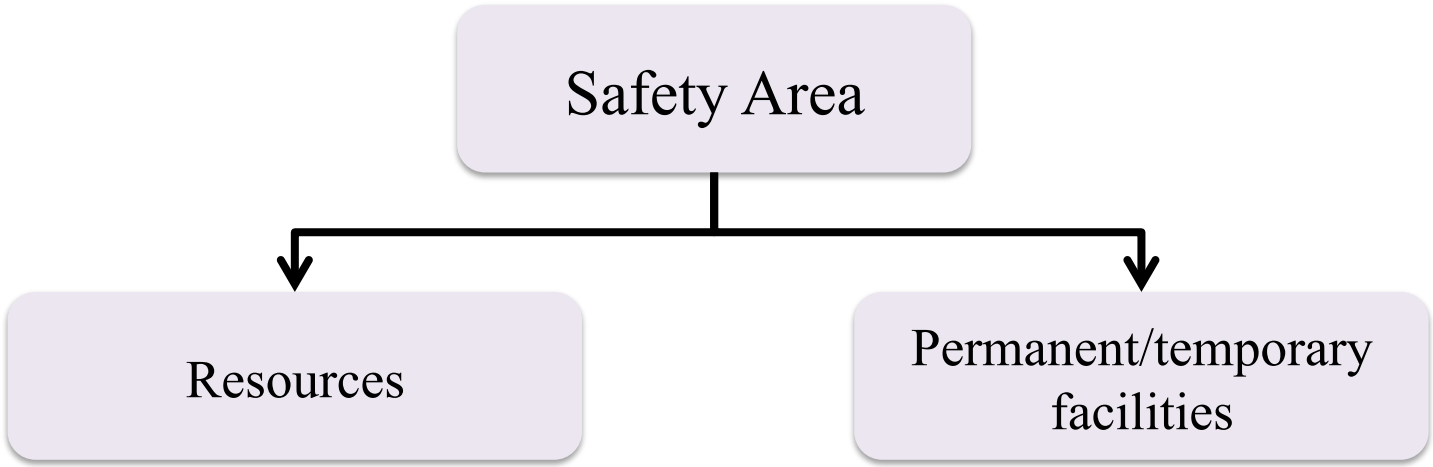


Methodology

❑ Safety Area

- Construction equipment and workers-on-foot

→ Alert and warning areas

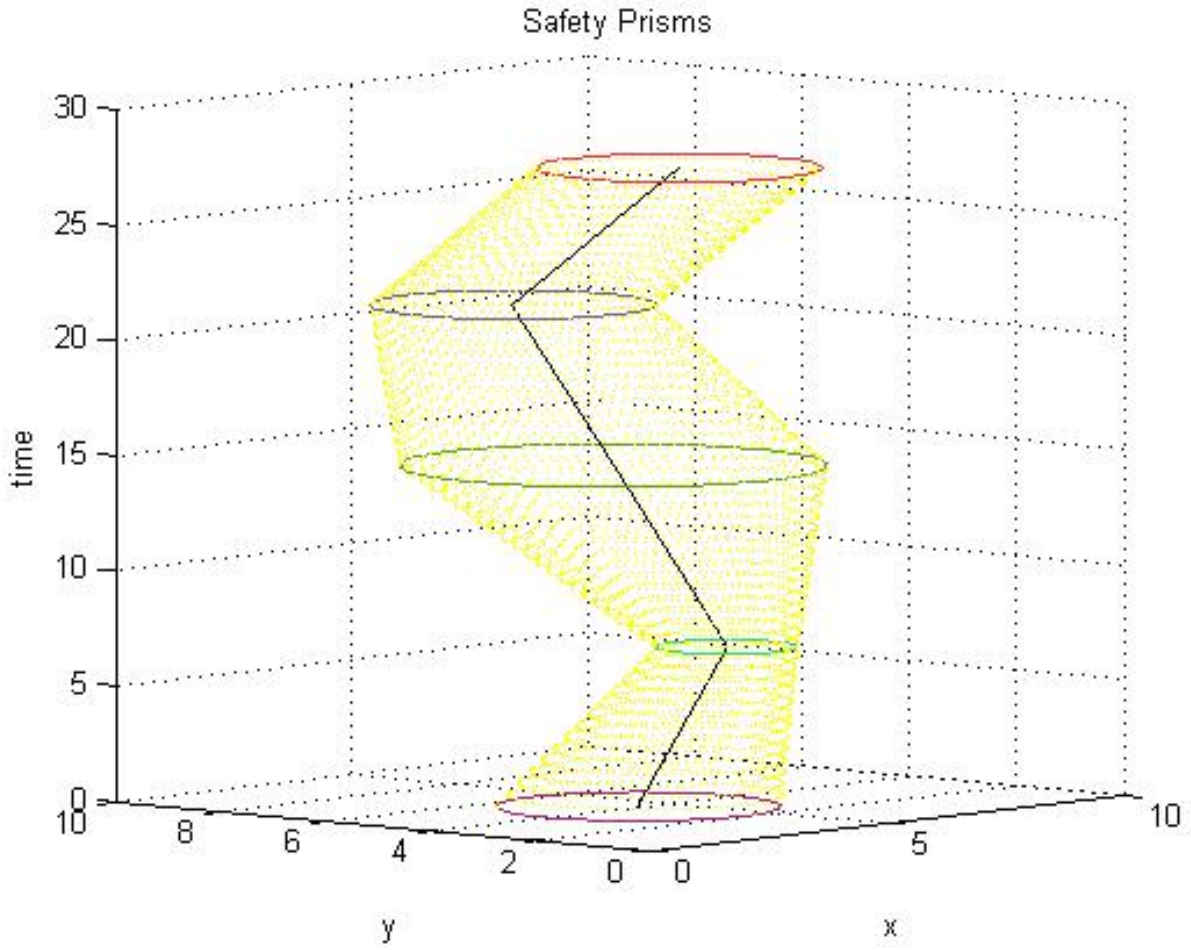
- Temporary or permanent site facilities and obstacles

→ The area around them that other construction resources are not allowed to be inside except by authorizations

Initialize the step-by-step optimization process

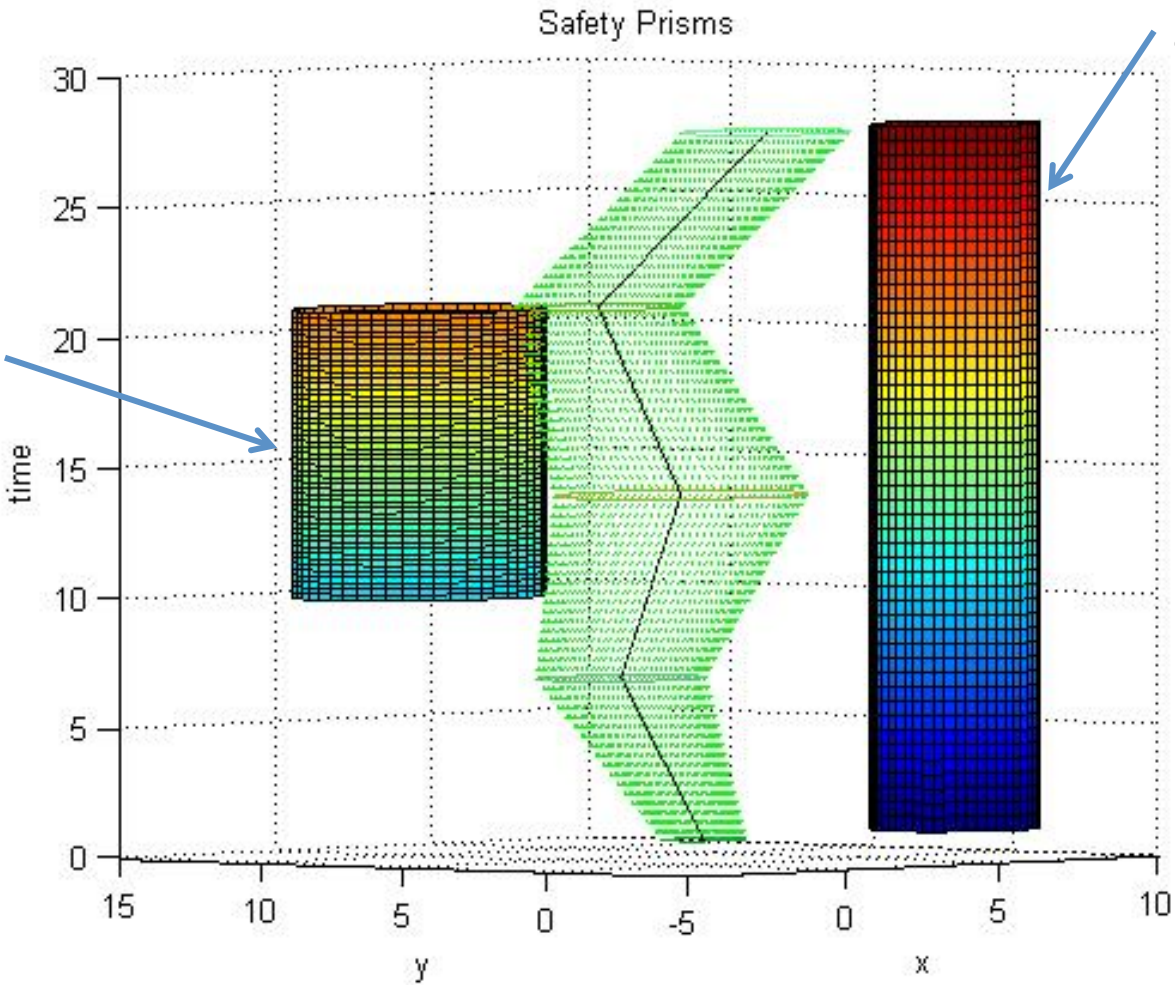
Methodology

❑ Initial Visualization



Methodology

❑ Initial Visualization



Permanent obstacle (existing facility)

Temporary obstacle (temporary facility)

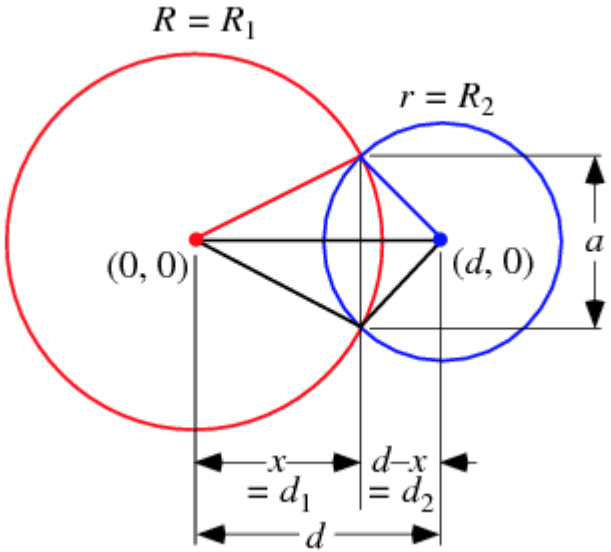
Methodology

❑ Location Optimization

- Assumptions:
  - The 2D intersection between circles is considered only at certain time intervals
  - Safety circles can intersect but only in warning areas
  - Safety area around obstacles is considered as cylinder

❑ Location Optimization

- Purpose: to minimize the potential hazardous contacts between resources



$$min\,[f(x,y)_t = \sum_{k=1}^{m} (IA_{i,j})_t\,]$$

$$m = C_2^{n_t} = n_t!/2\times(n_t-2)!\quad,$$

n = number of resources at time t

$$D \geq R2_i + R1_j\ ,\ R2_i \geq R2_j$$

$$D = \sqrt{[x_i(t)-x_j(t)]^2 + [y_i(t)-y_j(t)]^2}$$

Methodology

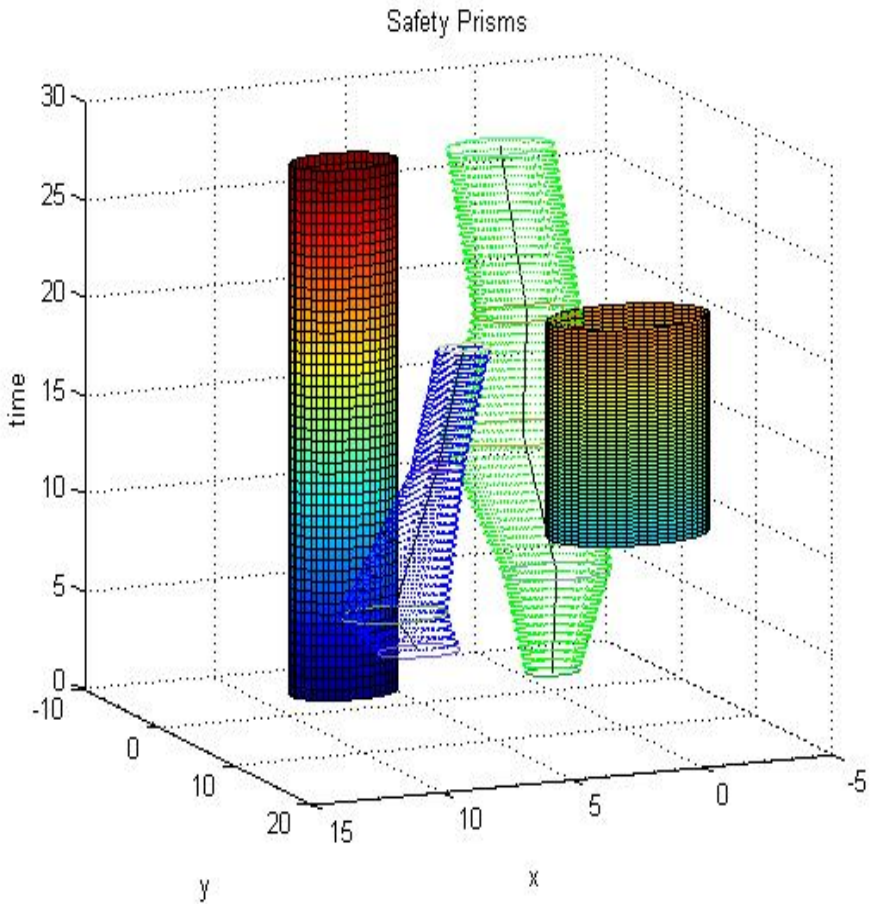
❑ Location Optimization

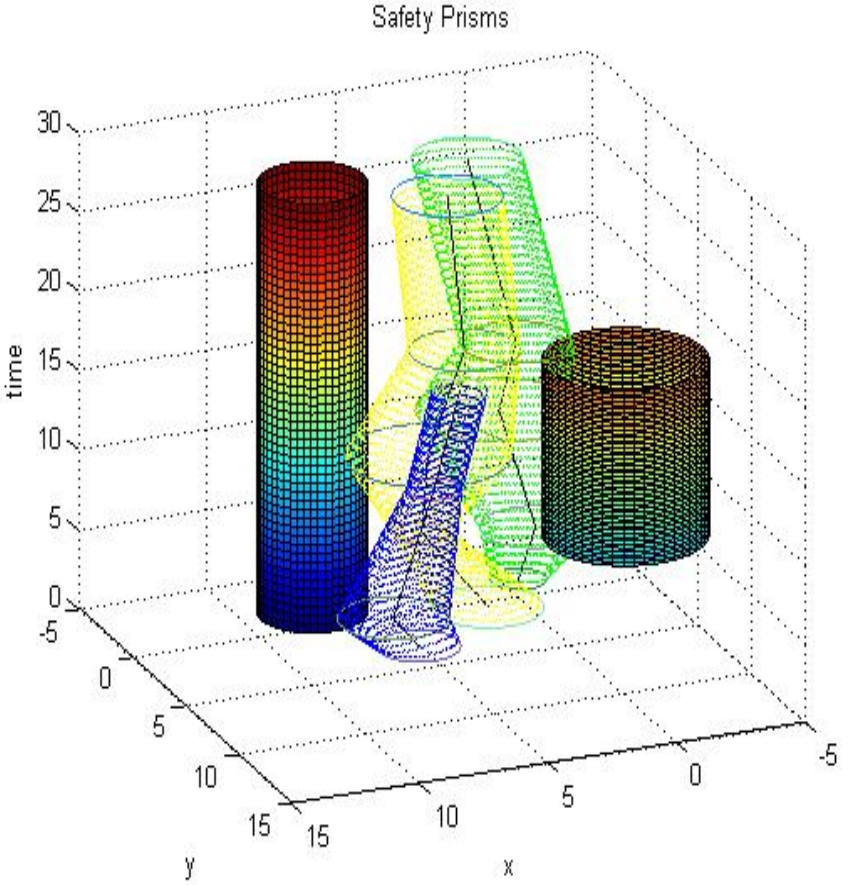
1. $D \geq R2_i + R2_j \rightarrow$
   $IA = 0$
2. $D \leq R2_i - R2_j \;, \rightarrow\; R2_j \leq R2_i \;\rightarrow$
   $IA = \pi R2_j^2$
3. $R2_i - R2_j \leq D \leq R2_i + R2_j \;, \rightarrow$
   $IA = R2_j^2 \cos^{-1}(D^2 + R2_j^2 - R2_i^2 / 2DR2_j) + R2_i^2 \cos^{-1}(D^2 + R2_i^2 - R2_j^2 / 2DR2_i) - 1/2 \sqrt{(-D + R2_j + R2_i)(D + R2_j - R2_i)(D - R2_j + R2_i)(D + R2_j + R2_i)}$

❑ Optimum Trajectory Visualization

Resource	Time	X coordinate	Y coordinate	Warning distance	Alert distance
Equipment 1	1	0	0	10	2
	7	1	4	11	2
	14	2	3	14	2
	21	3	7	11	2
	28	2	0	11	2
Equipment 2	1	2	2	11	2
	7	5	3	9	2
	14	6	6	11	2
	21	5	7	13	2
	28	4	3	11	2
Equipment 3	5	8	10	9	2
	7	9	10	11	2
	14	7	9	9	2
	20	6	9	8	2

❑ Optimum Trajectory Visualization





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Potential Contributions

- Help contractors and project managers to better control the movements of the resources

- Help project participants in taking preventive actions instead of 'after the fact' remedies

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Concluding Remarks

- Analyze and adjust the planned locations of construction resources on sites
- Prevent the hazards occuring due to an excessive proximity between different resources
- Reduce the complexity of resources' movements and increase their predictability

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Thank you for your attention!

Q&A