SLAM Based Autonomous Navigation of Mobile Robot

Project Members:

Bimal Paneru(069/BEX/408)

Niraj Basnet(069/BEX/422)

Rabin Giri(069/BEX/431)

Sagar Shrestha(069/BEX/436)

Project Supervisor:

Mr. Dinesh Baniya Kshatri

INTRODUCTION

- Autonomous Navigation
    - Navigation without human intervention
- Simultaneous Localization and Mapping (SLAM)
    - Chicken-egg problem of robotics
- Localizing, mapping and navigating from one location to another.

NAVIGATION SYSTEM

SENSOR FUSION

LOCALIZATION

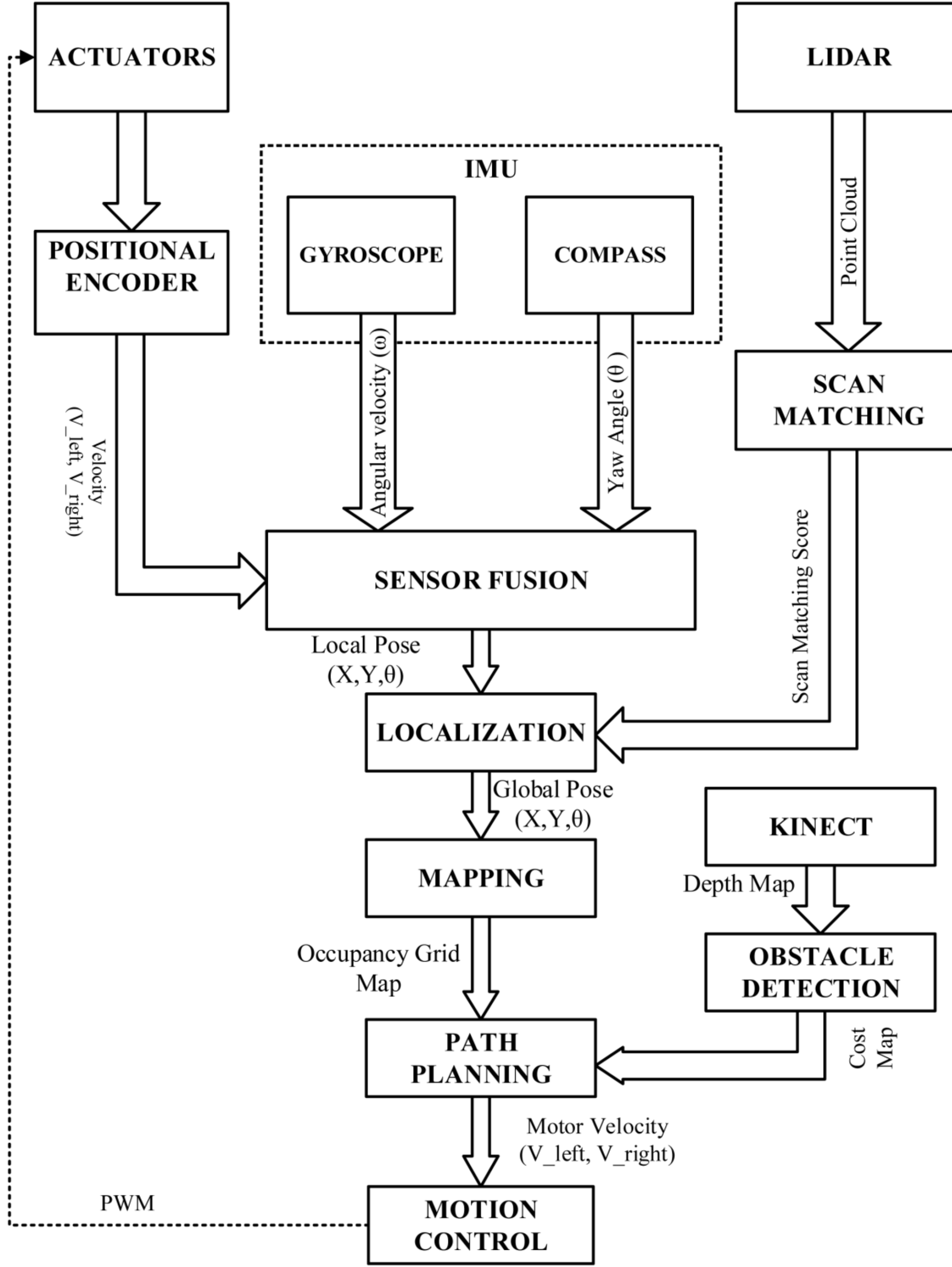
MAPPING

SLAM

PATH PLANNING

MOTION CONTROL

SYSTEM BLOCK DIAGRAM



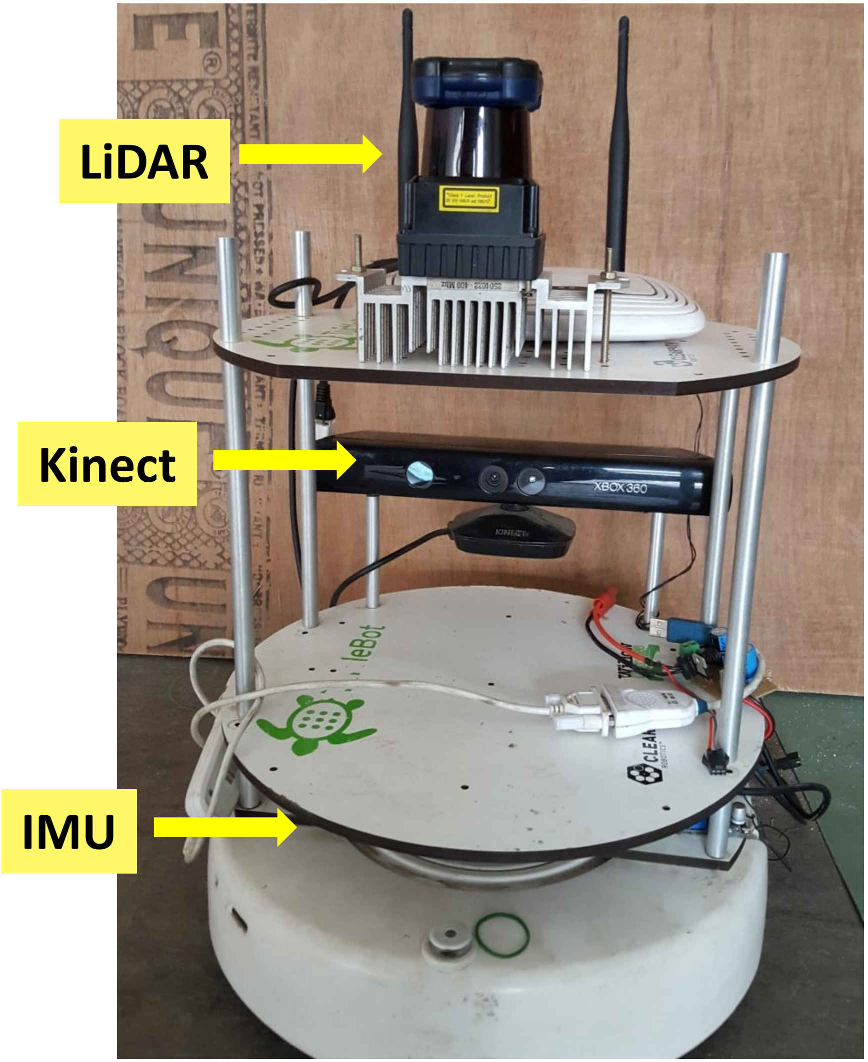
APPLICATIONS

Cleaning with Navigation (left)

Automatic Transportation of load (right)

TOOLS AND PLATFORMS

- **Hardware**
  - Inertial Measurement Unit (IMU)
  - Encoder
  - LiDAR
  - ARM
  - Kinect
- **Software**
  - Robot Operating System (ROS)
  - STM HAL
  - Keil uVision IDE



SENSOR FUSION

- Sources of odometry
  - Encoder + IMU (Gyroscope + Compass)
- Fusion output is corrected orientation and position

Algorithm : Kalman filter

$$x(t-1|t-1) \xrightarrow{predict} \underset{priori}{x(t|t-1)} \xrightarrow[update]{measurent} \underset{posteri}{x(t|t)}$$

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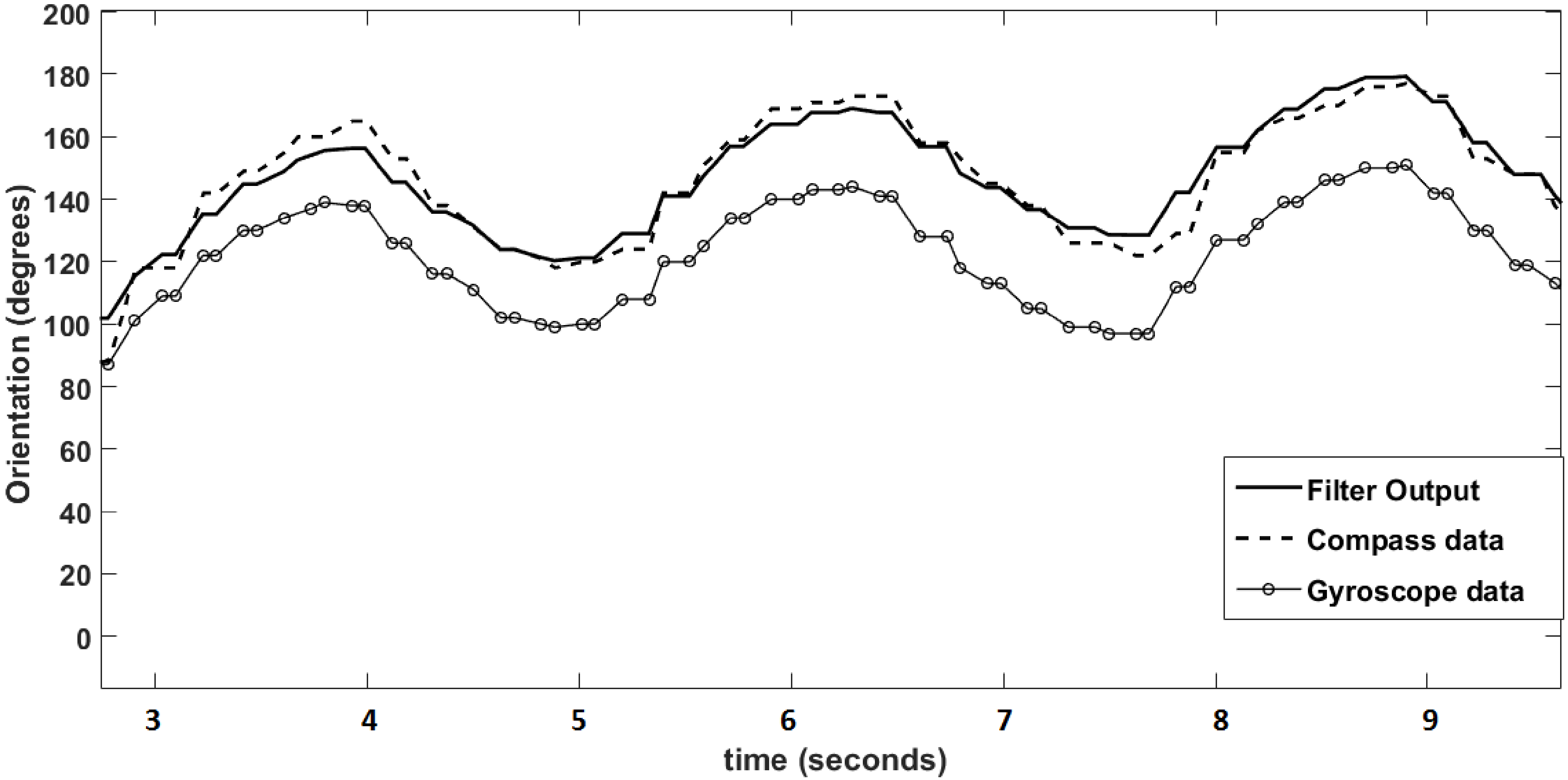
SENSOR FUSION : Kalman Filter



LOCALIZATION

- Positioning the robot in world space.
- Appropriate algorithms to localize using multiple sensors data

Algorithms

- Monte Carlo Localization (MCL)
- Adaptive Monte Carlo Localization(AMCL)

$$p(x_{0:t} \mid u_{1:t}, z_{1:t}, m)$$

Where,

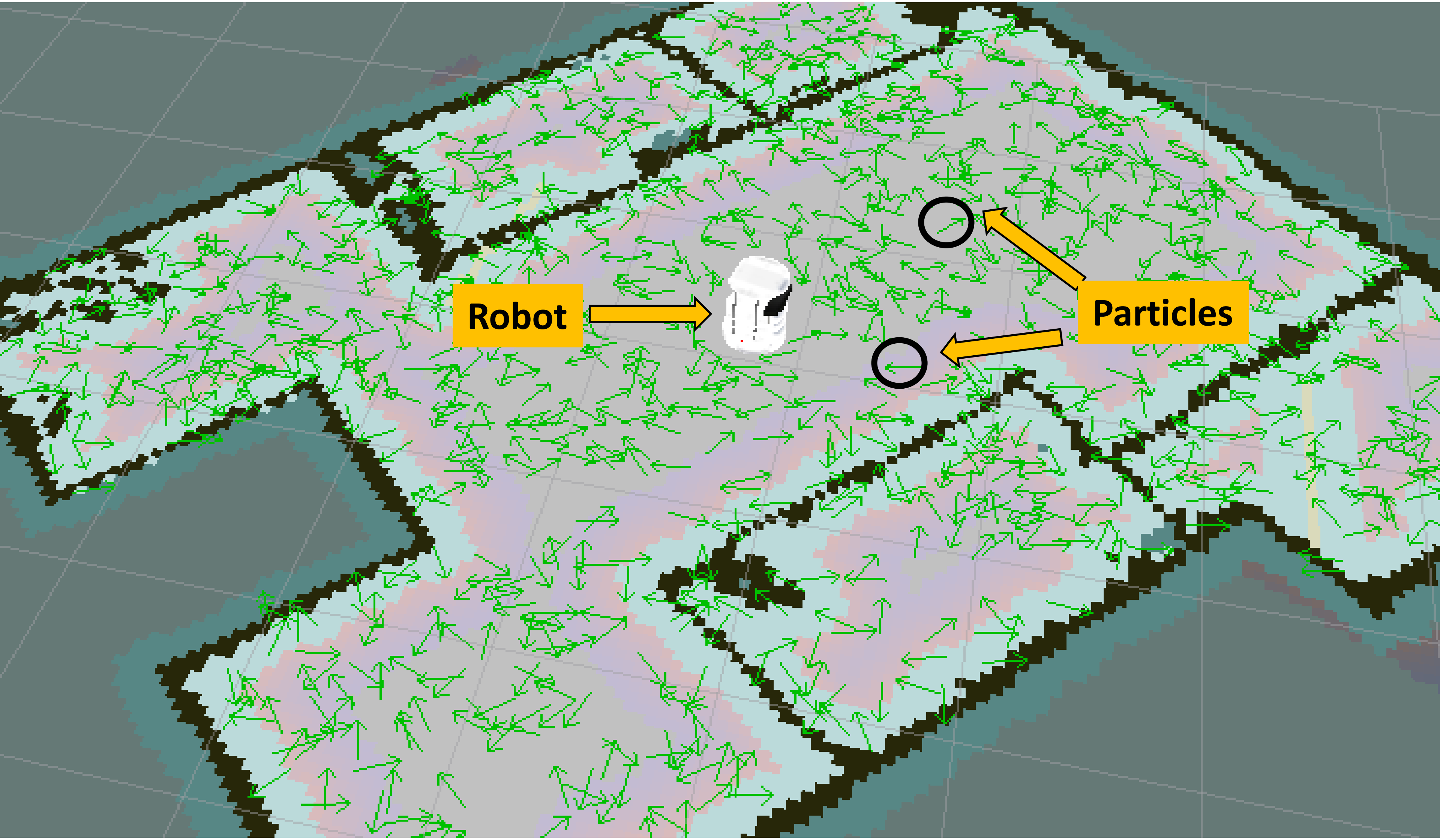
$u_{1:t} = \{u_1, u_2, \ldots, u_t\}$ ➡ Control input

$z_{1:t} = \{z_1, z_2, \ldots, z_t\}$ ➡ Observations

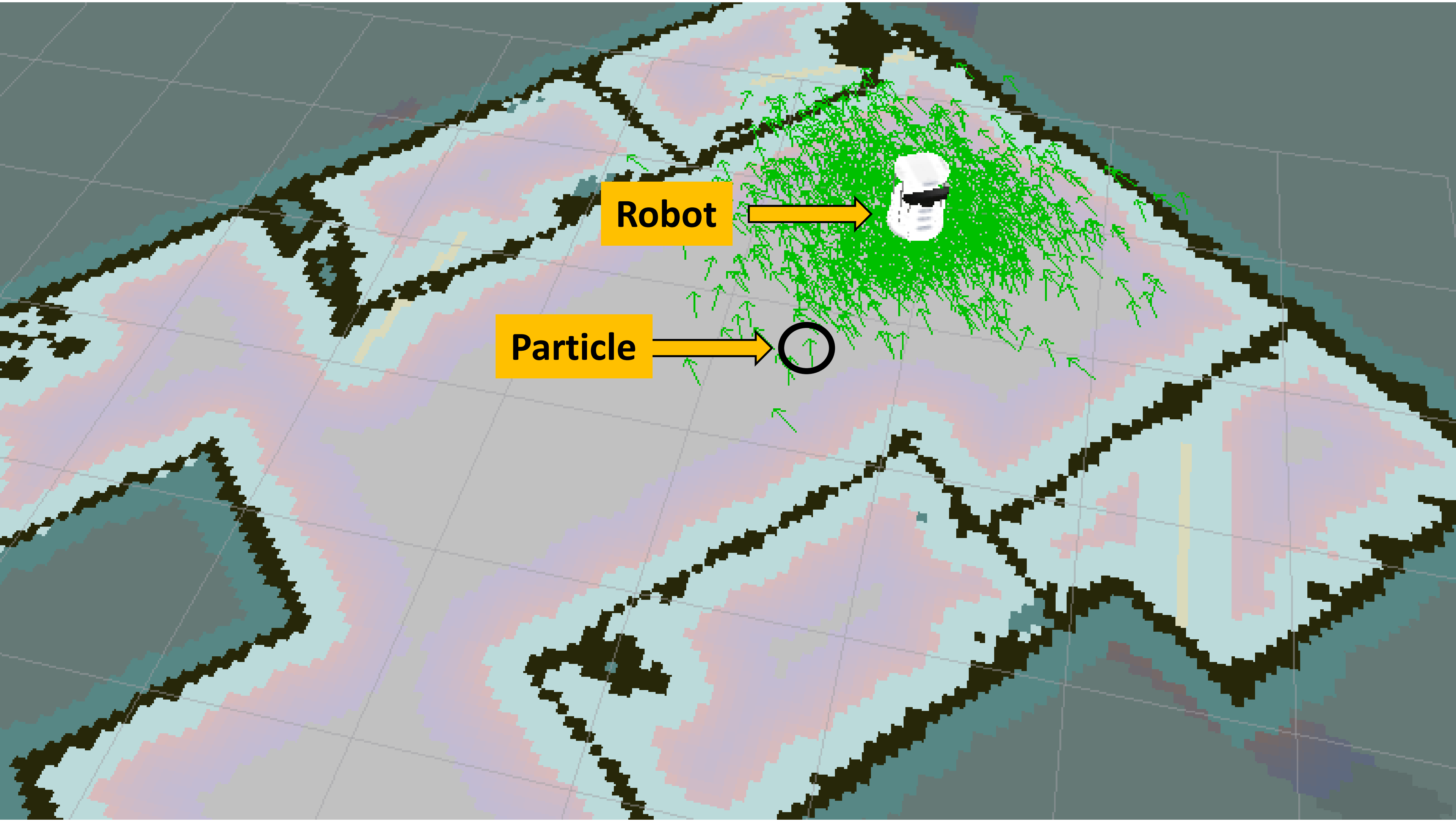
$x_{0:t} = \{x_0, x_1, \ldots, x_t\}$ ➡ Path of the robot

m ➡ Map of the environment

LOCALIZATION : Random Particle Injection



LOCALIZATION : Particle Converges



MAPPING

- Map Development of surrounding
- LiDAR fused with odometry data for reliability

Algorithm : Occupancy Grid Mapping

$$p(m \mid x_{1:t}, z_{1:t})$$

Where,

$z_{1:t} = \{z_1, z_2, \ldots, z_t\}$ ➡ Observations from time 1 to t

$x_{1:t} = \{x_1, x_2, \ldots, x_t\}$ ➡ Positions of the robot

m ➡ Map of the environment

MAPPING : Occupancy Grid Map

- Represents the world in 2048x2048 pixels
- 1 pixel = 0.05x0.05 square meters

Occupied Space

Free Space

Unexplored Space

PATH PLANNING : Global

- Optimum path planning between source and destination
- Graph Search for finding routes

Algorithm : A*

$$f'(n) = g(n) + h(n)$$

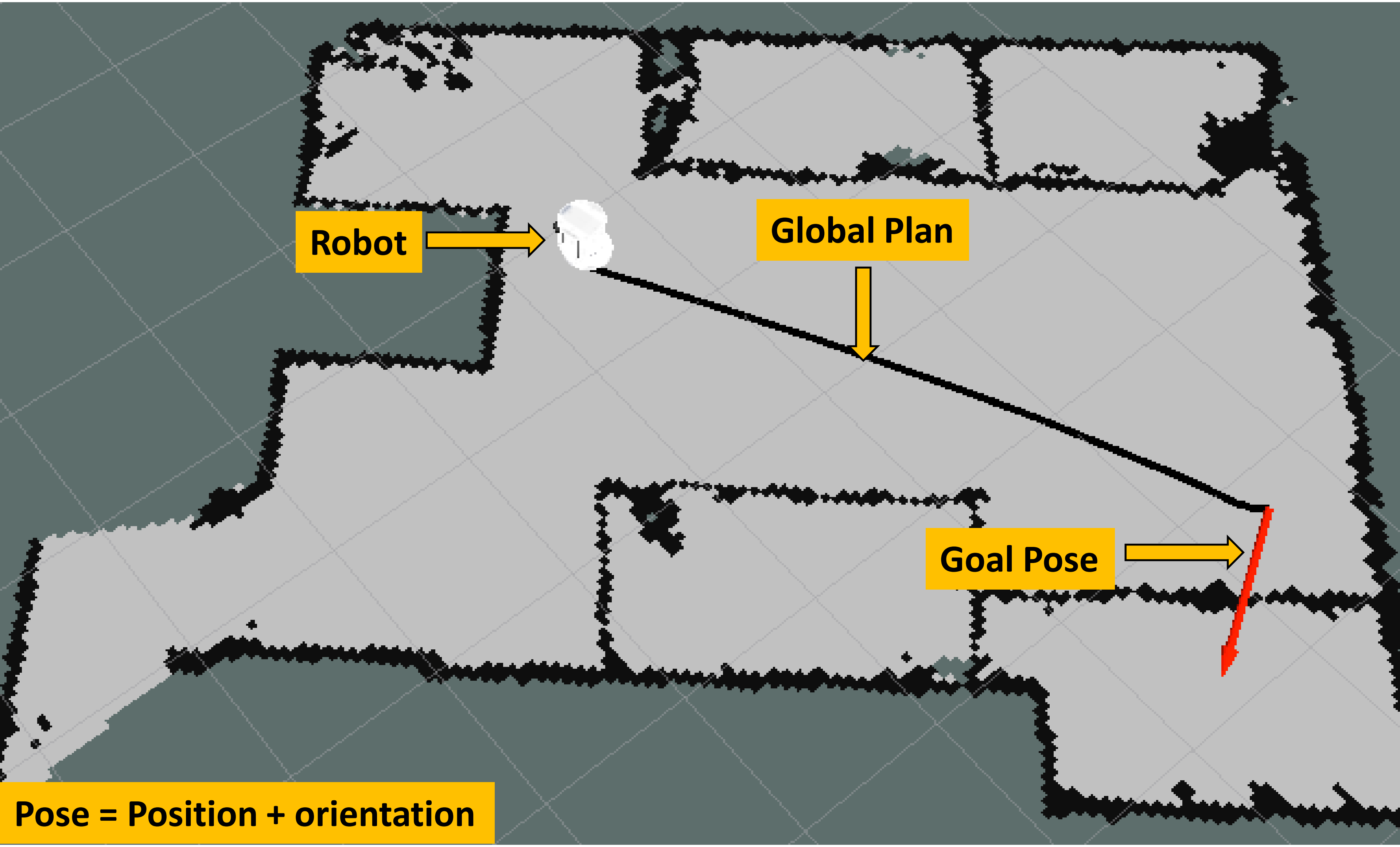
Where,

$f'(n) \rightarrow$ Total cost of node n

$g(n) \rightarrow$ Cost of reaching node n from starting location

$h(n) \rightarrow$ Value of heuristic function at node n

PATH PLANNING : Global



PATH PLANNING : Local

- Execute segments of the Global plan sequentially

Algorithm : Dynamic Window Approach (DWA)

$$O(v,w) = a * heading(v,w) + b * velocity(v,w) + c * clearance(v,w)$$

Where,

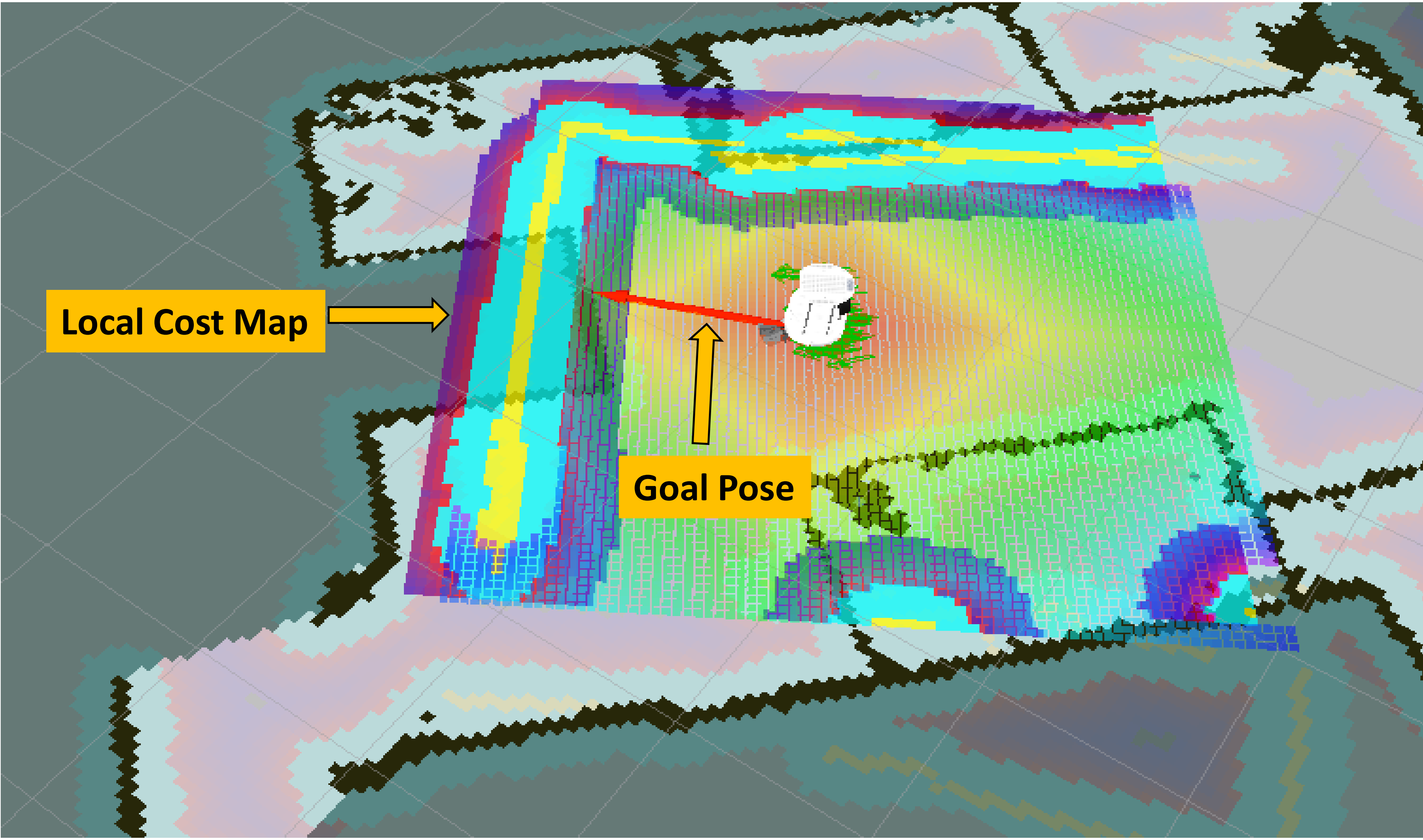
$O(v,w) \longrightarrow$ Objective function for linear velocity *v* and angular velocity *w*

$heading(v,w) \longrightarrow$ Heading towards goal

$clearance(v,w) \longrightarrow$ Clearance from obstacle

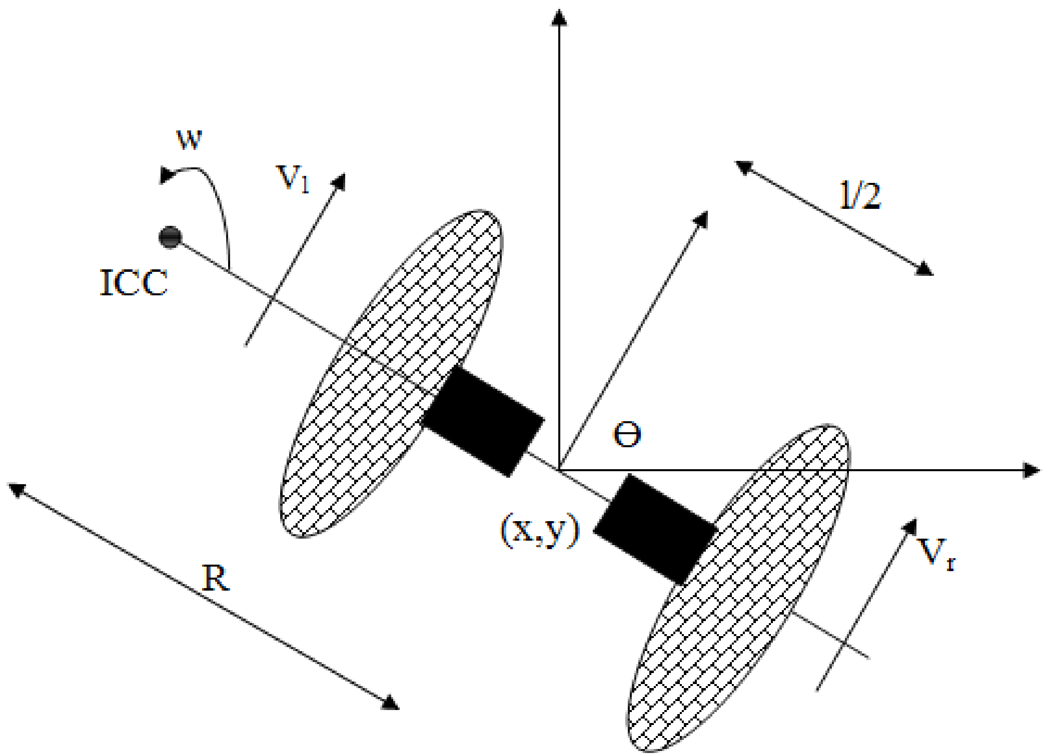
$velocity(v,w) \longrightarrow$ Forward velocity of the robot

PATH PLANNING : Local



MOTION CONTROL : Kinematics

- Differential Drive Kinematics

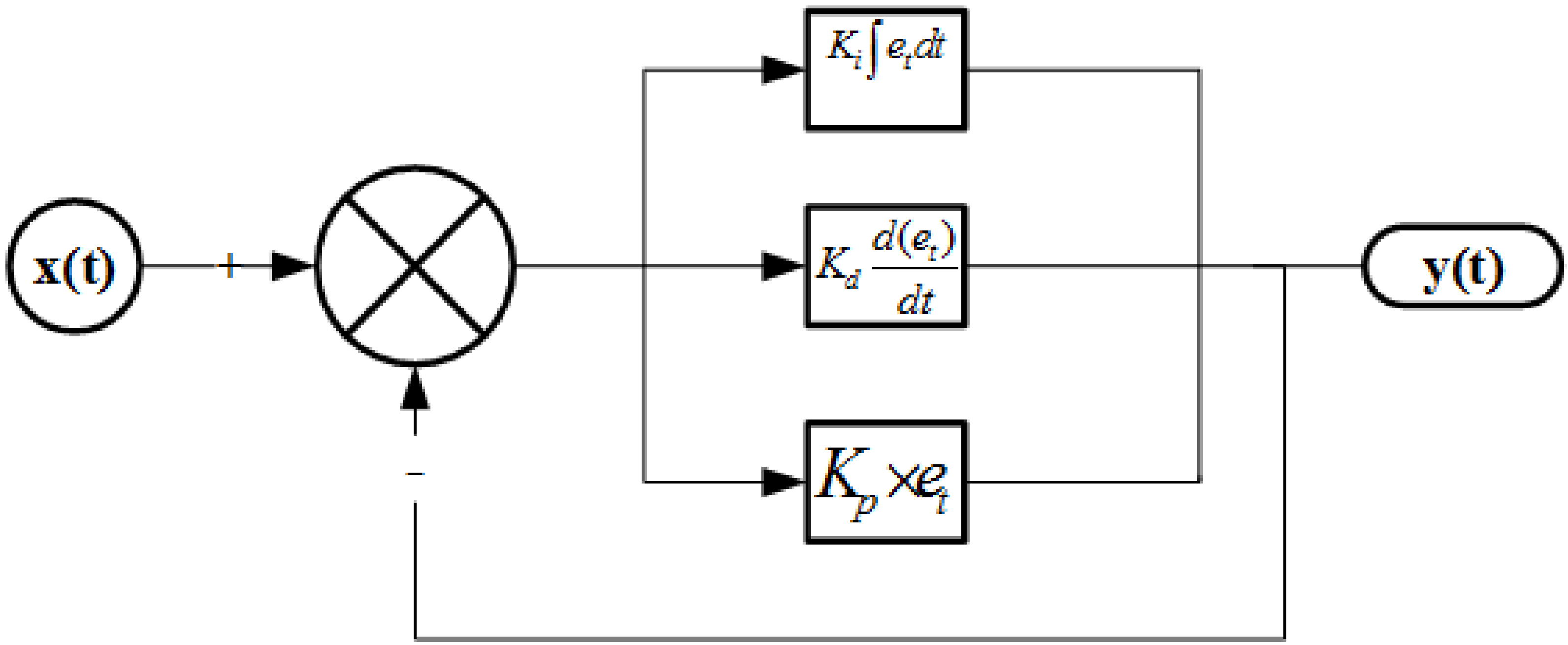


$$w(R + l/2) = V_r$$

$$w(R - l/2) = V_l$$

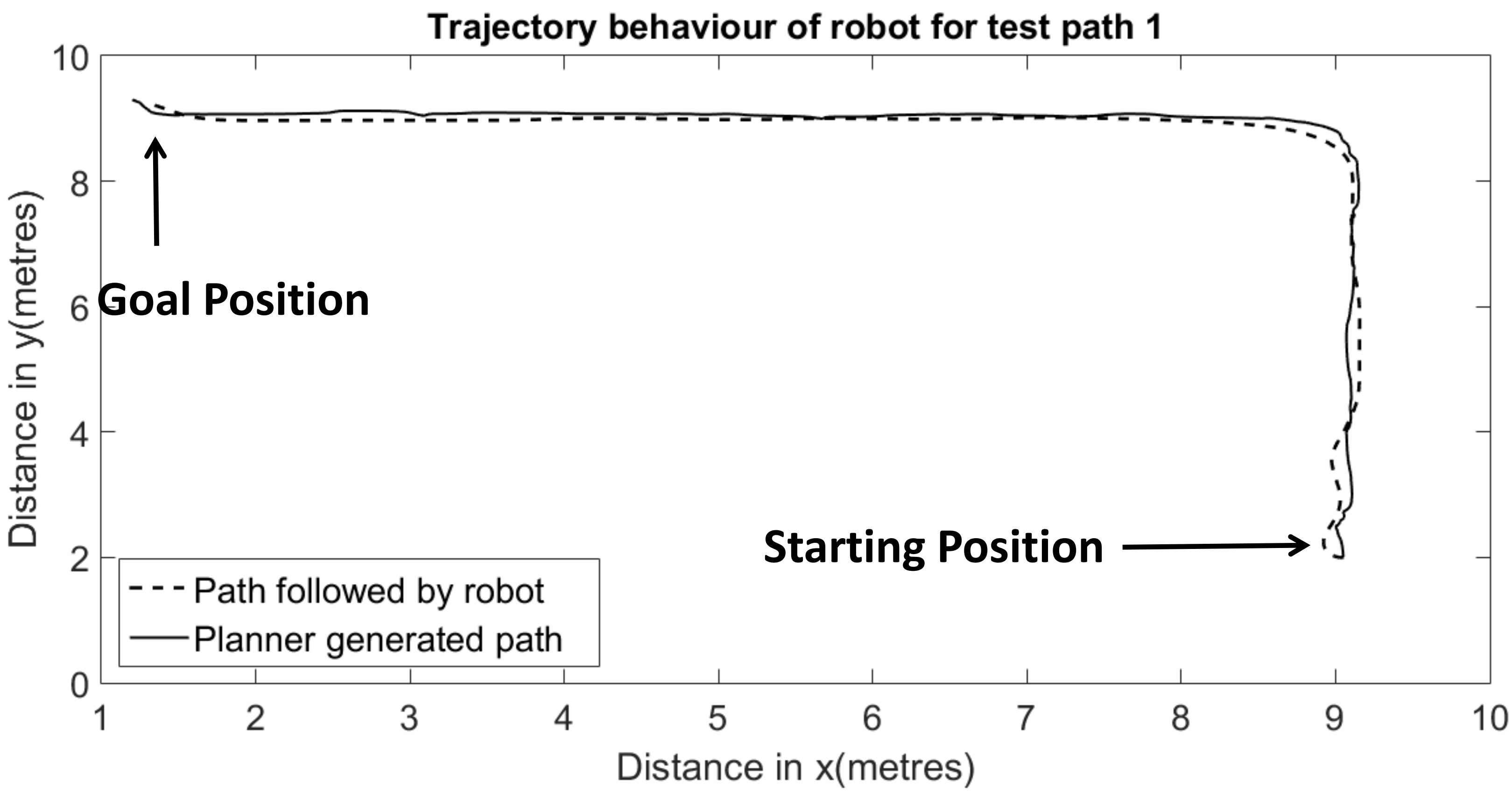
MOTION CONTROL : PID

- PID control on the motors to attain desired velocities



COMPLETE NAVIGATION

- Path Planned and actual trajectory followed by robot



COMPLETE NAVIGATION

Test path	Final Plan position(x_p,y_p)(m)	Final postion of robot(x_r,y_r)(m)	Deviation at goal(m)
1	(1.367,9.194)	(1.346,9.211)	0.027
2	(4.296,1.984)	(4.45,2.05)	0.1675
3	(4.037,3.1)	(3.985,3.054)	0.0694
4	(9.15,4.5)	(9.25,4.38)	0.1562

- Maximum deviation from goal in four experiments = 16.75 cm

CONCLUSION

- Sensor Fusion of IMU data for orientation with 2 degree of maximum error
- Localization with MCL using 500 particles
- Mapping with grid size 2048x2048 and scale: 1 pixel equivalent to 0.05 meters
- Path planning with less than 0.2 meters deviation on final location during navigation

Thank you!...