INTELLIGENT ROBOT GUIDANCE IN FIXED EXTERNAL CAMERA NETWORK FOR NAVIGATION IN CROWDED AND NARROW PASSAGES

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Video Download Information

This entire presentation with narration can be downloaded as video from:

- (40 MB, medium video quality)

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Robots in Ubiquitous Sensor Network

SERVICE ROBOTS


@roomba


@hospi


@southmead


@kinghtscope

Service robot at home and public places are expected to increase in coming years.

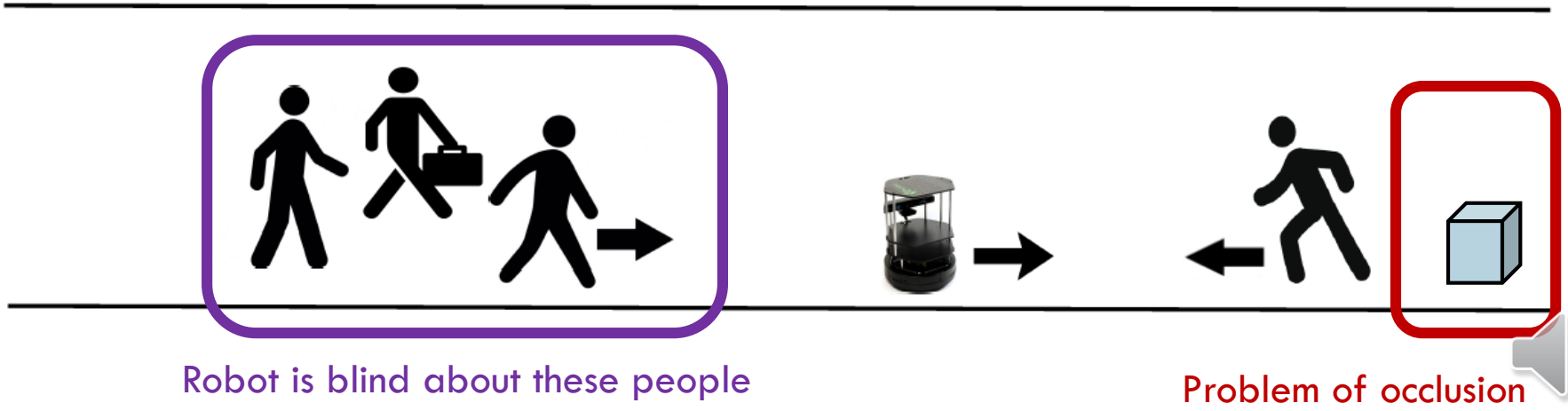
- USN: Collection and utilization of information in real time, and at any-time and any-where

- USN's broad idea:
  - There will be sensors able to exchange information with gateways and
  - Perform assigned tasks

- In coming years, service robots will have to be integrated with USN

Problem 1: Limitation of sensor specs

- Sensors (ex: camera) are mostly 'forward' facing
  - Blind about moving entities on the back side
- Sensors are generally attached at a lower height
  - Blind about far-off obstacles
  - Occlusion causes loss of information

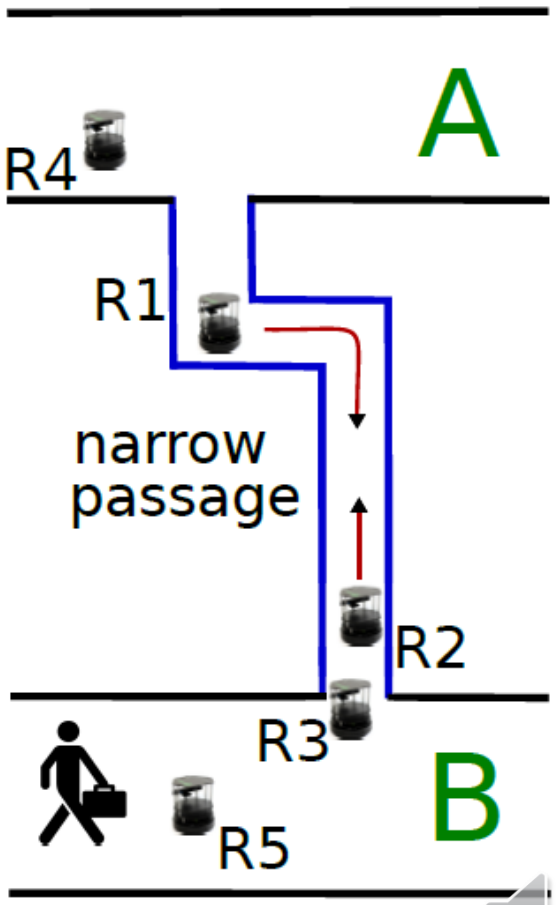


Robot is blind about these people

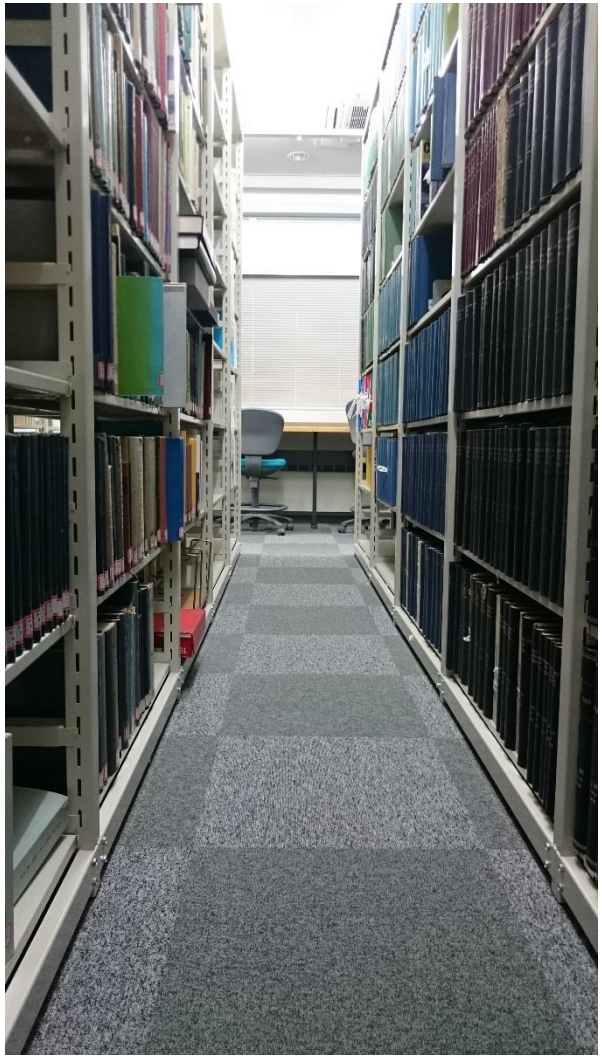
Problem of occlusion

Problem 2: Deadlock in narrow passages

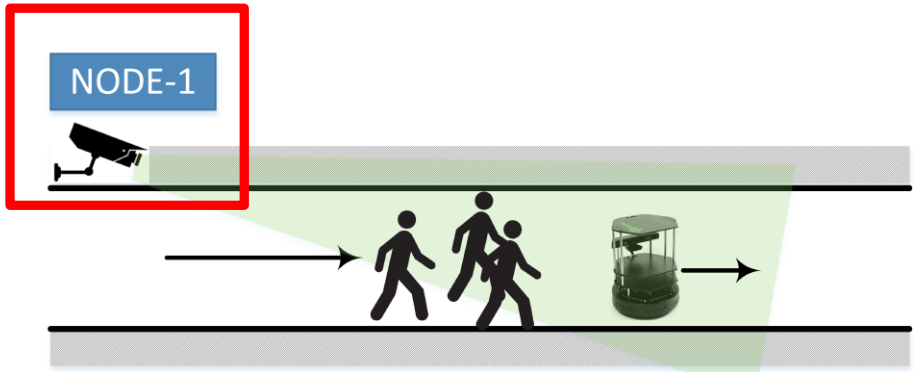
- There are narrow passages in warehouses, libraries, etc.
- Multiple robots cannot simultaneously access narrow passages
  - Causes deadlock
- Requires intelligent resource sharing and conflict resolve
  - Must consider factors like robot's task priority, battery life, …
  - Intelligent path planning



Example of a narrow passages in library

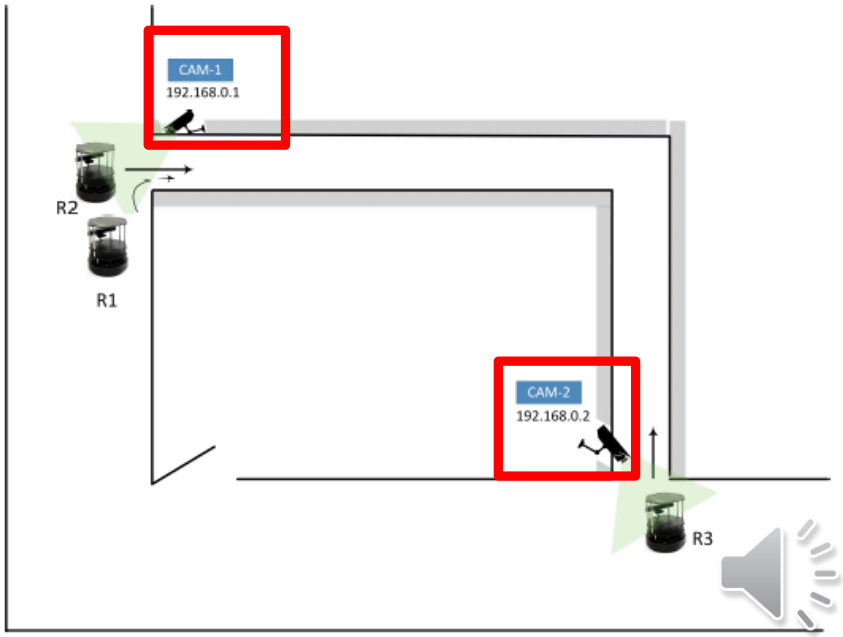


Idea: Robots access external camera info



- Provides a birds-eye view
- Robot is no longer constrained by sensor spec

- A resource allocator can be designed using ubiquitous robot location information



Power Estimation and Task Priority

Power Estimator

$$P_i = P_{\text{before } i^{\text{th}} \text{ task}} - P_{\text{after } i^{\text{th}} \text{ task}}.$$

$$P_{E(x)} = \frac{1}{N} \sum_{i=1}^{N} P_{T(x_i)}).$$

Table 1: Database of Task and Actual Power Consumed

Task ID (T_i)	Power Consumed (P_i)
T_1	P_1
T_2	P_2
T_1	P_3
T_3	P_4
$\vdots$	$\vdots$
T_1	P_5

DB

Total power for multiple tasks:

$$P_{total} = \sum_{i=1}^{m} P_{T(i)}.$$

Table 2: Mapping Tasks and Task Priority

Task	Task ID (T_i)	Task Priority (T_p)
Surveillance	T_1	10
Cleaning	T_2	3
Delivery	T_3	8
Patrolling	T_4	9
$\vdots$	$\vdots$	$\vdots$
Others	T_5	5

Modified Priority Queue

- Request from robot comes as $\{R_i : \Lambda_i\}$ pair, where

$$\Lambda_i = \{T_{pi}, P_{li}, X_{ri}, Y_{ri}\}.$$

$$\text{Priority Score} = \left(\frac{1}{\text{Power Left}}\right) \times \text{Task Priority}$$

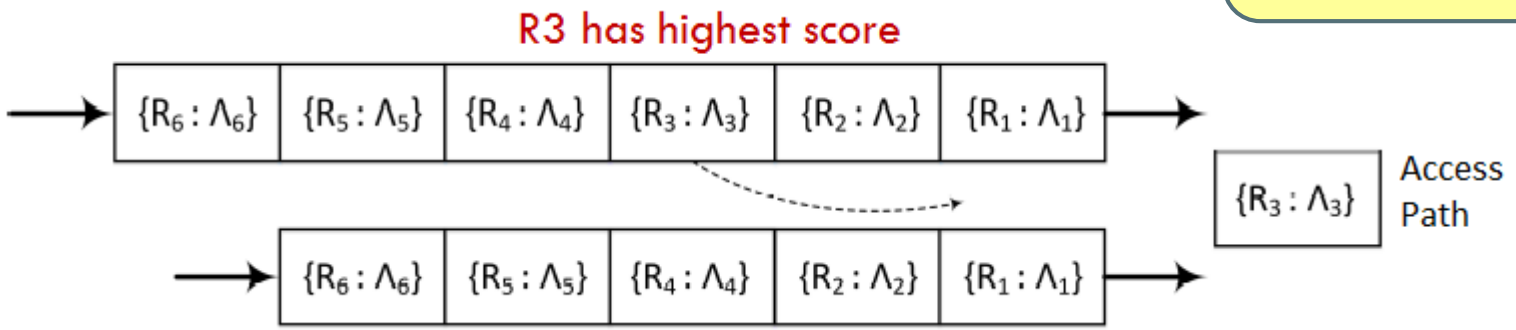
$$= \left(W_P \cdot \frac{1}{P_{ln}}\right) \times W_T \cdot T_{pn}$$

$$\text{Score, } S = \begin{cases} \infty, & \text{if } P_{ln} \le P_{TH} \\ \left(W_P \cdot \frac{1}{P_{ln}}\right) \times W_T \cdot T_{pn}, & \text{otherwise} \end{cases}$$

Emergency

- R_i: Robot ID
- T_i: Task Priority
- P_i: Current Power Level
- X_i: Current X Coordinate
- Y_i : Current X Coordinate

- W_P: Power Weight
- W_T: Task Priority Weight
- P_{TH}: Threshold Power



JSON Request Example

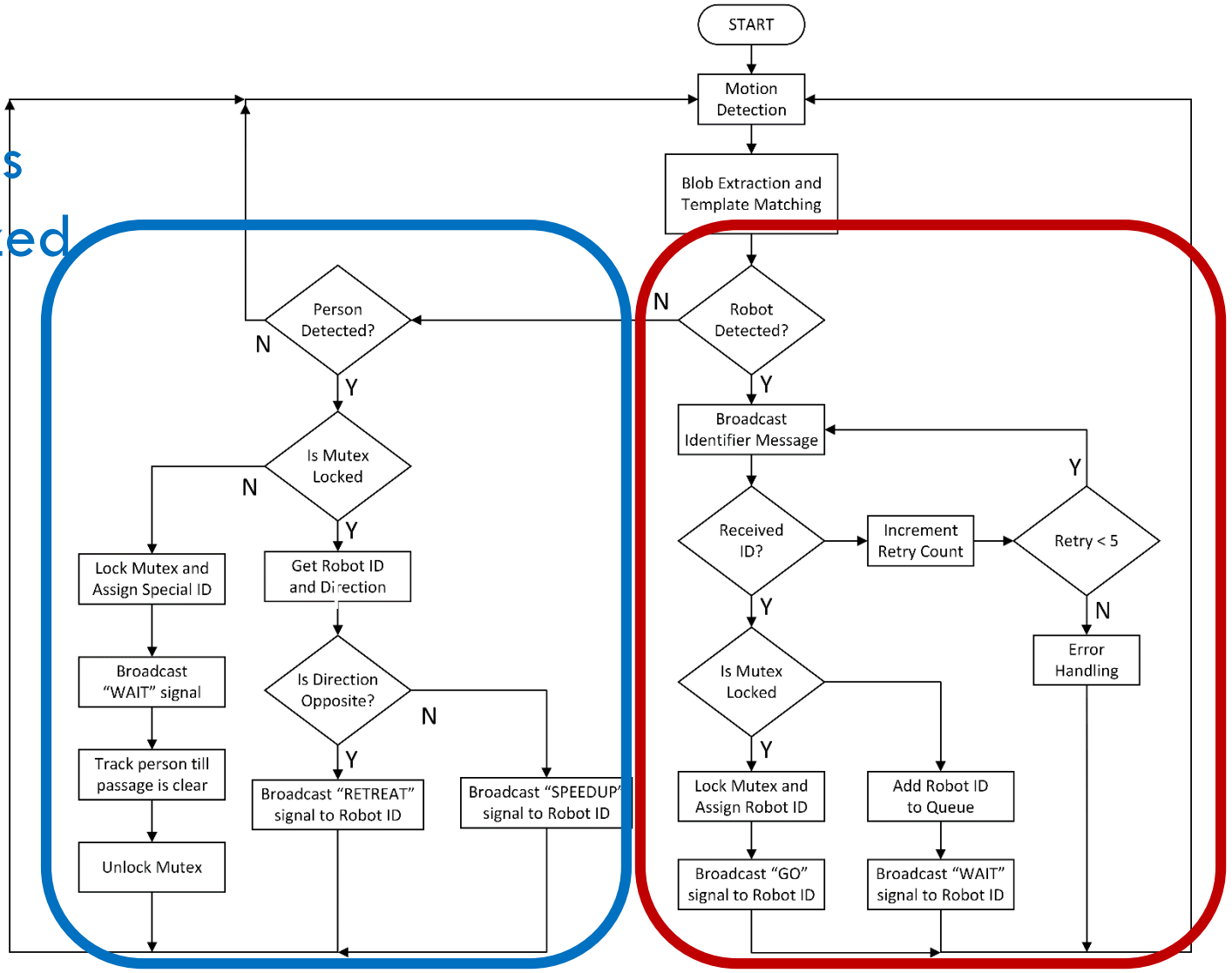
Listing 1: An Example of Robot's Request in JSON Format

```
1 {"NodeMsg": {          // node message
2 "robotID": "03",       // id of trigger node
3 "time": "<timestamp>",// unix timestamp
4 "pathID": "AtoB",      // ID of the path to access
5 "params": [            // Robot's parameters
6 {"power":"<value>"},   // Power Remaining
7 {"taskID": "1"},       // ID of the task in operation
8 {···}]                  // other parameters
9 }}
```

Both Robot and Camera Nodes have a JSON parser

Flowchart of Path Allocation

Person is prioritized



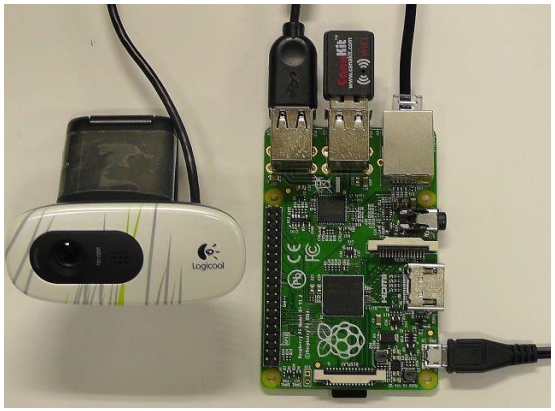
Experiment Setup

Sensors and System

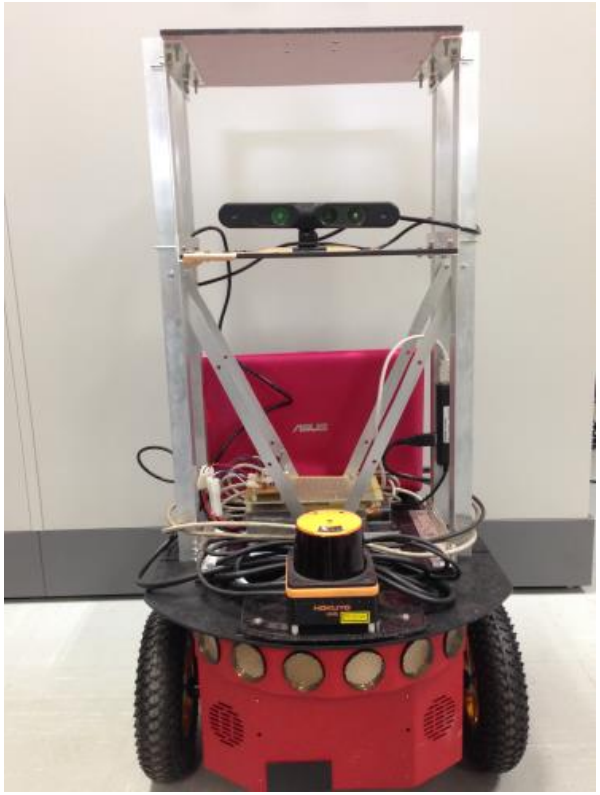
- Microsoft Kinect Sensor
- UHG08LX LRF
- Robot Operating System
- Ubuntu 14.04 OS

SLAM

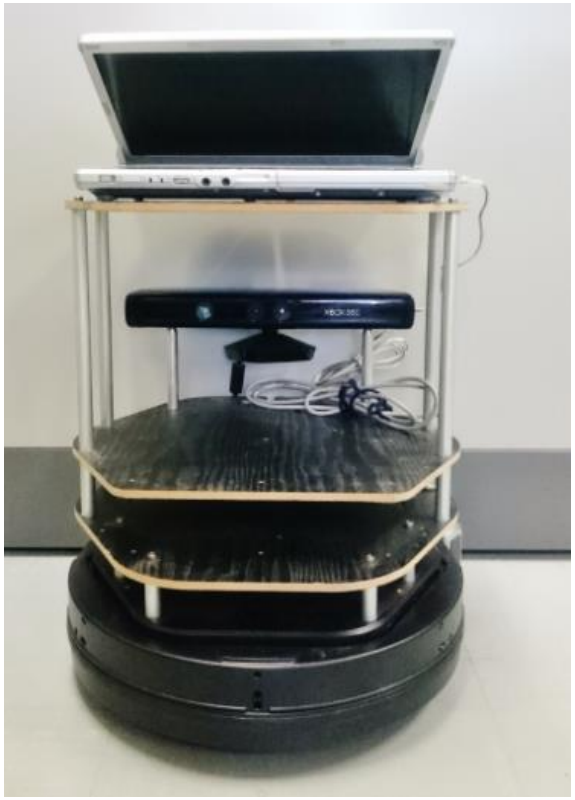
- Mapping: Grid Mapping
- Localization: Particle Filter



Raspberry Pi + Camera

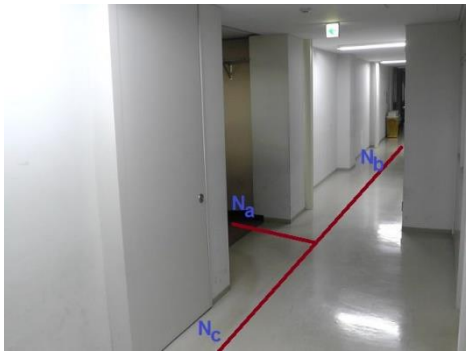


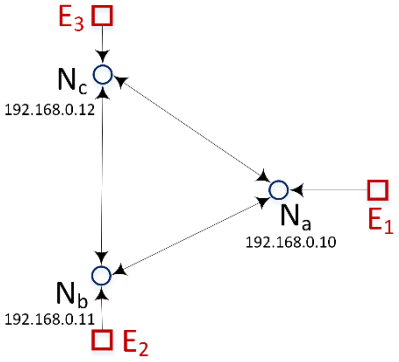
Pioneer P3-DX



Turtlebot

Results: Narrow Path Sharing





(a) (b) (c) (d)

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Results:

Robot-view vs External Camera-view

(a)

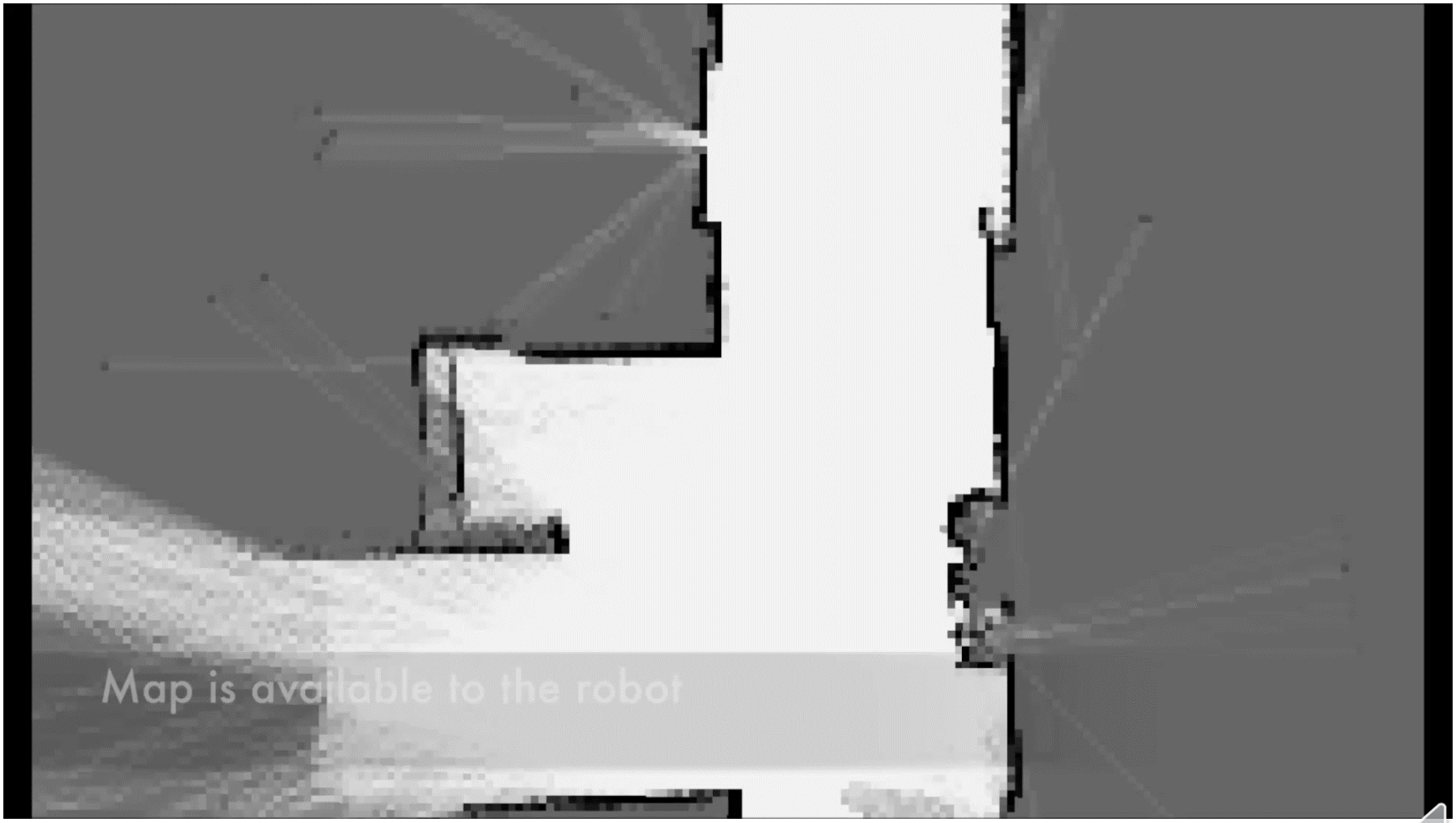
Robot's camera-view

(b)

External camera-view

Assumption: Map Available. Robots Localize

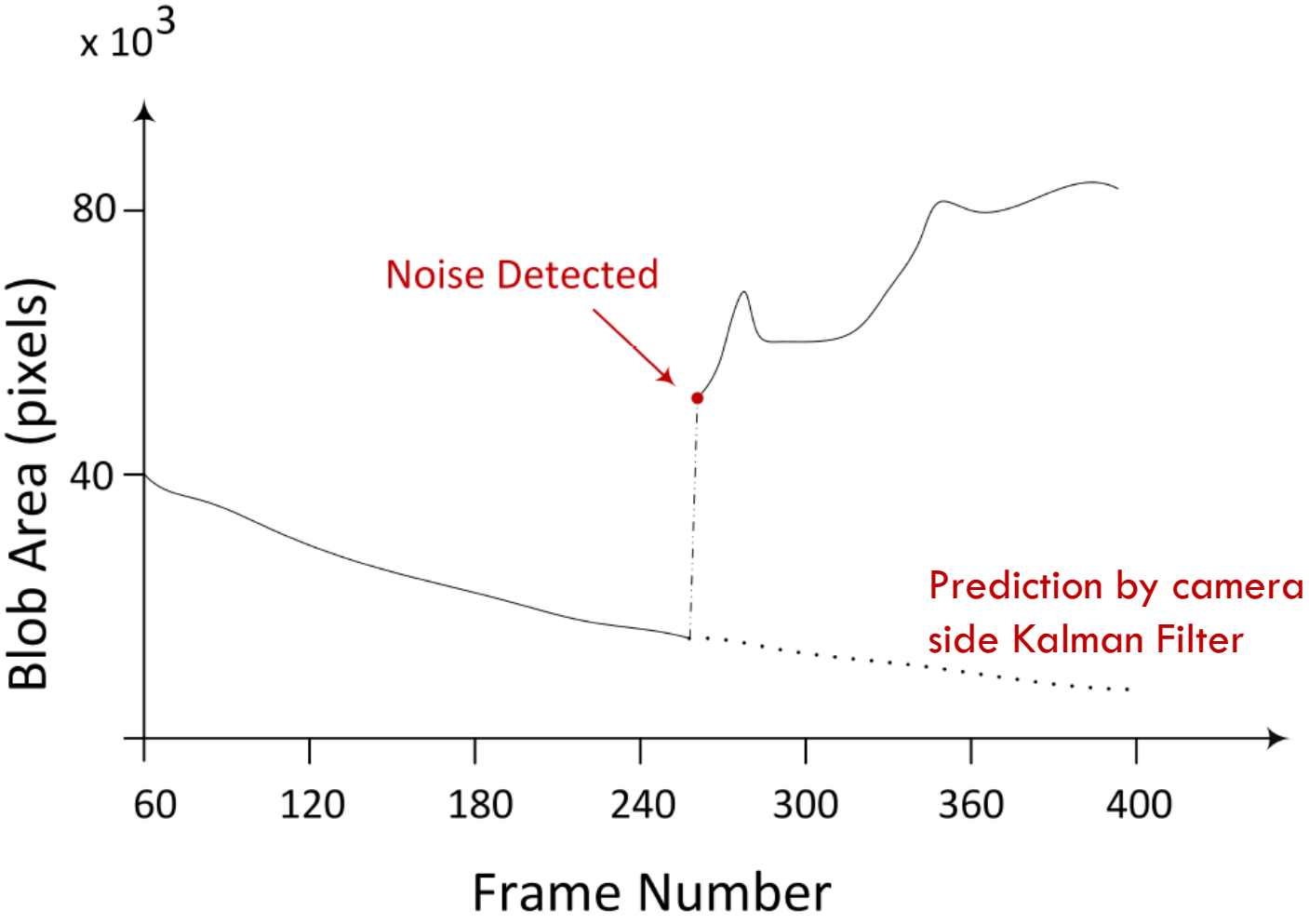
VIDEO



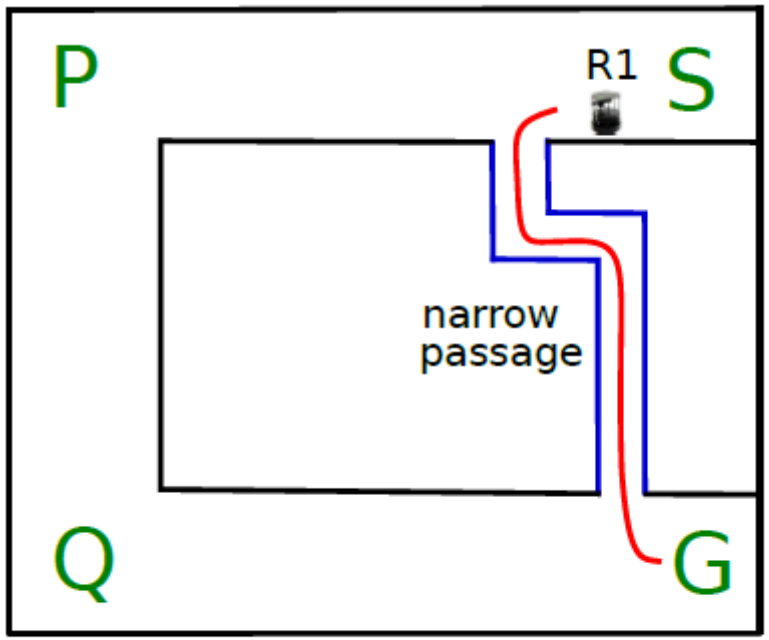
Results: Utilizing External Cam Info

VIDEO

Robot's Position Estimation in Occlusion

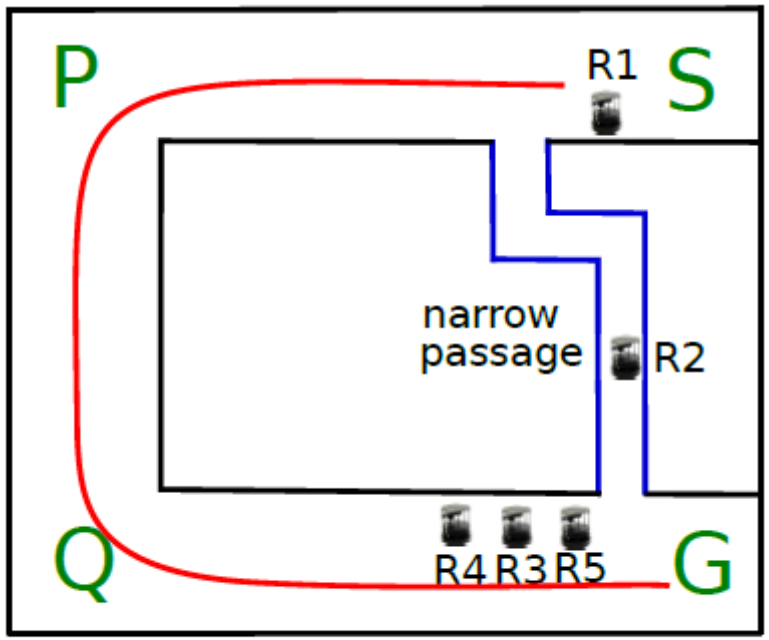


Intelligent Path Planning



(a)

Shortest path via narrow passage



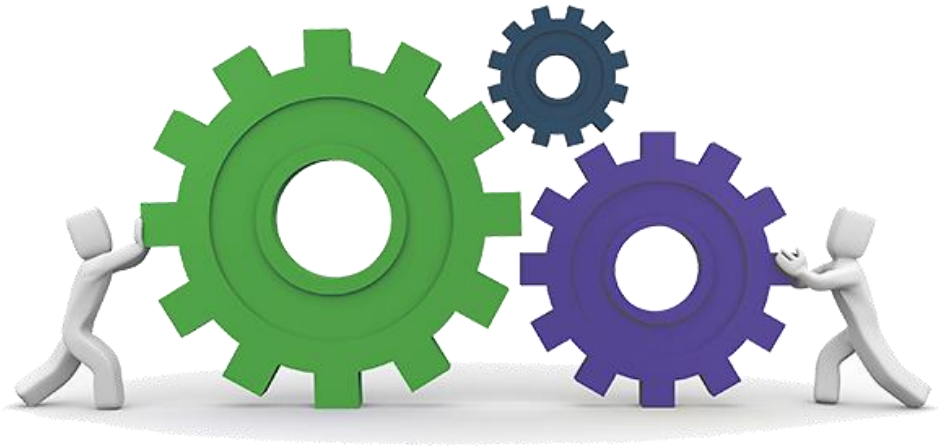
(b)

Many waiting robots. Taking alternate long path is more efficient

Conclusion and Discussion

- External camera sensor network can provide a lot of relevant information to the robots to do their tasks efficiently.
- Robots can plan better trajectories and plan optimal paths towards their goal.
- It's feasible to design a resource allocator in such sensor network. Resource is not limited to narrow path & can be extended to other resources like docking/charging points.
- External camera N/W can provide remote information to robots to perform tasks with better efficiency.

THANK YOU



Questions, Comments & Research Collaborations

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