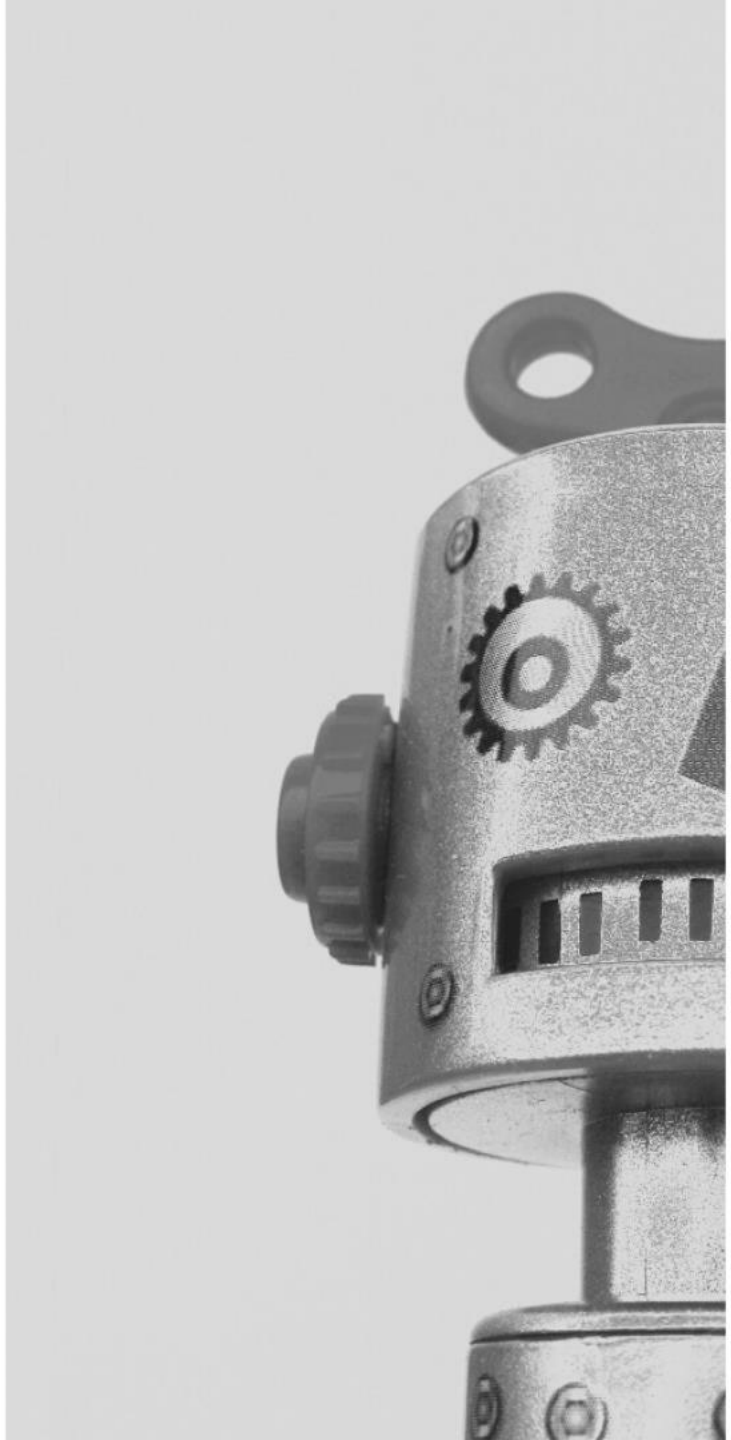
By robotcitizen



Mapping and Navigation

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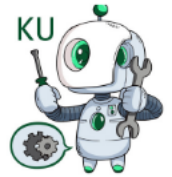
OVERVIEW



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Mapping and Navigation Concept

- Understanding the mapping and navigation concept
- Setup Software Environment

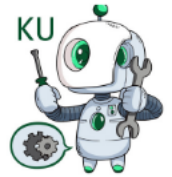
Creating a Map

- SLAM
- Creating a map with slam gmapping package
- Save the map and Spawn the robot

Navigation and Autonomous driving

- AMCL Localization
- Install and testing Kinect (3D sensor)
- Autonomous driving with a simple program

Mapping and Navigation Concept



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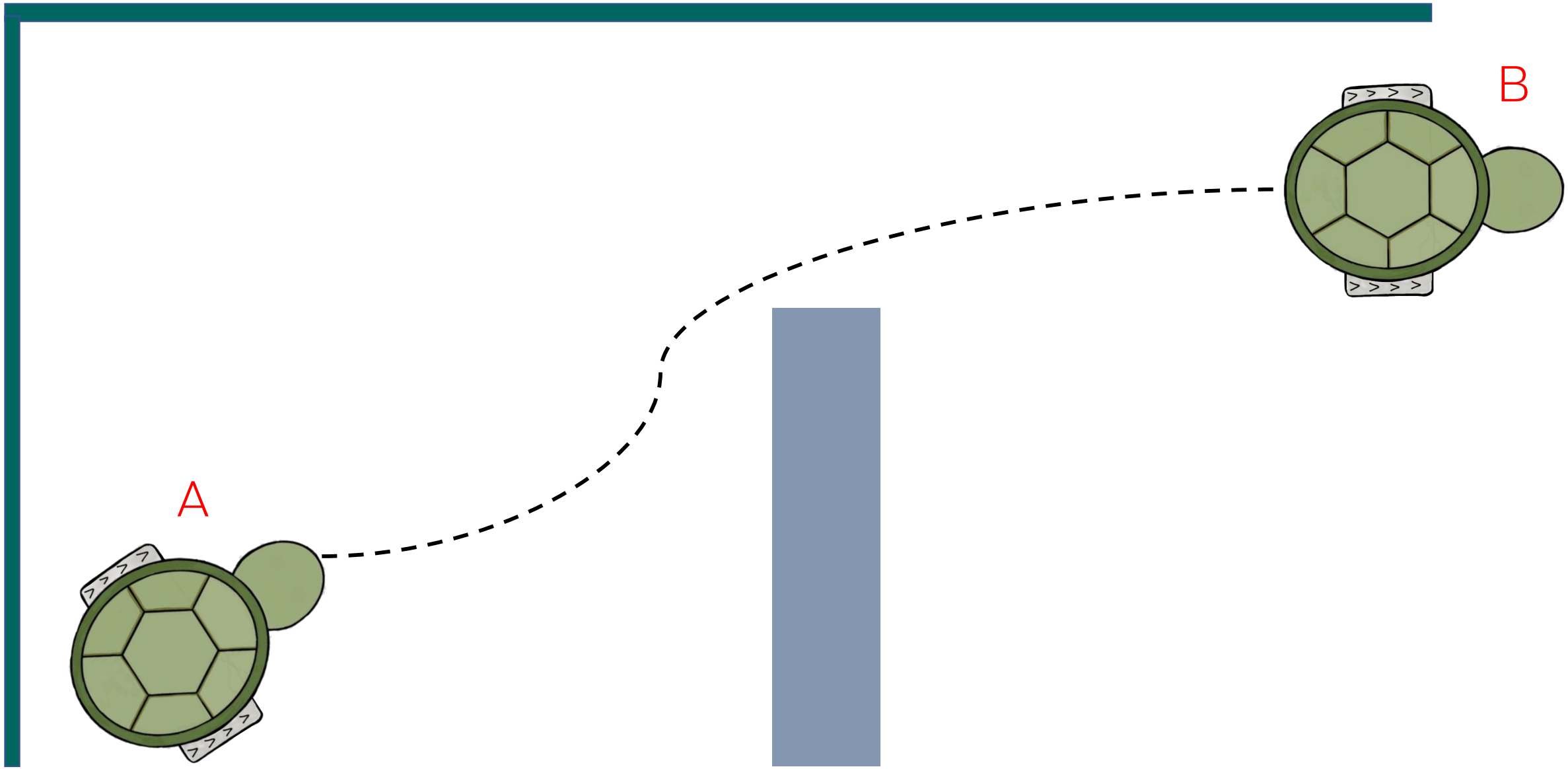
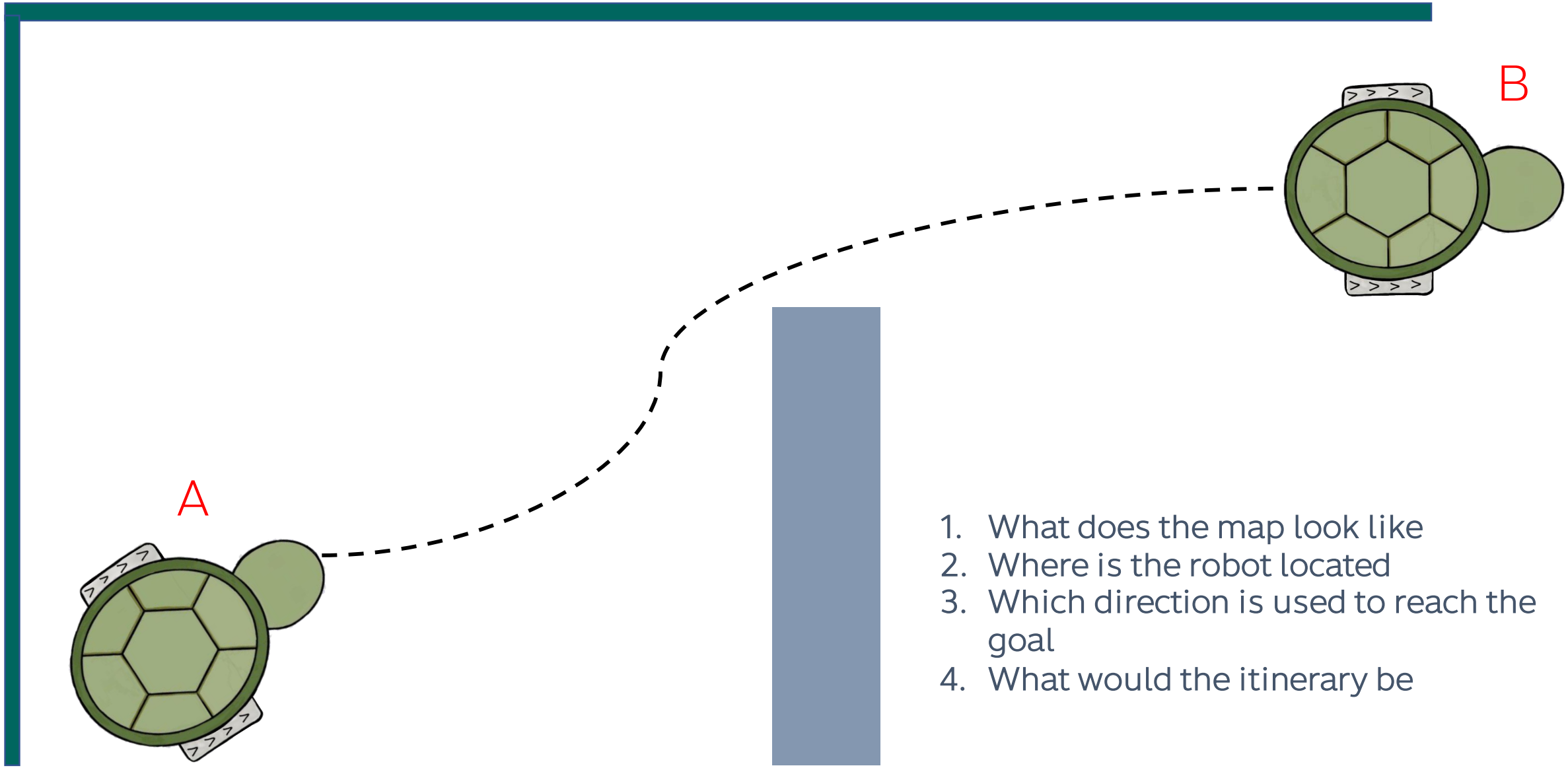
Mapping and Navigation Concept



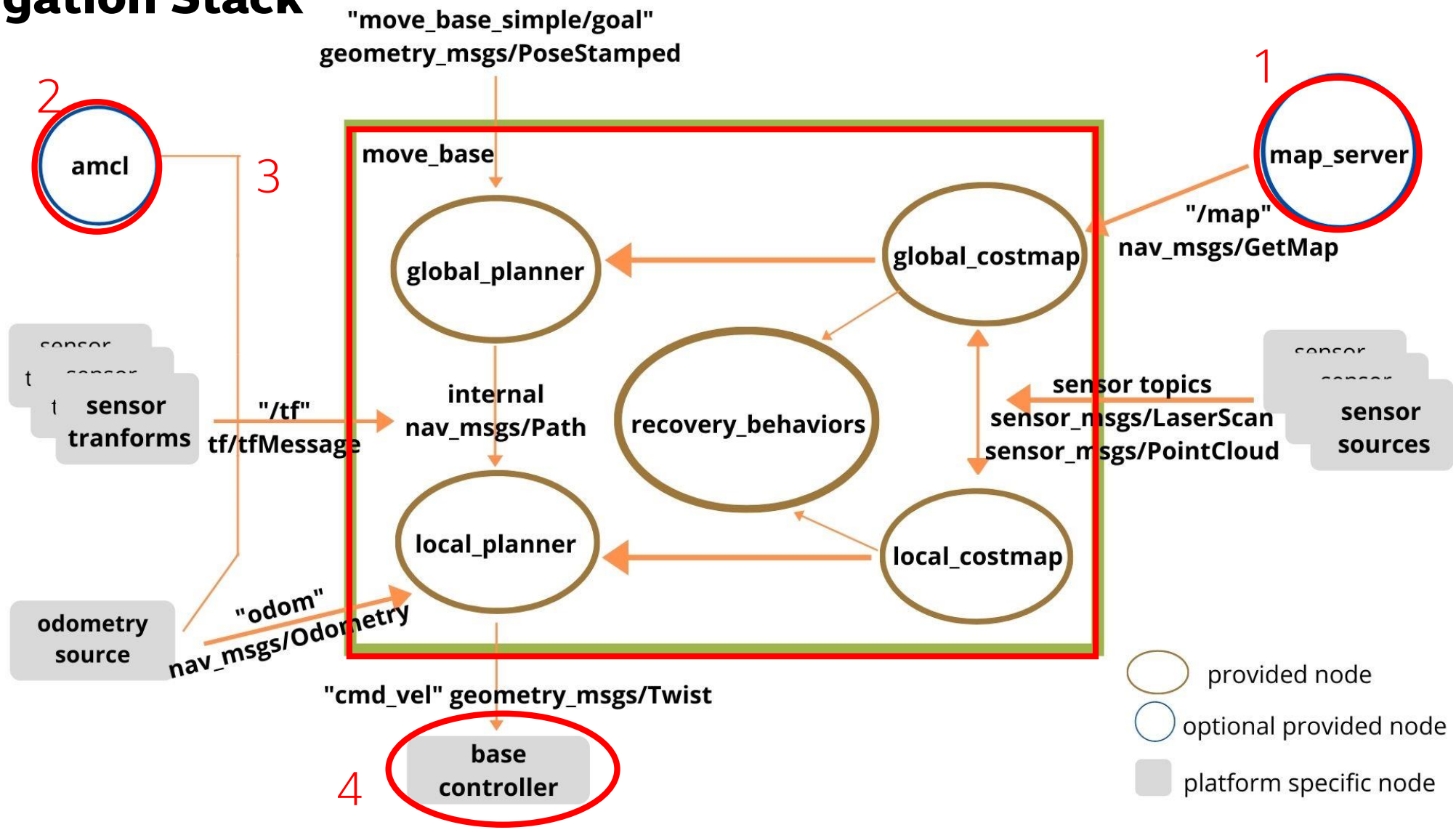
Mapping and Navigation Concept



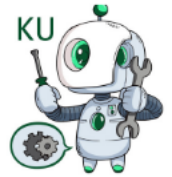
1. What does the map look like
2. Where is the robot located
3. Which direction is used to reach the goal
4. What would the itinerary be

Mapping and Navigation Concept

ROS Navigation Stack



Creating a Map



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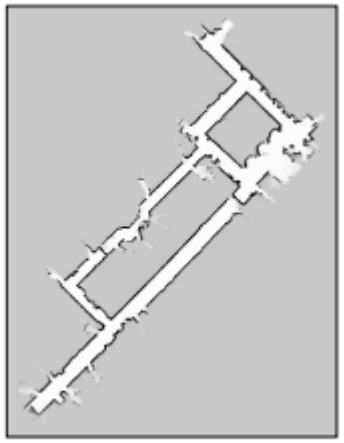
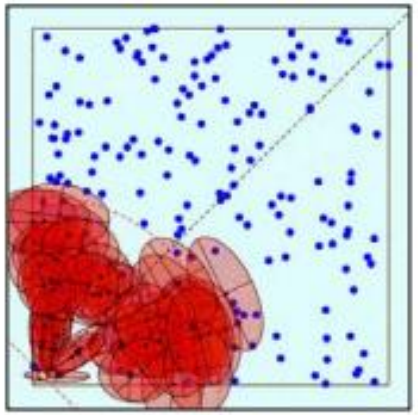
Creating a Map (SLAM Concept)

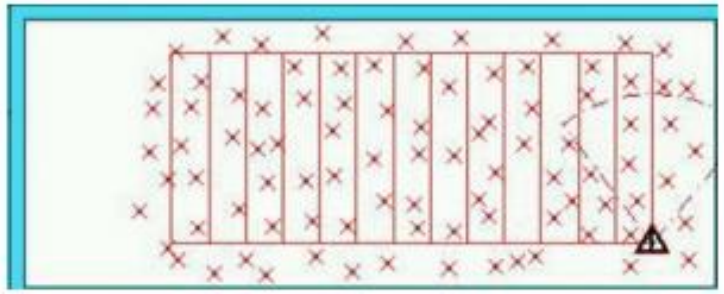
Map Representations in Robotics

- Grid maps or scans, 2d, 3d



- Landmark-based





Ref: Introduction to Mobile Robotics (engl.) - Autonomous Mobile System at University of Freiburg

Creating a Map (With Known Poses)

- Normally, mapping with known poses involves, given the measurements and the poses

$$d = \{x_1, z_1, x_2, z_2, \ldots, x_t, z_t\}$$

- To calculate the most likely map

$$m^\star = \text{argmax}_m P(m \mid d)$$

Creating a Map (With Known Poses)

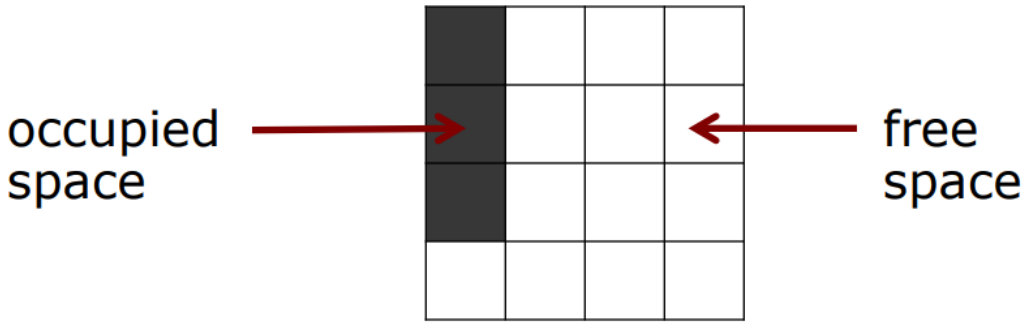
Grid Maps

- We discretize the world into cells
- The grid structure is rigid
- Each cell is assumed to be occupied or free
- It is a non-parametric model
- It requires substantial memory resources
- It does not rely on a feature detector

Creating a Map (With Known Poses)

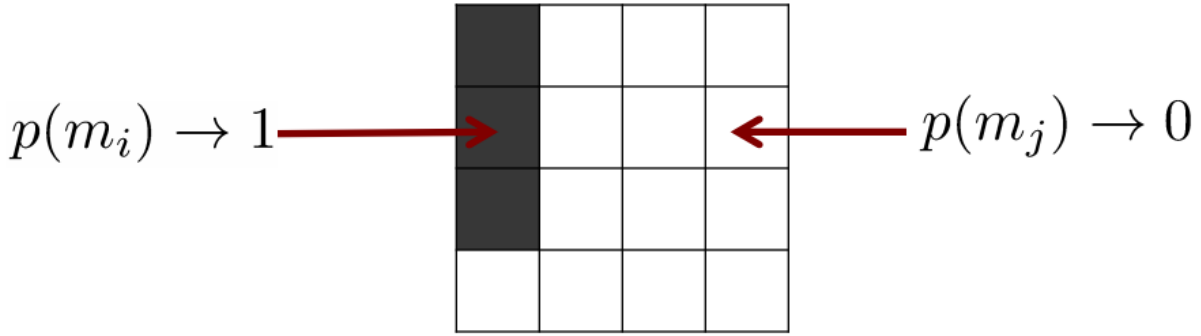
Assumption 1

- The area that corresponds to a cell is either completely free or occupied



Representation

- Each cell is a binary random variable that models the occupancy

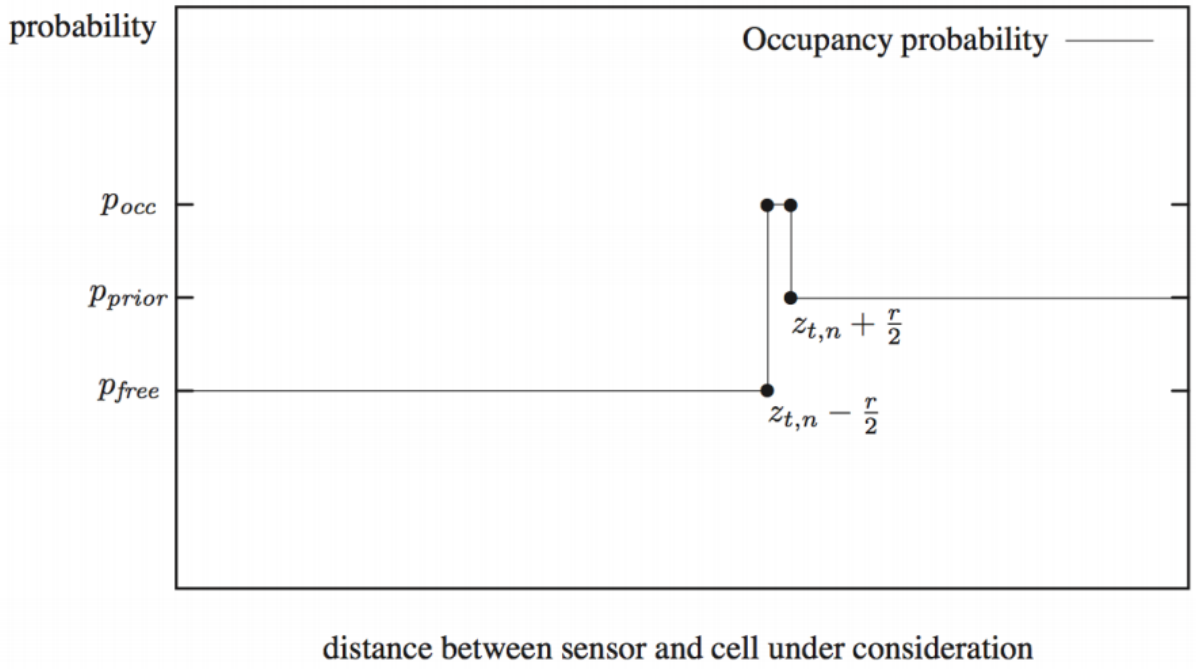


Creating a Map (With Known Poses)

Occupancy Probability

- Each cell is a binary random variable that models the occupancy
- Cell is occupied $p(m_i) = 1$
- Cell is not occupied $p(m_i) = 0$
- No information $p(m_i) = 0.5$
- The environment is assumed to be static

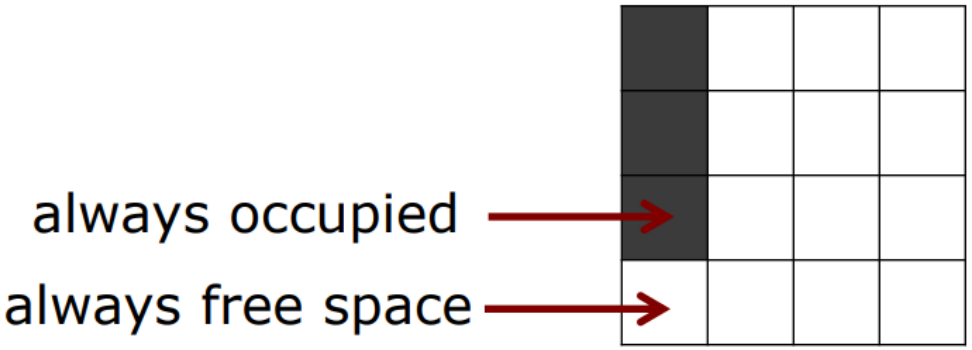
Inverse Sensor Model for Laser Range Finders



Creating a Map (With Known Poses)

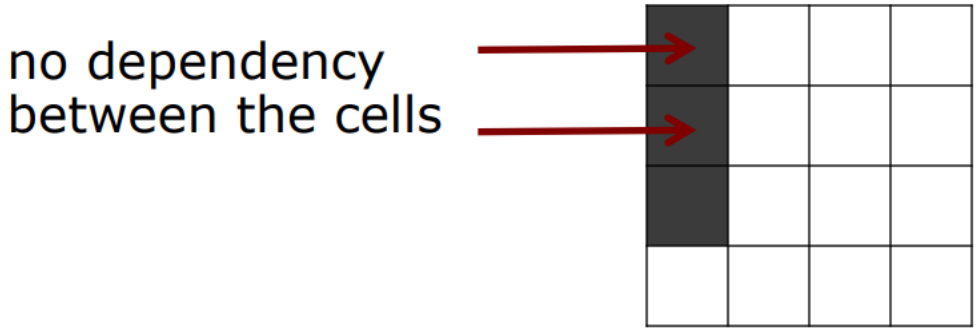
Assumption 2

- The world is static (most mapping systems make this assumption)



Assumption 3

- The cells (the random variables) are independent of each other



Creating a Map (With Known Poses)

Representation

- The probability distribution of the map is given by the product over the cells

$$p(m) = \prod_i p(m_i)$$

example map
(4-dim state)

4 individual cells

Estimating a Map From Data

- Given sensor data $z_{1:t}$ and the poses $x_{1:t}$ of the sensor, estimate the map

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

binary random variable

➡ Binary Bayes filter
(for a static state)

Creating a Map (With Known Poses)

Log Odds Notation

- The log odds notation computes the logarithm of the ratio of probabilities

$$\frac{p(m_i \mid z_{1:t}, x_{1:t})}{1 - p(m_i \mid z_{1:t}, x_{1:t})}$$

$$= \underbrace{\frac{p(m_i \mid z_t, x_t)}{1 - p(m_i \mid z_t, x_t)}}_{\text{uses } z_t} \underbrace{\frac{p(m_i \mid z_{1:t-1}, x_{1:t-1})}{1 - p(m_i \mid z_{1:t-1}, x_{1:t-1})}}_{\text{recursive term}} \underbrace{\frac{1 - p(m_i)}{p(m_i)}}_{\text{prior}}$$

$$\Rightarrow \quad l(m_i \mid z_{1:t}, x_{1:t}) = \log\left(\frac{p(m_i \mid z_{1:t}, x_{1:t})}{1 - p(m_i \mid z_{1:t}, x_{1:t})}\right)$$

Occupancy Mapping in Log Odds Form

- The product turns into a sum

$$l(m_i \mid z_{1:t}, x_{1:t})$$

$$= \underbrace{l(m_i \mid z_t, x_t)}_{\text{inverse sensor model}} + \underbrace{l(m_i \mid z_{1:t-1}, x_{1:t-1})}_{\text{recursive term}} - \underbrace{l(m_i)}_{\text{prior}}$$

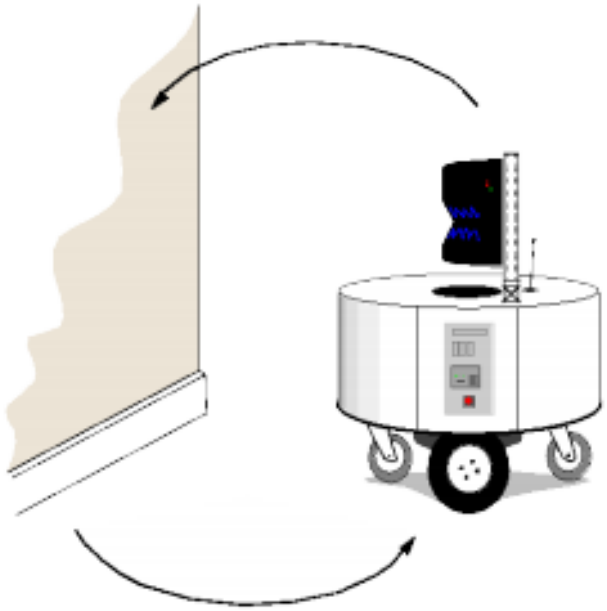
- Or in short

$$l_{t,i} = \text{inv\_sensor\_model}(m_i, x_t, z_t) + l_{t-1,i} - l_0$$

Creating a Map (SLAM Concept)

SLAM has long been regarded as a **chicken-or-egg** problem:

- a **map** is needed for **localization** and
- a **pose estimate** is needed for **mapping**
- **Localization**: inferring location given a **map**
- **Mapping**: inferring a map given **locations**
- **SLAM**: learning a map and locating the robot simultaneously



Ref: Introduction to Mobile Robotics (engl.) - Autonomous Mobile System at University of Freiburg

Creating a Map (SLAM Concept)

Given:

- The robot's controls

$$U_{1:k} = \{u_1, u_2, \ldots, u_k\}$$

- Relative observations

$$Z_{1:k} = \{z_1, z_2, \ldots, z_k\}$$

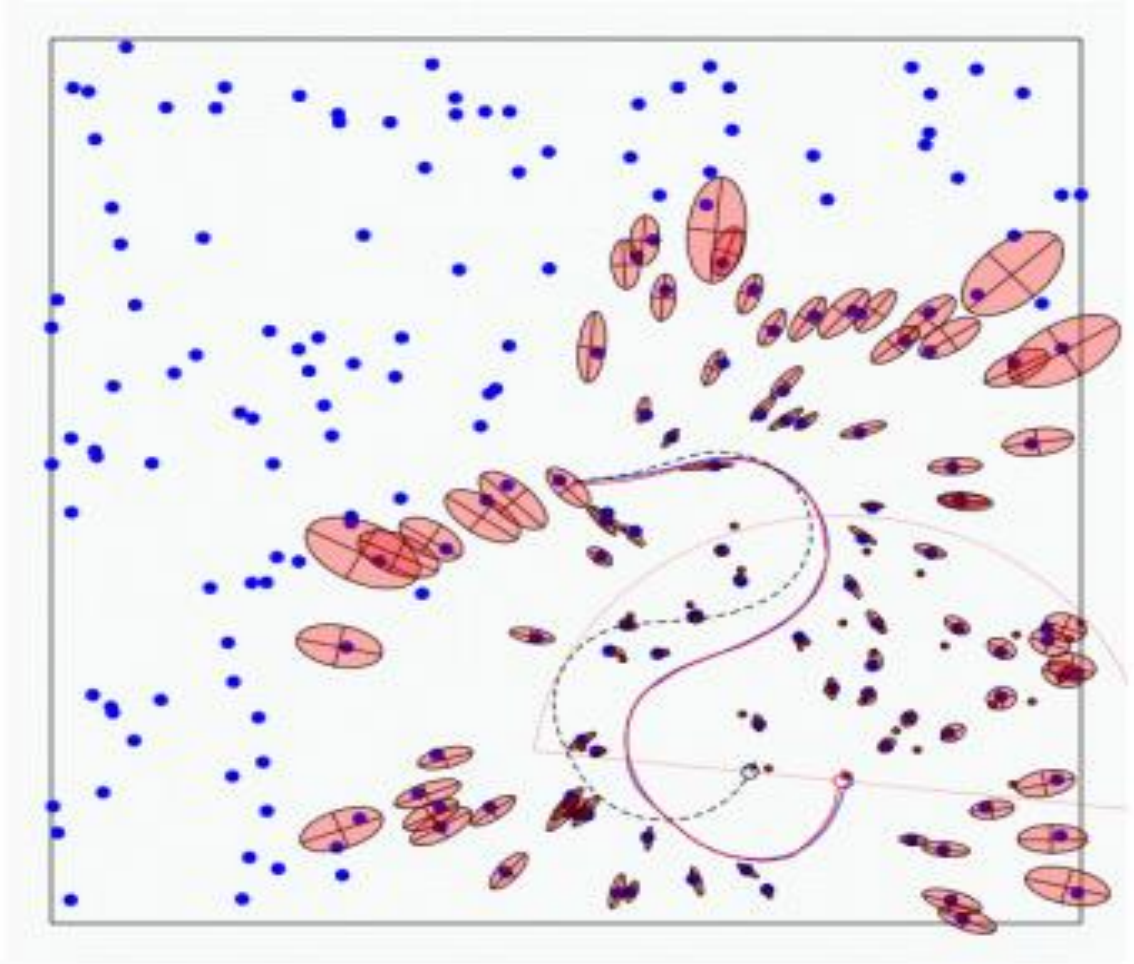
Wanted:

- Map of features

$$m = \{m_1, m_2, \ldots, m_n\}$$

- Path of the robot

$$X_{1:k} = \{x_1, x_2, \ldots, x_k\}$$



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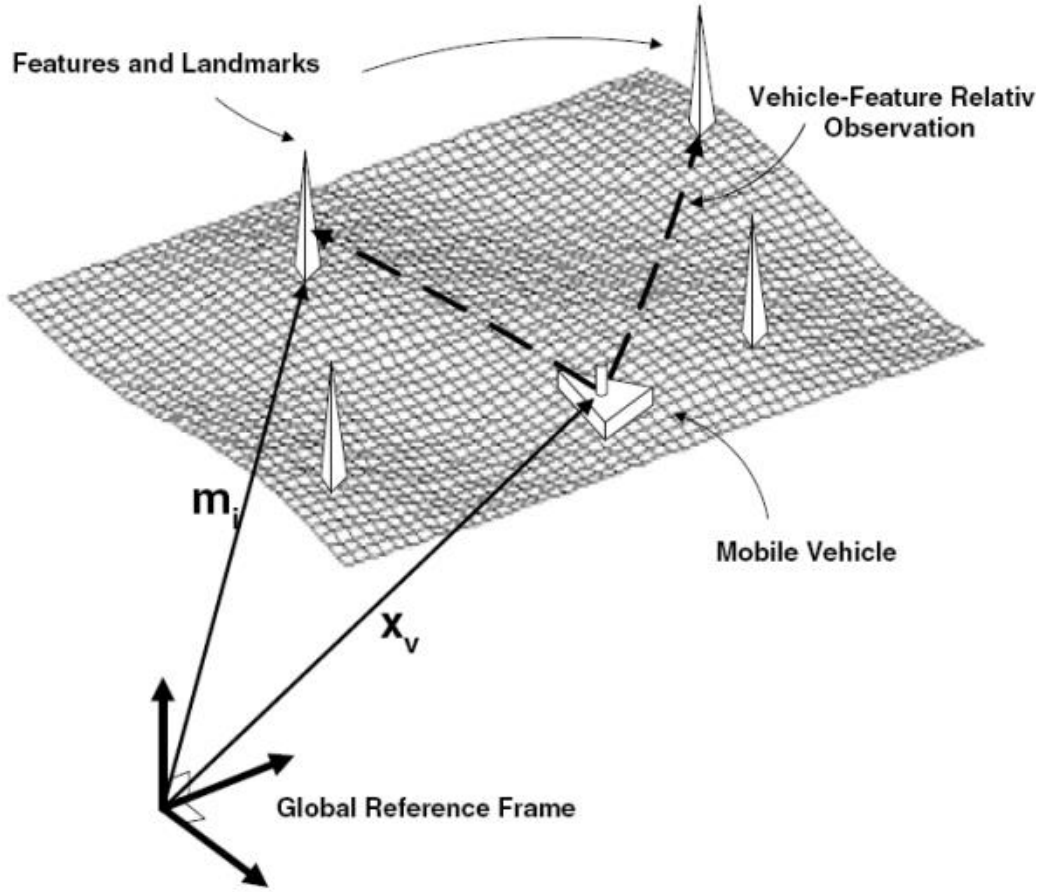
Creating a Map (SLAM Concept)

Feature-Based SLAM

- **Absolute** robot poses
- **Absolute** landmark positions
- But only **relative** measurements of landmarks



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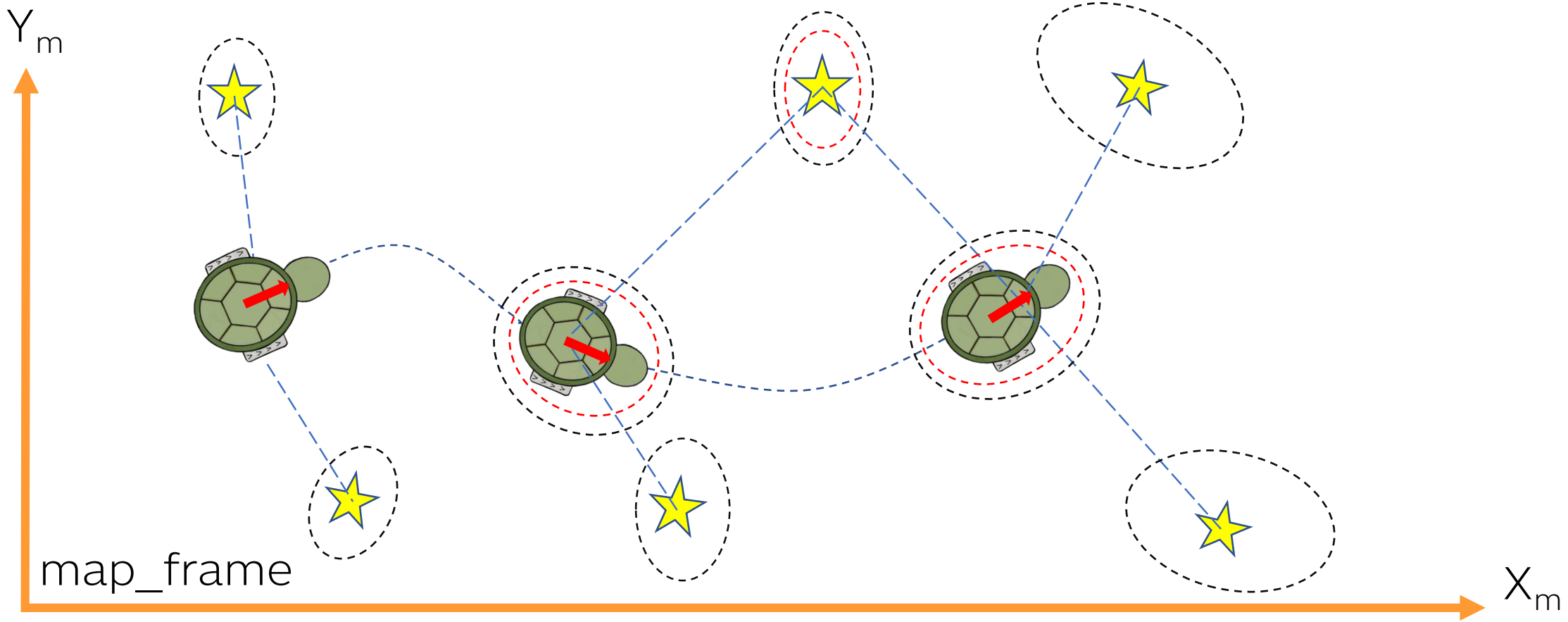
Creating a Map (SLAM Concept)

Why is SLAM a hard problem ??

1. Robot path and map are both unknown
2. Errors in map and pose estimates correlated



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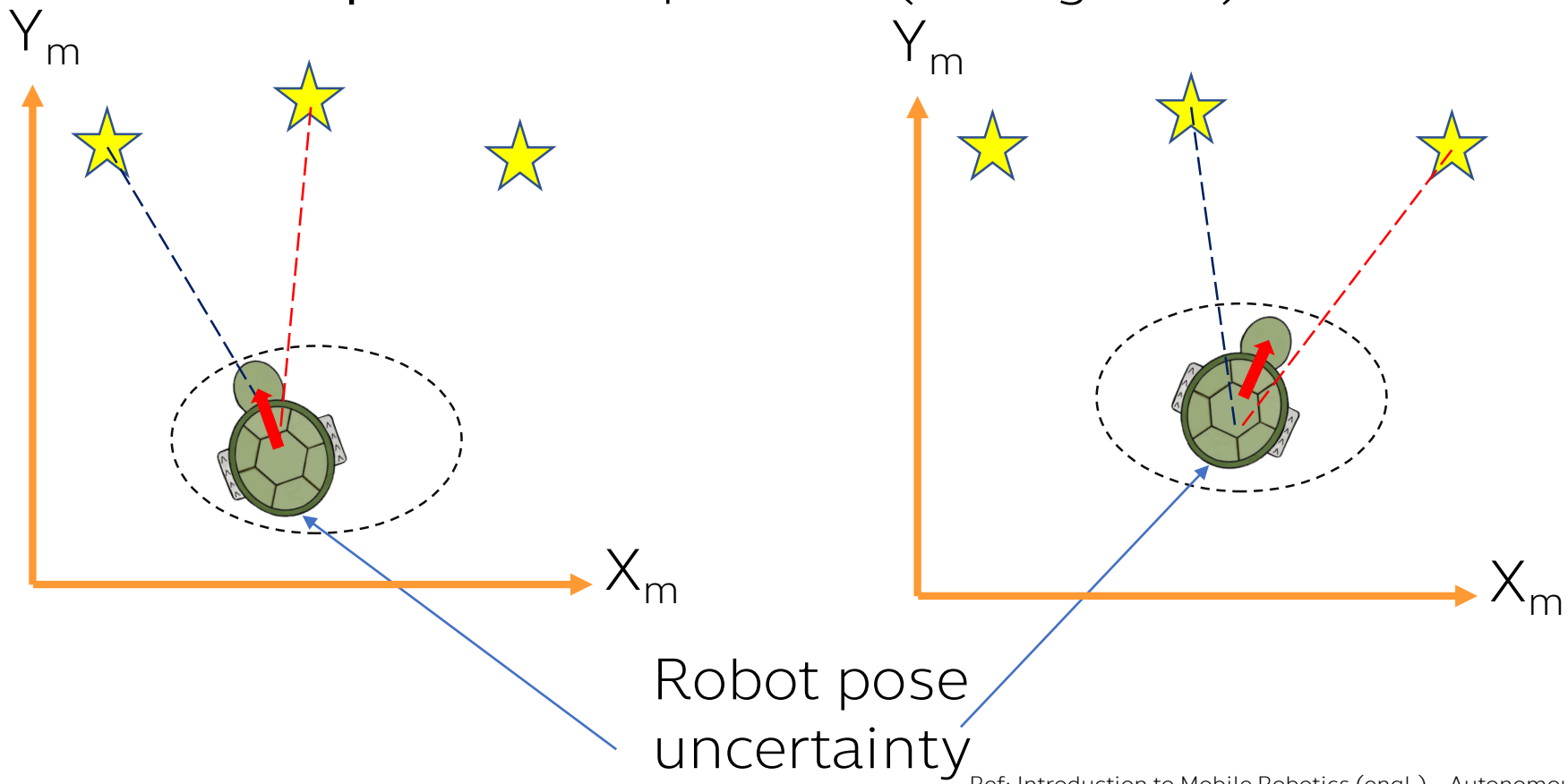
Creating a Map (SLAM Concept)

Why is **SLAM** a hard problem ??

3. The **mapping between observations and landmarks is unknown**
4. Picking **wrong** data associations can have **catastrophic** consequences (divergence)



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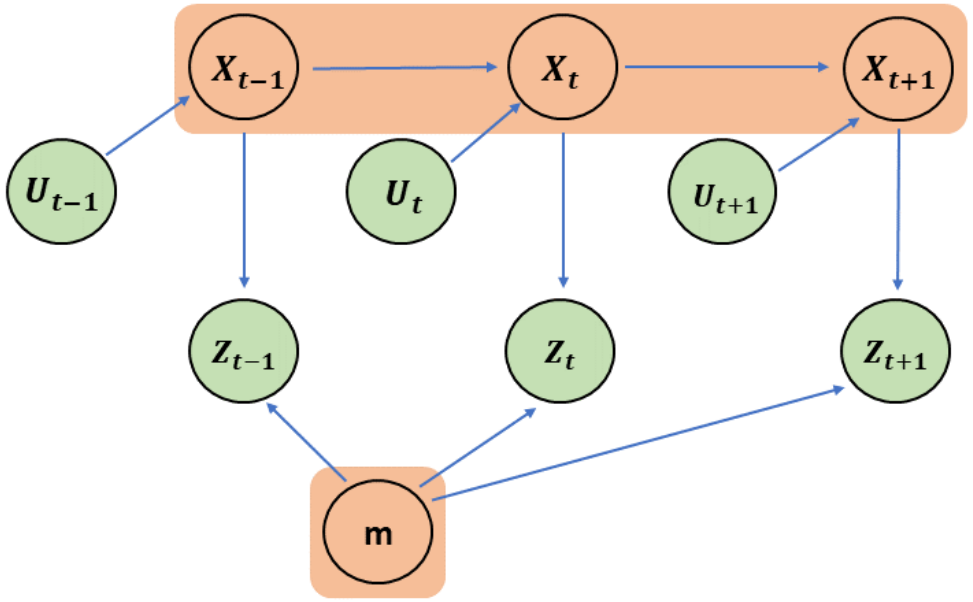
Creating a Map (SLAM Concept)

SLAM: Simultaneous Localization And Mapping

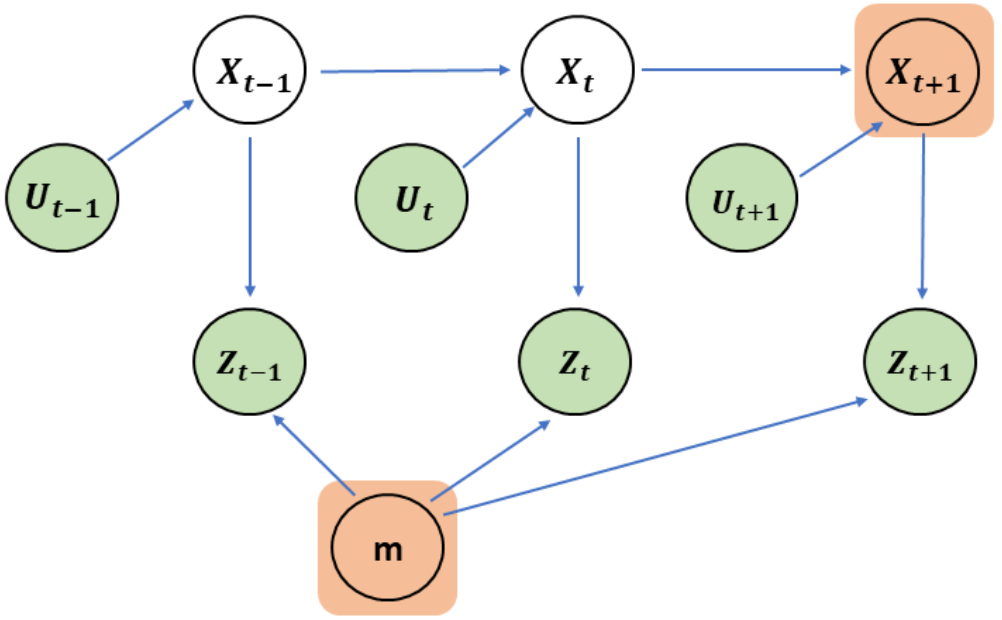
- Full SLAM:



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

Estimate entire path and map

- Online SLAM:

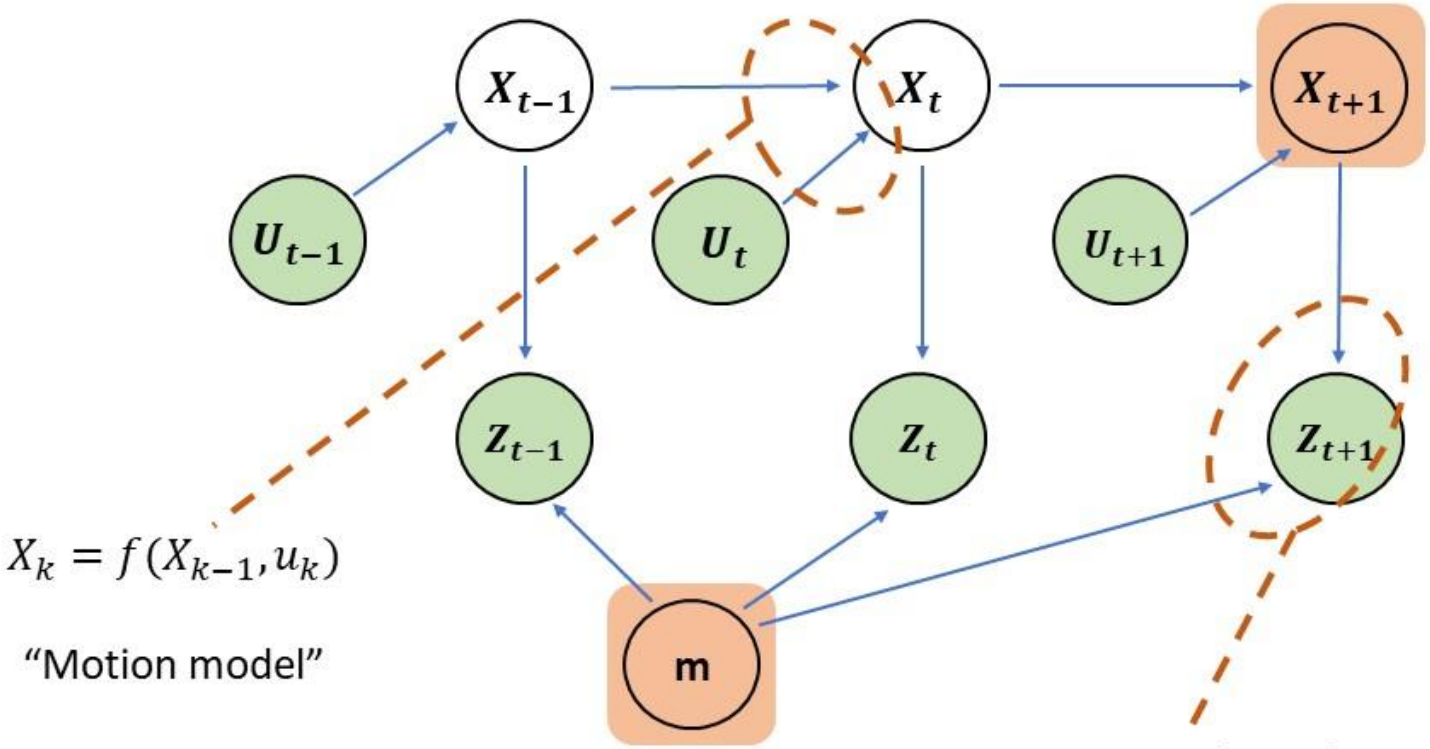


$$p(x_t, m \mid z_{1:t}, u_{1:t}) = \iint \ldots \int p(x_{1:t}, m \mid z_{1:t}, u_{1:t})\, dx_1 dx_2 \ldots dx_{t-1}$$

Estimates most recent pose and map

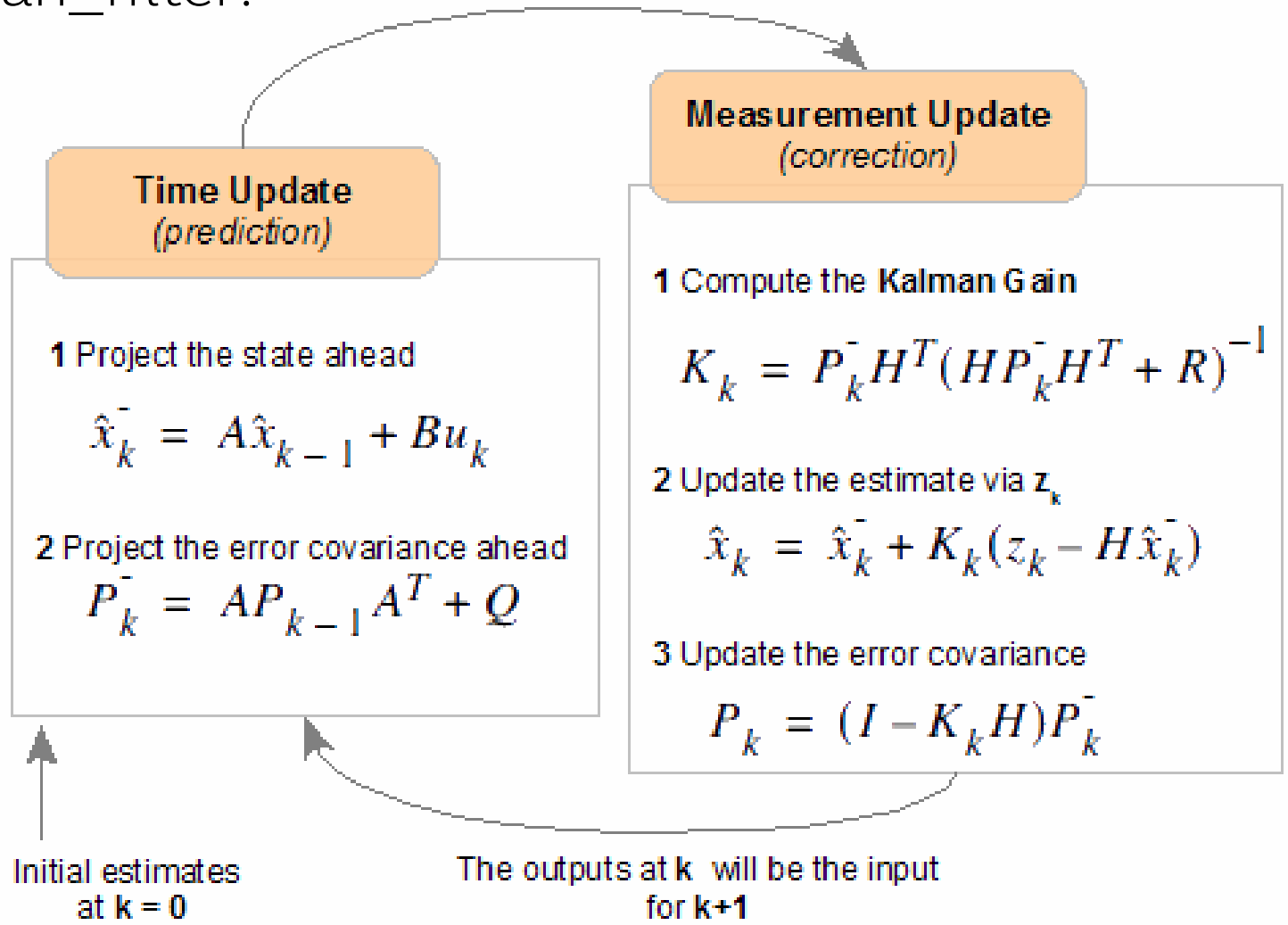
Creating a Map (SLAM Concept)

Motion and Observation Model



Creating a Map (SLAM Concept)

Algorithm Kalman_filter:



Ref: http://bilgin.esme.org/BitsAndBytes/KalmanFilterforDummies

Creating a Map (SLAM Concept)

EKF-SLAM:

Localization

3x1 pose vector

3x3 cov. matrix

$$\mathbf{x}_k = \begin{bmatrix} x_k \\ y_k \\ \theta_k \end{bmatrix} \qquad C_k = \begin{bmatrix} \sigma_x^2 & \sigma_{xy} & \sigma_{x\theta} \\ \sigma_{yx} & \sigma_y^2 & \sigma_{y\theta} \\ \sigma_{\theta x} & \sigma_{\theta y} & \sigma_\theta^2 \end{bmatrix}$$

SLAM

Landmarks simply extend the state. Growing state vector and covariance matrix

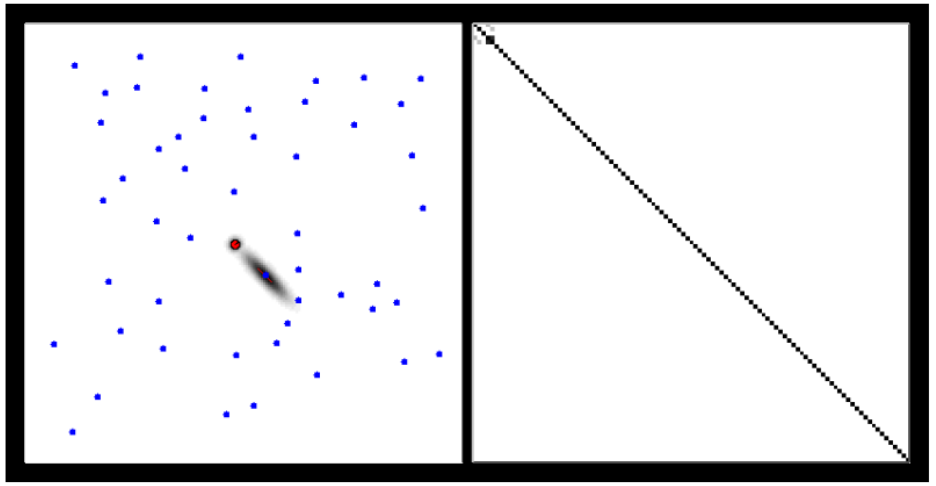
$$\mathbf{x}_k = \begin{bmatrix} \mathbf{x}_R \\ \mathbf{m}_1 \\ \mathbf{m}_2 \\ \vdots \\ \mathbf{m}_n \end{bmatrix}_k \qquad C_k = \begin{bmatrix} C_R & C_{RM_1} & C_{RM_2} & \cdots & C_{RM_n} \\ C_{M_1R} & C_{M_1} & C_{M_1M_2} & \cdots & C_{M_1M_n} \\ C_{M_2R} & C_{M_2M_1} & C_{M_2} & \cdots & C_{M_2M_n} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ C_{M_nR} & C_{M_nM_1} & C_{M_nM_2} & \cdots & C_{M_n} \end{bmatrix}_k$$

Creating a Map (SLAM Concept)

Integrating New Landmarks

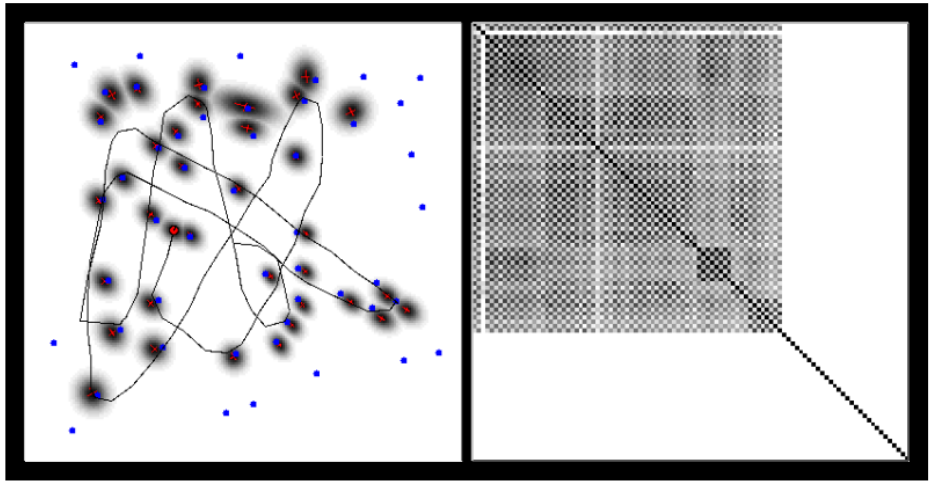
$$\mathbf{x}_k = \begin{bmatrix} \mathbf{x}_R \\ \mathbf{m}_1 \\ \mathbf{m}_2 \\ \vdots \\ \mathbf{m}_n \\ \mathbf{m}_{n+1} \end{bmatrix}_k \qquad C_k = \begin{bmatrix} C_R & C_{RM_1} & C_{RM_2} & \cdots & C_{RM_n} & C_{RM_{n+1}} \\ C_{M_1R} & C_{M_1} & C_{M_1M_2} & \cdots & C_{M_1M_n} & C_{M_1M_{n+1}} \\ C_{M_2R} & C_{M_2M_1} & C_{M_2} & \cdots & C_{M_2M_n} & C_{M_2M_{n+1}} \\ \vdots & \vdots & \vdots & \vdots & \ddots & \vdots \\ C_{M_nR} & C_{M_nM_1} & C_{M_nM_2} & \cdots & C_{M_n} & C_{M_nM_{n+1}} \\ C_{M_{n+1}R} & C_{M_{n+1}M_1} & C_{M_{n+1}M_2} & \cdots & C_{M_{n+1}M_n} & C_{M_{n+1}} \end{bmatrix}_k$$

Initial state (number of landmark = 0)



Map Correlation matrix

State N (number of landmark >> 0)



Map Correlation matrix

Creating a Map (SLAM Concept)

EKF-SLAM: Summary

- The first SLAM solution
- Convergence proof for **linear Gaussian case**
- Can diverge if nonlinearities are large (and the reality is nonlinear…)
- Problem: becomes computationally intractable for large maps!
- Cost per step: quadratic in n, the number of landmarks: $O(n^2)$
- Total cost to build a map with n landmarks: $O(n^3)$
- Memory consumption: $O(n^2)$

SLAM Techniques

- EKF SLAM
- FastSLAM
- Graph-based SLAM
- ETC.

Creating a Map (SLAM Concept)

ROS slam_gmapping package
based on Grid Mapping with Particle Filter (PF)

poses map observations & movements

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

SLAM posterior

Robot path posterior

landmark positions

$$\equiv p(x_{1:t} \mid z_{1:t}, u_{0:t-1}) \cdot \prod_{i=1}^{M} p(l_i \mid x_{1:t}, z_{1:t})$$

Robot path posterior (localization problem)

Conditionally independent landmark positions

Creating a Map (SLAM Concept)

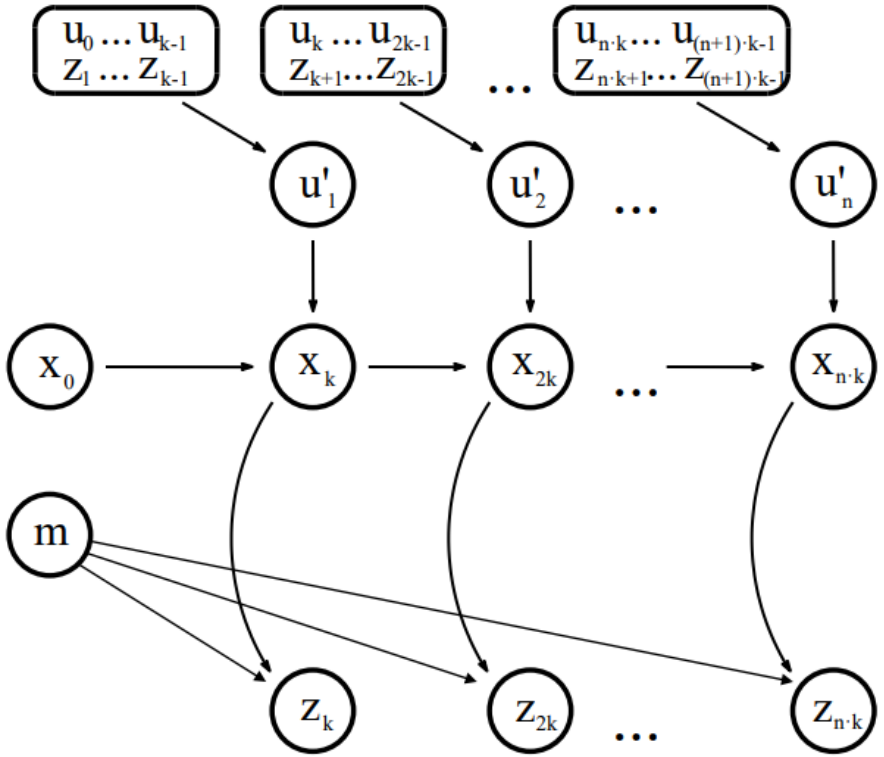
Rao-Blackwellization

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

This is localization, use MCL

Use the pose estimate from the MCL and apply mapping with known poses

With Scan-Matching



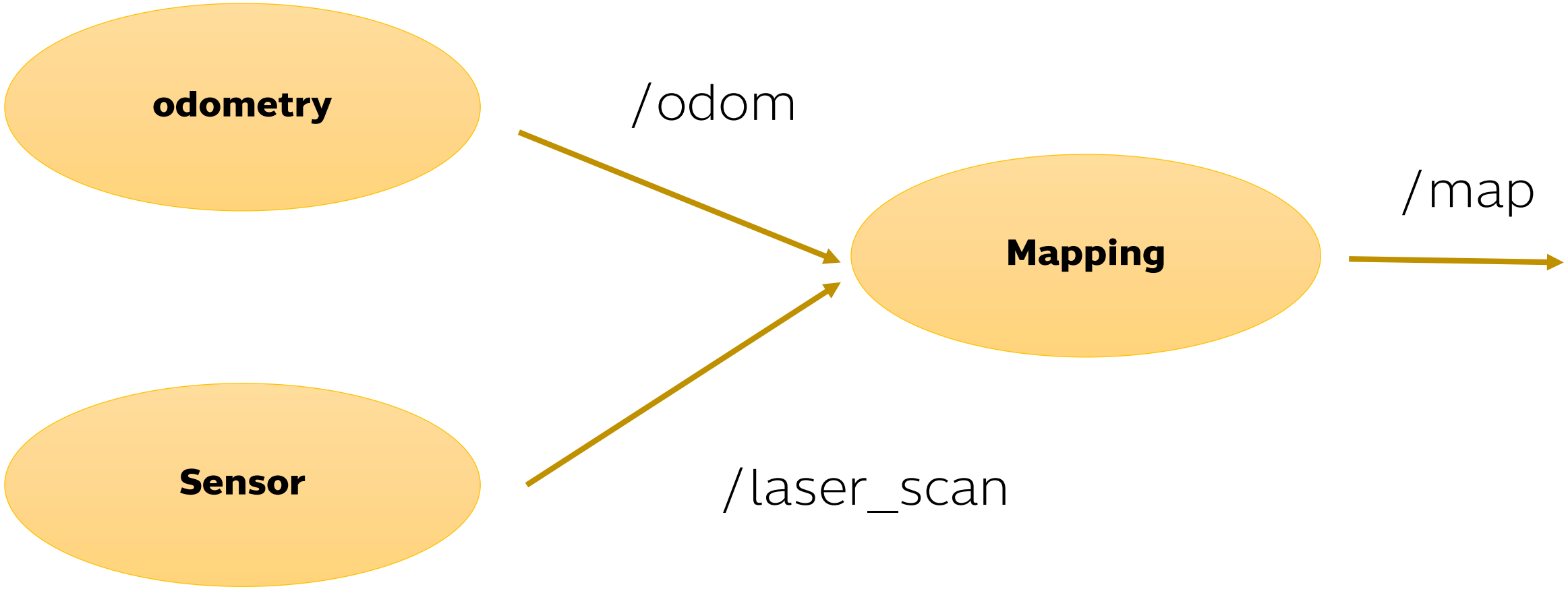
for more information please see:

http://www2.informatik.uni-freiburg.de/~stachnis/pdf/grisetti07tro.pdf

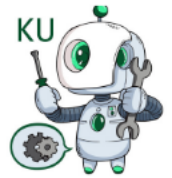
http://wiki.ros.org/gmapping

Mapping and Navigation Concept

Mapping



Localization



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Localization

Adaptive Monte Carlo localization (AMCL)

Monte Carlo localization (MCL), also known as particle filter localization, is an algorithm for robots to localize using a particle filter. Given a map of the environment, the algorithm estimates the position and orientation of a robot as it moves and senses the environment

Ref :https://www.mathworks.com/help/nav/ug/localize-turtlebot-using-monte-carlo-localization.html

Localization

AMCL dynamically adjusts the number of particles based on KL-distance to ensure that the particle distribution converge to the true distribution of robot state based on all past sensor and motion measurements with high probability.

Ref :https://www.mathworks.com/help/nav/ug/localize-turtlebot-using-monte-carlo-localization.html

Localization

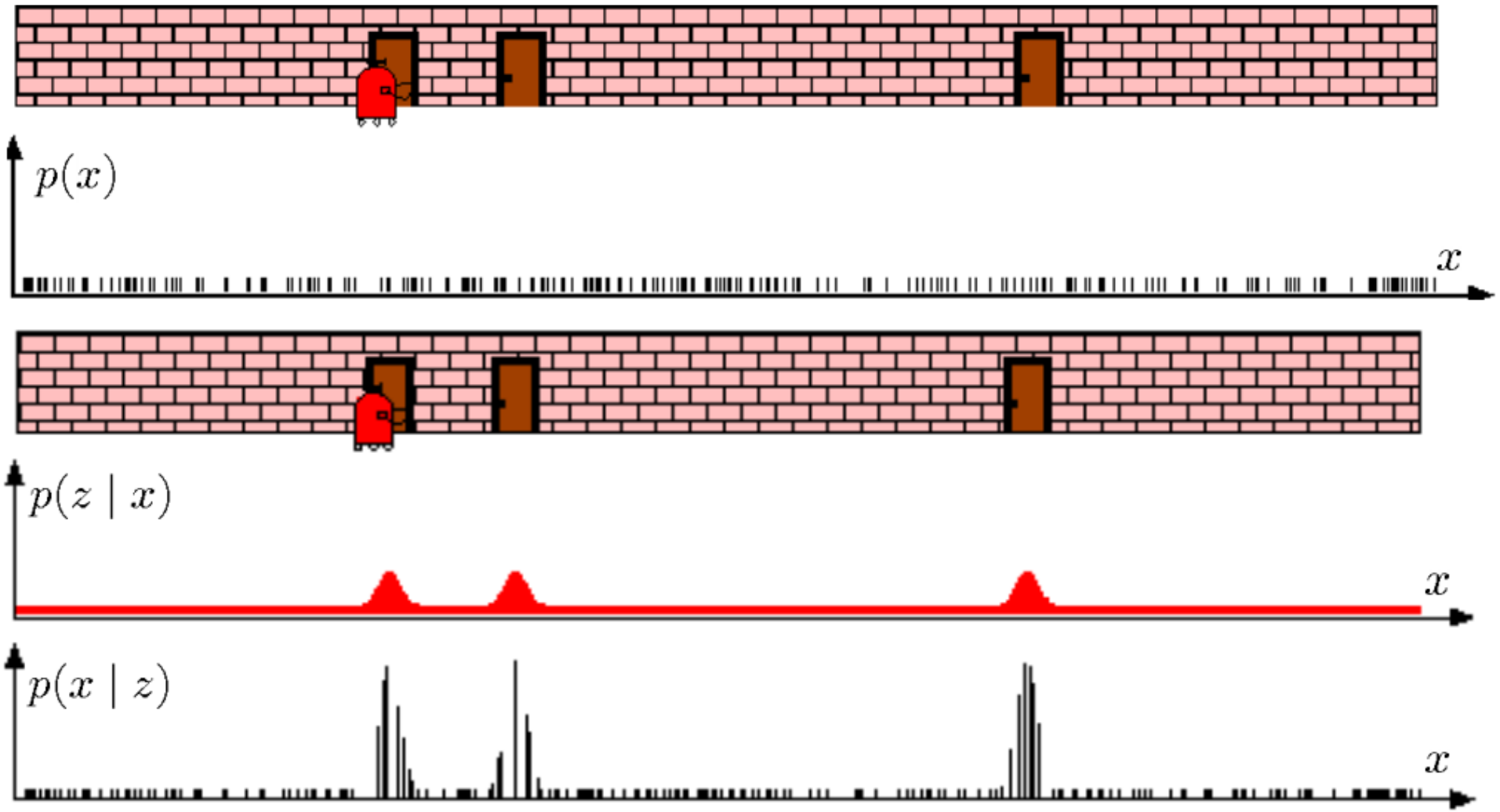
Particle Filters (PF)

- Sample the next generation for particles using the proposal distribution (Often use the motion model)
- Compute the importance weights
- Resampling: “Replace unlikely samples by more likely ones”

Ref :https://www.mathworks.com/help/nav/ug/localize-turtlebot-using-monte-carlo-localization.html

Localization

Sensor Information: Importance Sampling

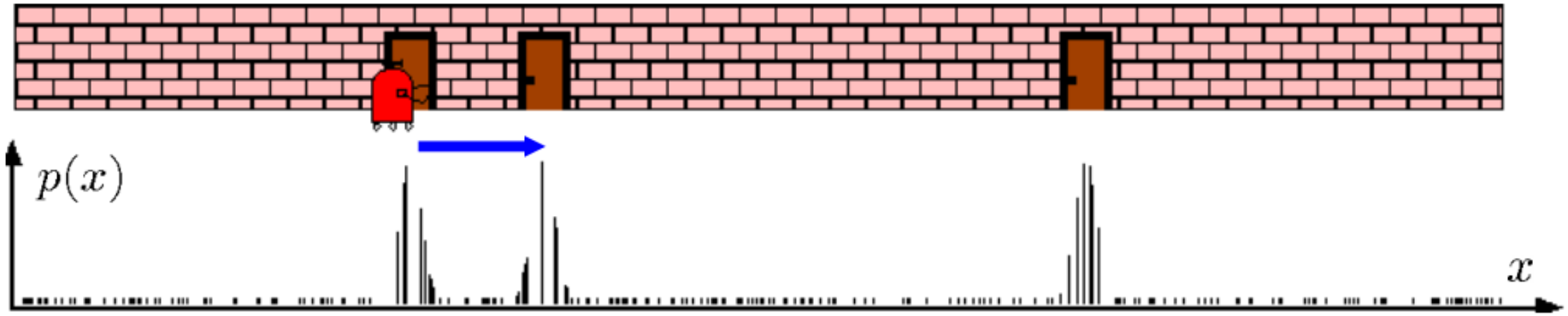


Sensor Model

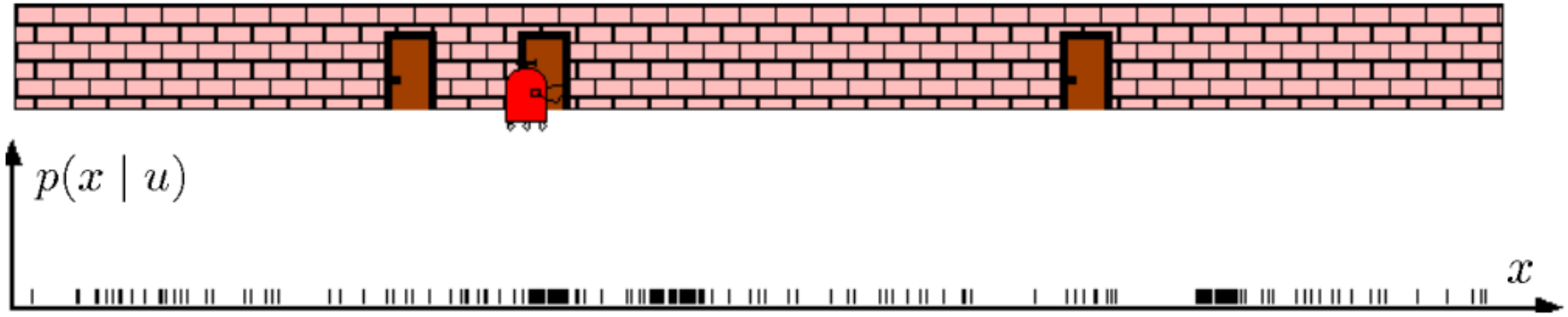
Importance Weighting

Localization

Robot Motion



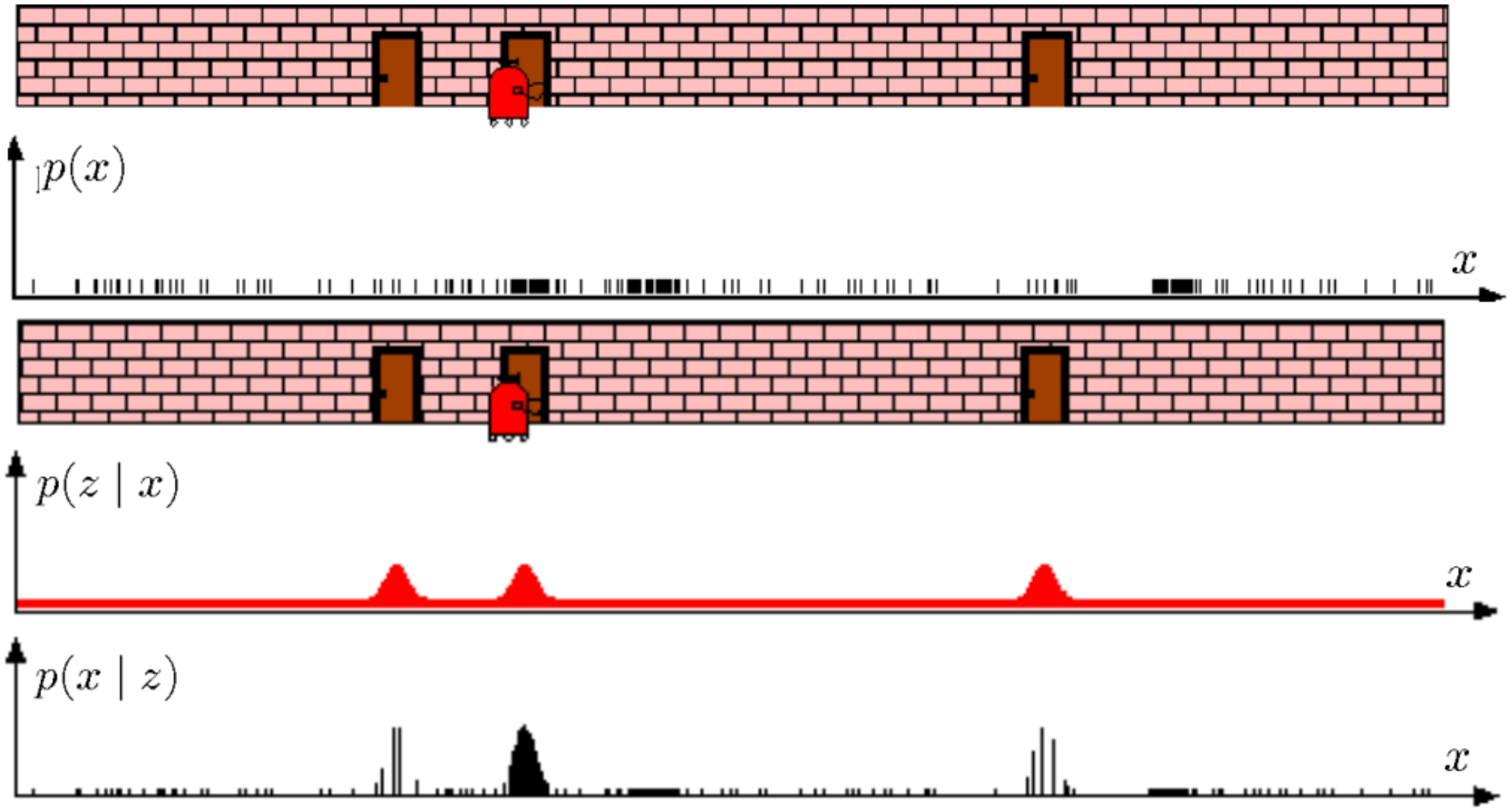
Motion Model



Resampling
and
Normalization

Localization

Sensor Information: Importance Sampling

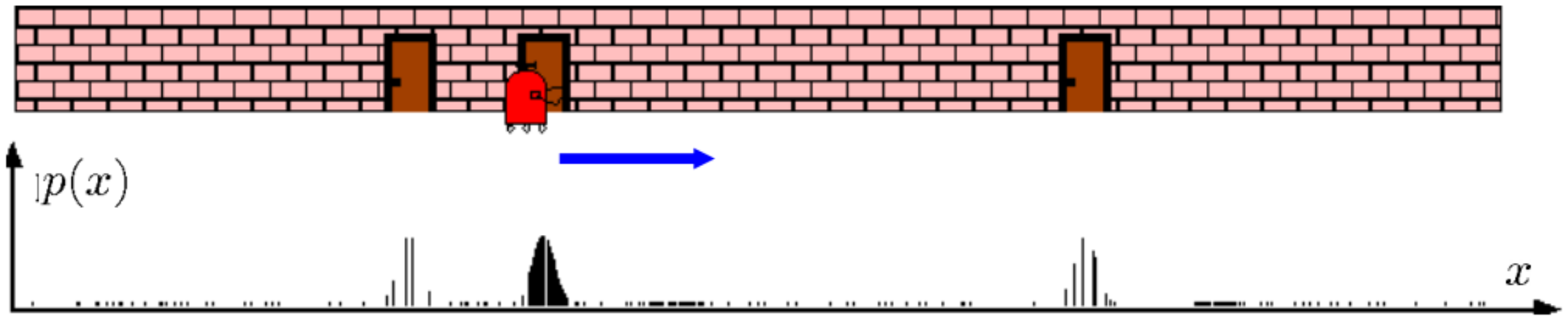


Sensor Model

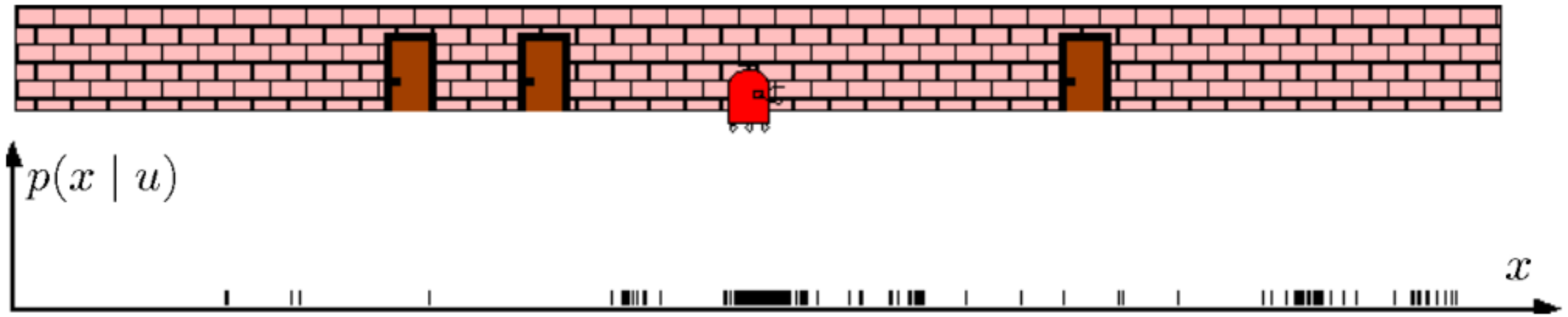
Importance Weighting

Localization

Robot Motion

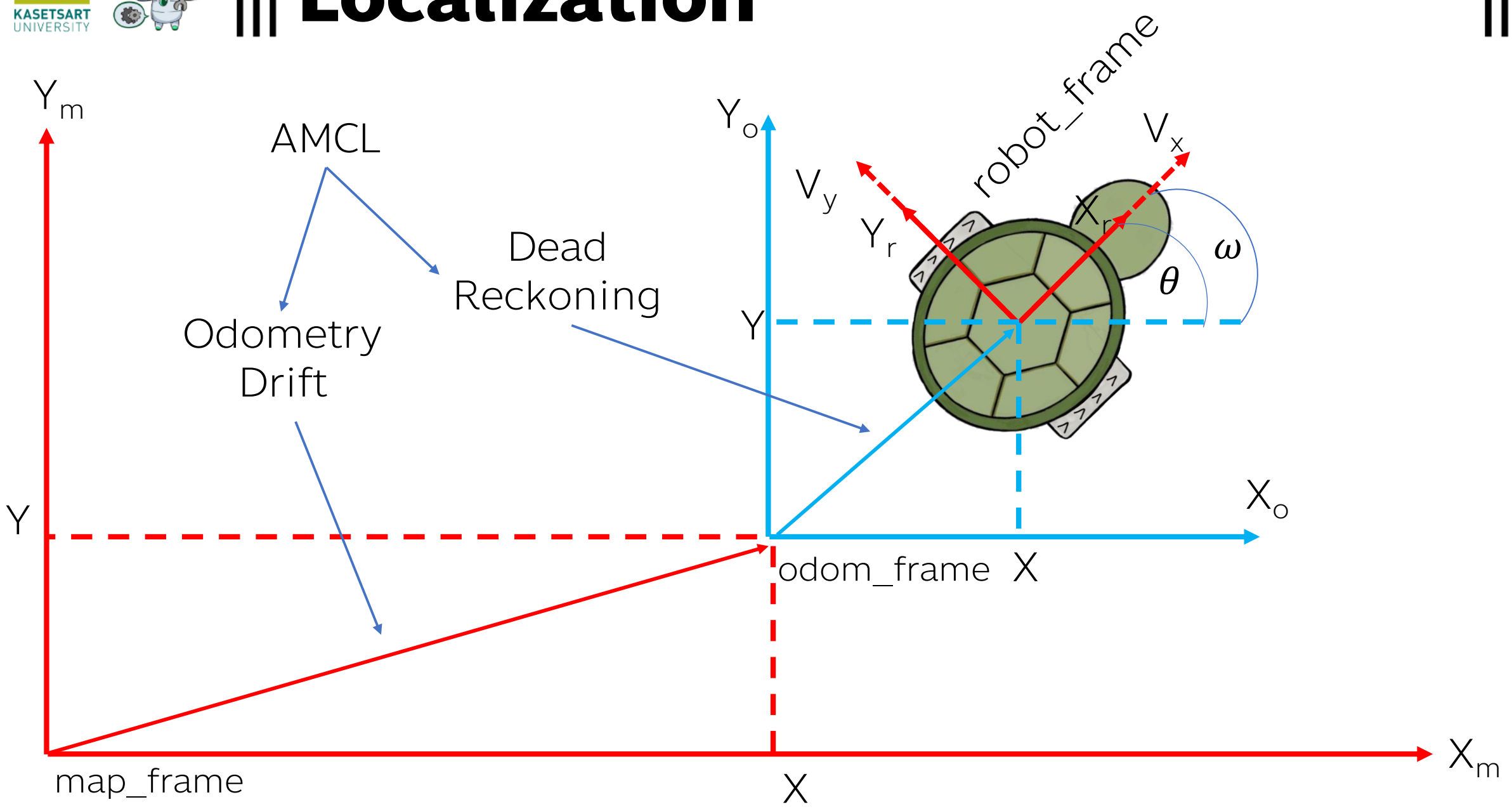


Motion Model

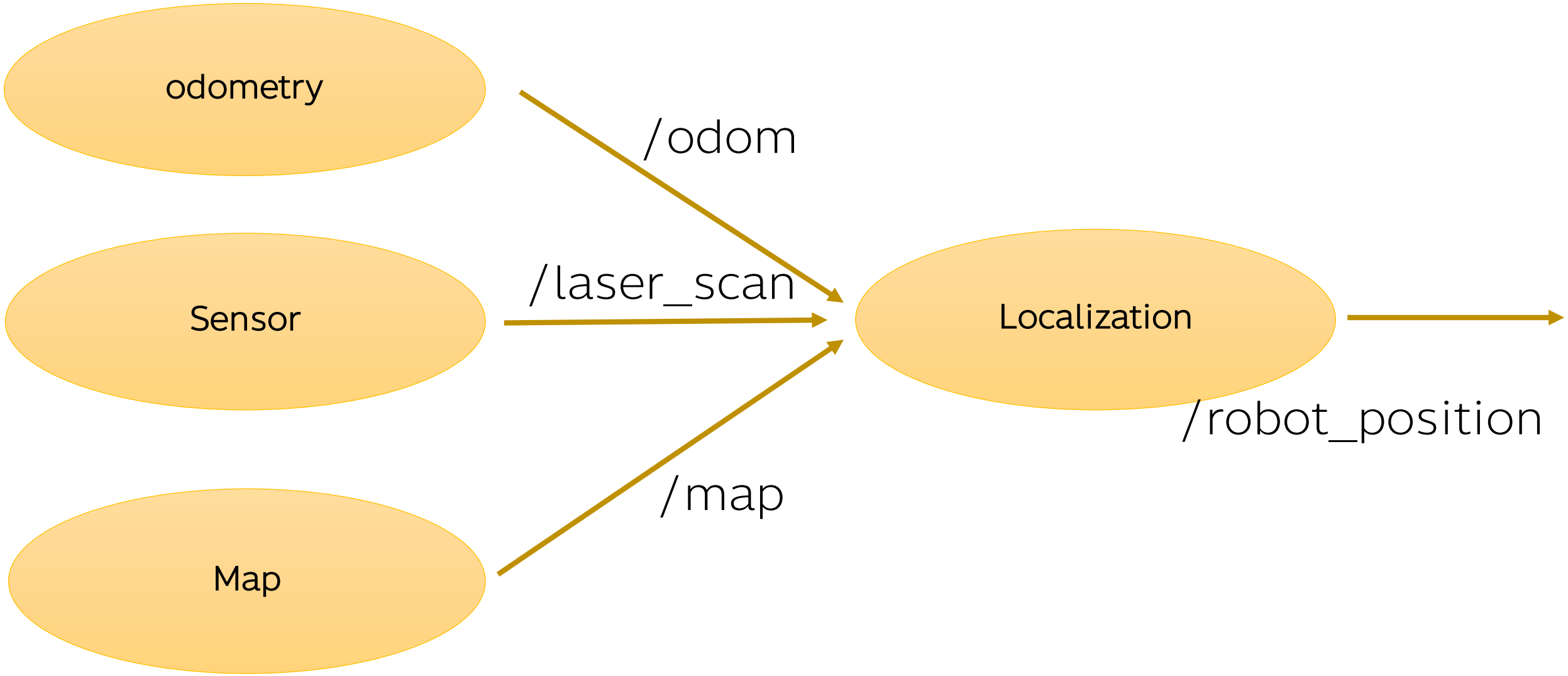


Resampling and Normalization

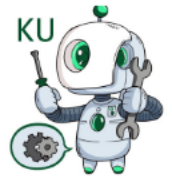
Localization



Localization



Mapping and Localization Example



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Creating a Map

Run following command On the Turtlebot:

Bring up the robot

```
$ roslaunch turtlebot_bringup minimal.launch
```

Run the gmapping demo app

```
$ roslaunch turtlebot_navigation gmapping_demo.launch
```

```
Registering First Scan
[ INFO] [1589187963.541649911]: Resizing costmap to 32 X 32 at 0.050000 m/pix
[ INFO] [1589187963.641544626]: Received a 32 X 32 map at 0.050000 m/pix
[ INFO] [1589187963.652621787]: Using plugin "obstacle_layer"
[ INFO] [1589187963.659199401]:     Subscribed to Topics: scan bump
[ INFO] [1589187963.732045008]: Using plugin "inflation_layer"
[ INFO] [1589187963.822148758]: Using plugin "obstacle_layer"
[ INFO] [1589187963.826630389]:     Subscribed to Topics: scan bump
[ INFO] [1589187963.902166812]: Using plugin "inflation_layer"
[ INFO] [1589187963.974495217]: Created local_planner dwa_local_planner/DWAPlann
erROS
[ INFO] [1589187963.978729699]: Sim period is set to 0.20
[ INFO] [1589187964.792233685]: Stopping device RGB and Depth stream flush.
[ INFO] [1589187964.979560588]: Recovery behavior will clear layer obstacles
[ INFO] [1589187964.988219664]: Recovery behavior will clear layer obstacles
[ INFO] [1589187965.050636841]: odom received!
```

Creating a Map

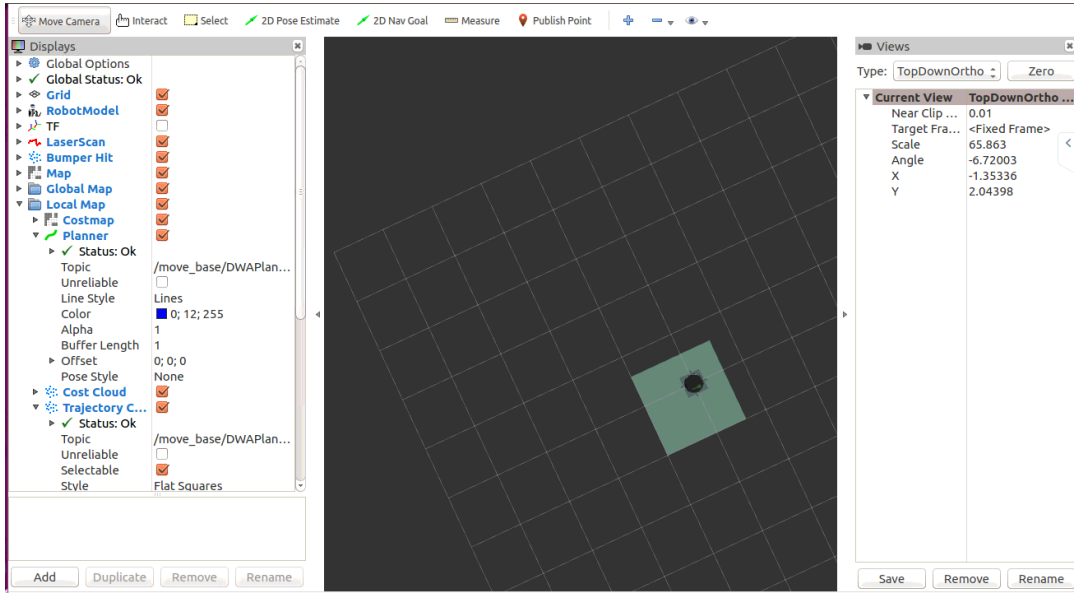
Run following command On Workstation:

Run the robot visualization to see the collecting map:

```
$ roslaunch turtlebot_rviz_launchers view_navigation.launch
```

Run controller node

```
$ roslaunch turtlebot_teleop logitech.launch
```



Creating a Map

Save the map to file:

```
$ rosrun map_server map_saver -f /tmp/my_map
```

```
user@ros-workshop:~$ rosrun map_server map_saver -f /tmp/my_map
[ INFO] [1589188055.299165053]: Waiting for the map
[ INFO] [1589188055.529010694]: Received a 32 X 32 map @ 0.050 m/pix
[ INFO] [1589188055.529054573]: Writing map occupancy data to /tmp/my_map.pgm
[ INFO] [1589188055.529200605]: Writing map occupancy data to /tmp/my_map.yaml
[ INFO] [1589188055.529301794]: Done
```

Localization

Run following command On Turtlebot:

Run the AMCL:

```
$ roslaunch turtlebot_navigation amcl_demo.launch map_file:=/tmp/my_map.yaml
```

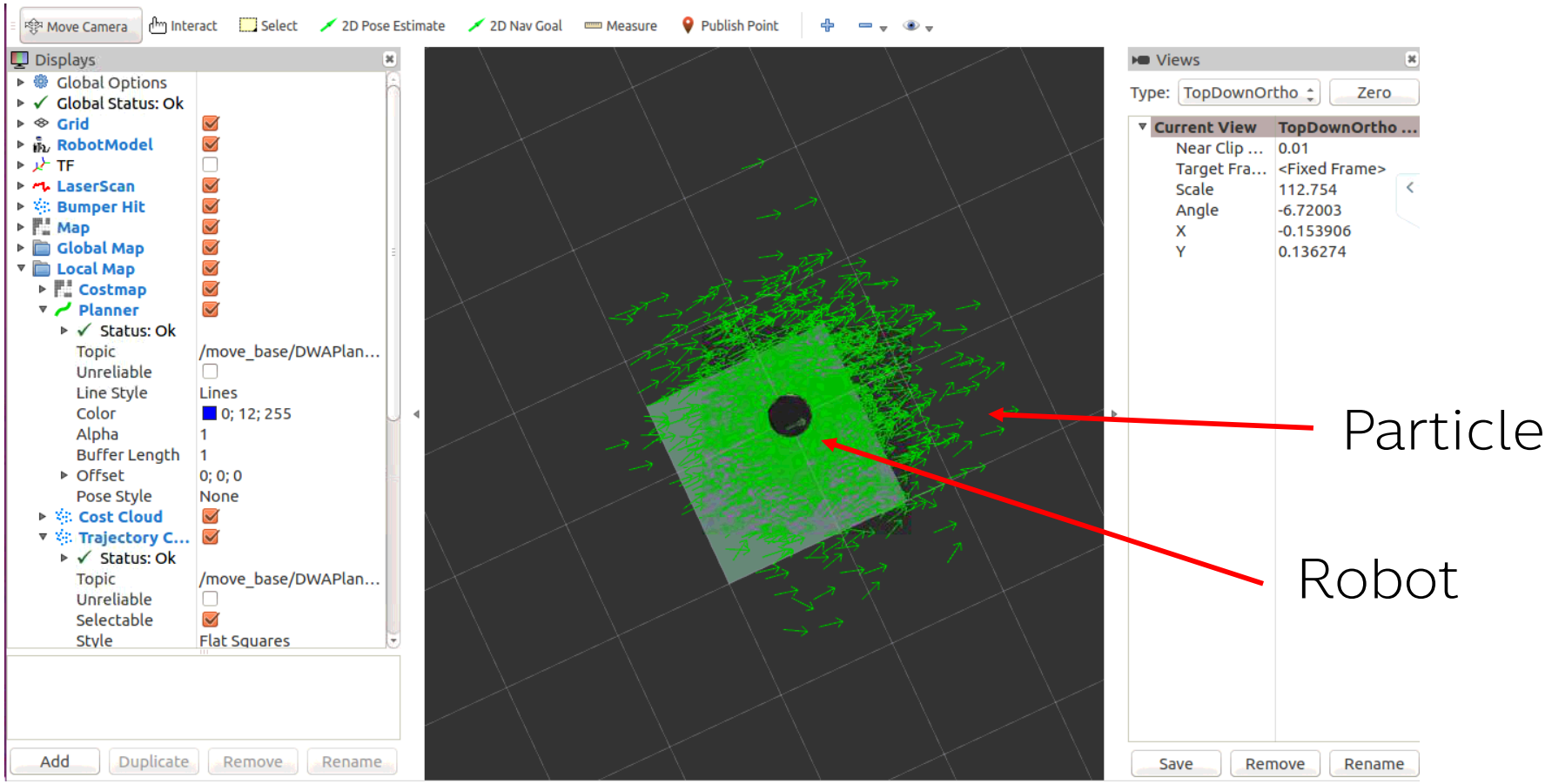
```
[ INFO] [1589188330.345375072]: Using plugin "static_layer"
[ INFO] [1589188330.353272344]: Requesting the map...
[ INFO] [1589188330.558622889]: Resizing costmap to 32 X 32 at 0.050000 m/pix
[ INFO] [1589188330.658583904]: Received a 32 X 32 map at 0.050000 m/pix
[ INFO] [1589188330.669448744]: Using plugin "obstacle_layer"
[ INFO] [1589188330.680303584]:     Subscribed to Topics: scan bump
[ INFO] [1589188330.750137639]: Using plugin "inflation_layer"
[ INFO] [1589188330.801454276]: Stopping device RGB and Depth stream flush.
[ INFO] [1589188330.849969357]: Using plugin "obstacle_layer"
[ INFO] [1589188330.854517455]:     Subscribed to Topics: scan bump
[ INFO] [1589188330.931099651]: Using plugin "inflation_layer"
[ INFO] [1589188331.005866802]: Created local_planner dwa_local_planner/DWAPlann
erROS
[ INFO] [1589188331.011846625]: Sim period is set to 0.20
[ INFO] [1589188332.010352631]: Recovery behavior will clear layer obstacles
[ INFO] [1589188332.016616784]: Recovery behavior will clear layer obstacles
[ INFO] [1589188332.079586595]: odom received!
```

Localization

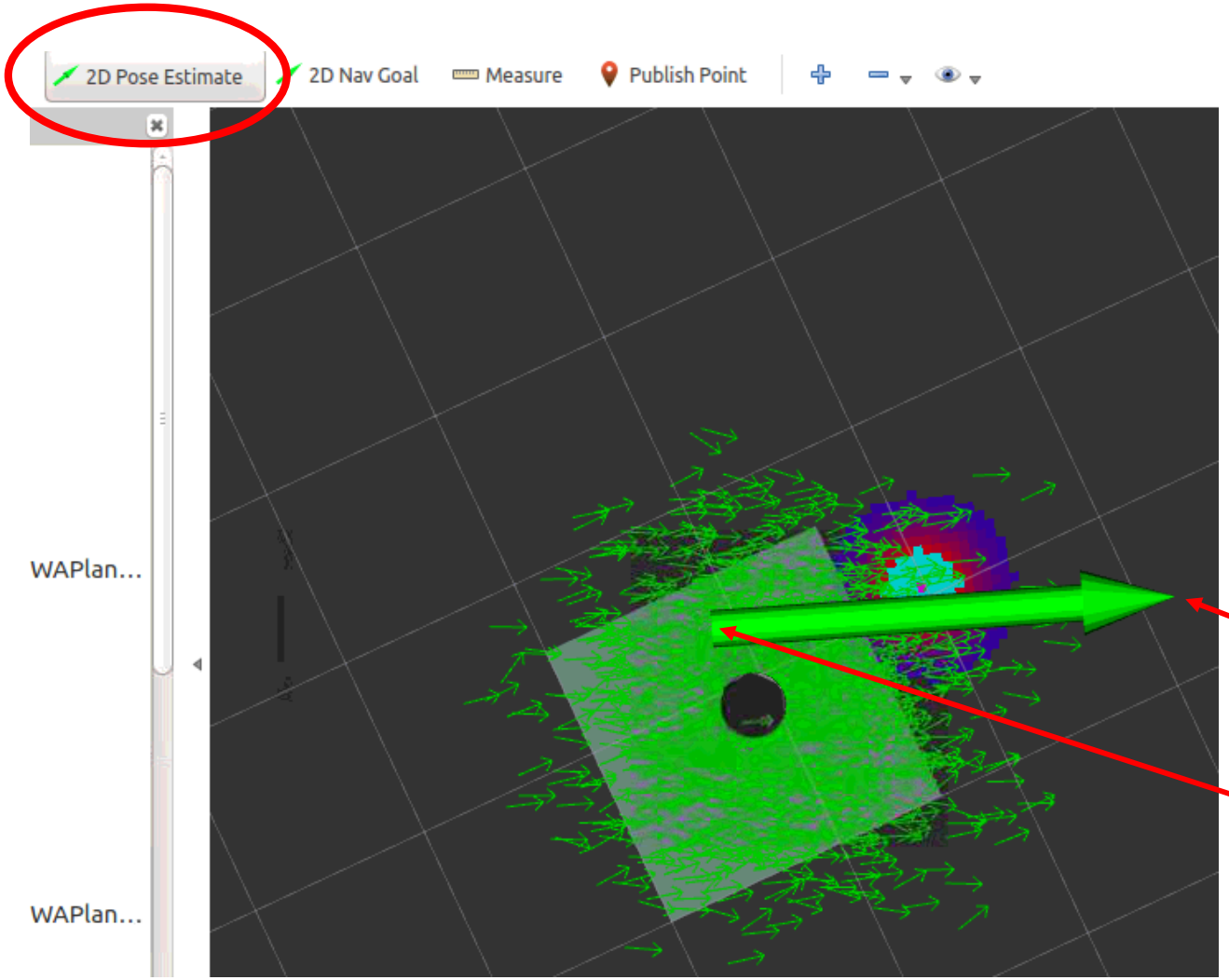
Run following command On Workstation:

Run the robot visualization to show the map and position of robot:

```
$ roslaunch turtlebot_rviz_launchers view_navigation.launch
```



Localization



1) Initial the position of the robot by click “2D Pose Estimate” button

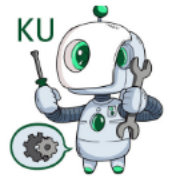
Then click and hold at guest position.

Turn around the position to give heading of robot.

Heading

Position

Navigation and Autonomous Driving



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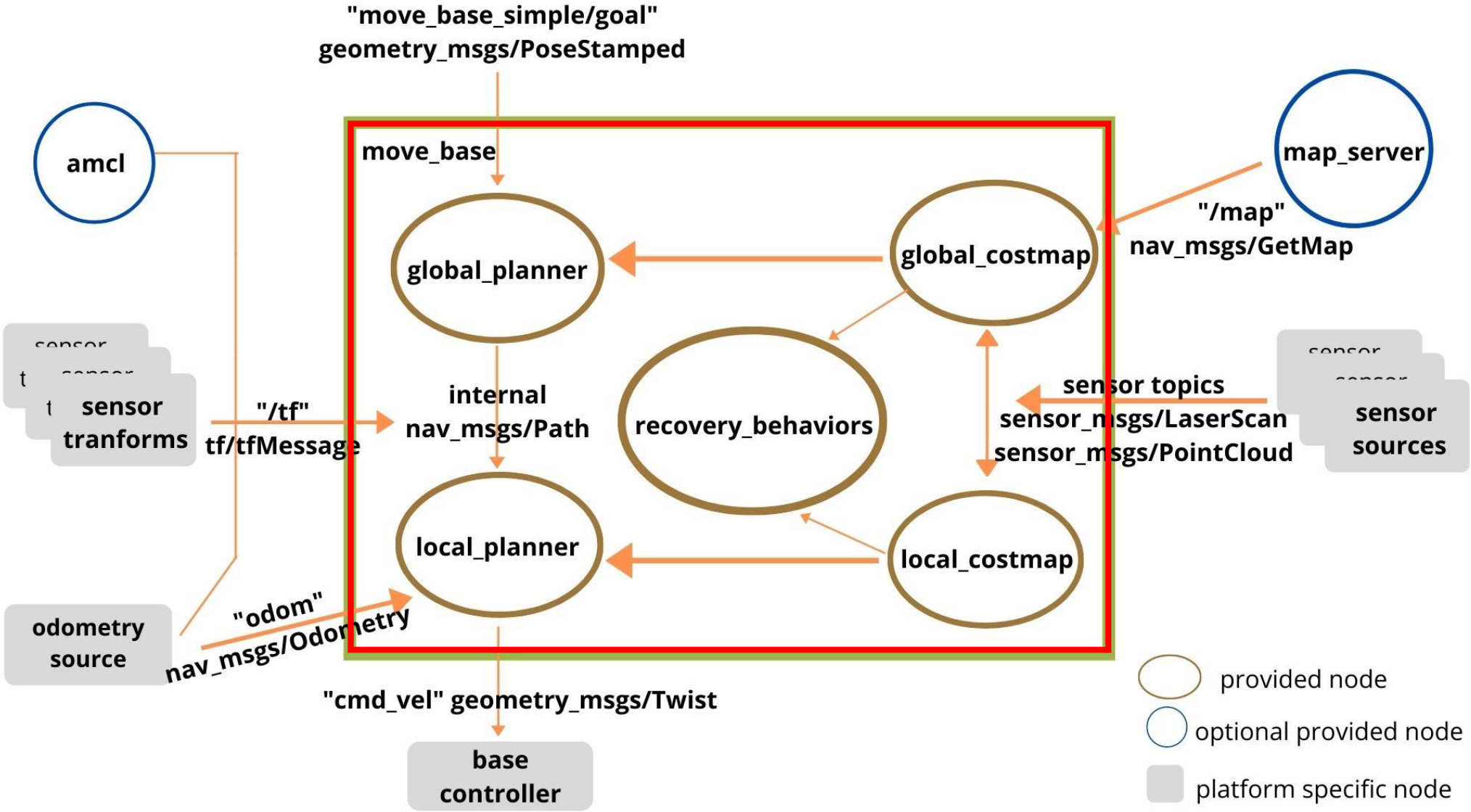
Navigation and Autonomous Driving



Navigation and Autonomous Driving

Goals:

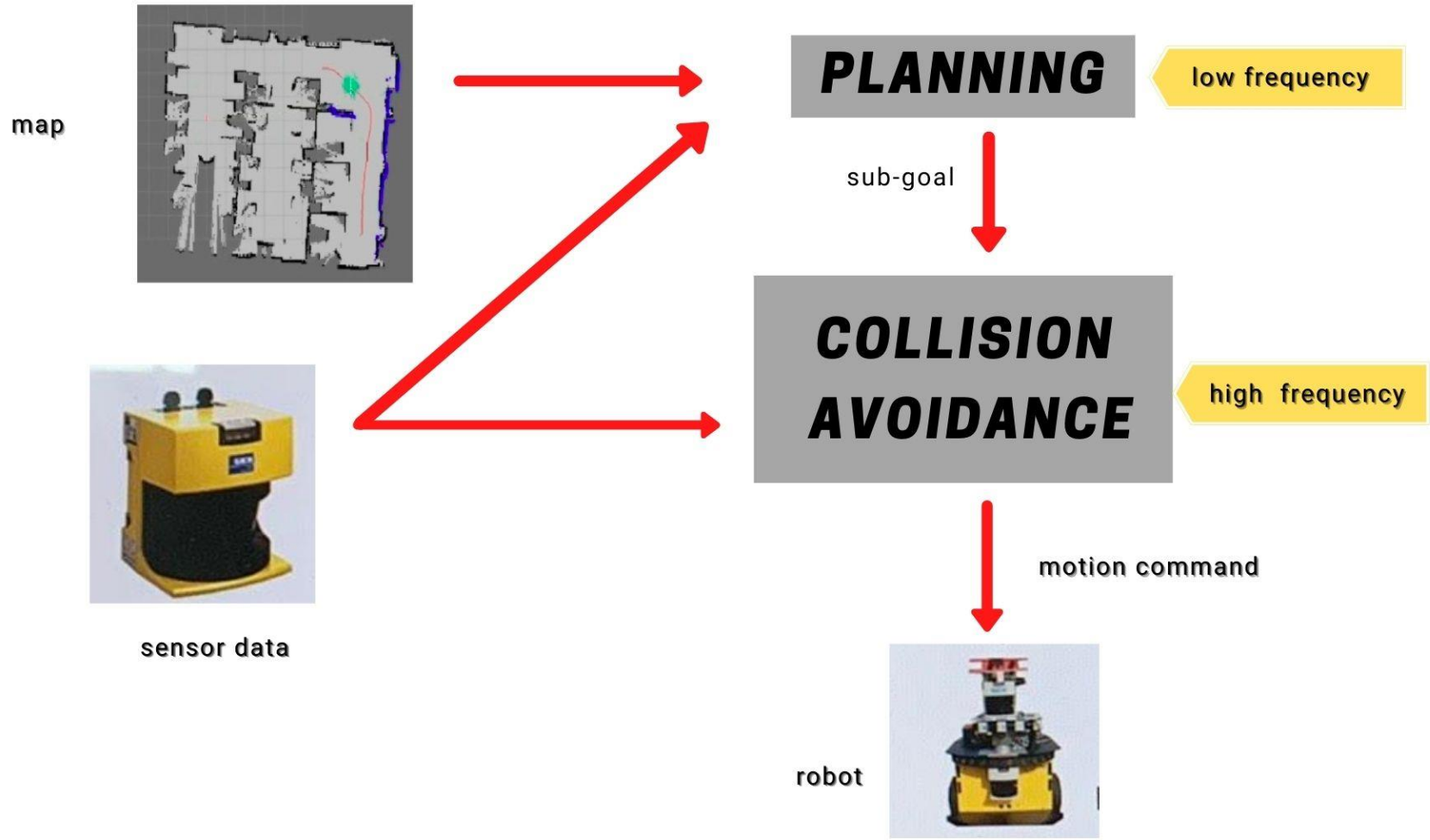
- Collision – free trajectory
- Robot should reach the goal location as quickly

Two Challenges:

- Calculate the optimal path taking potential uncertainties in the actions into account
- Quickly generate actions in the case of unforeseen objects

Navigation and Autonomous Driving

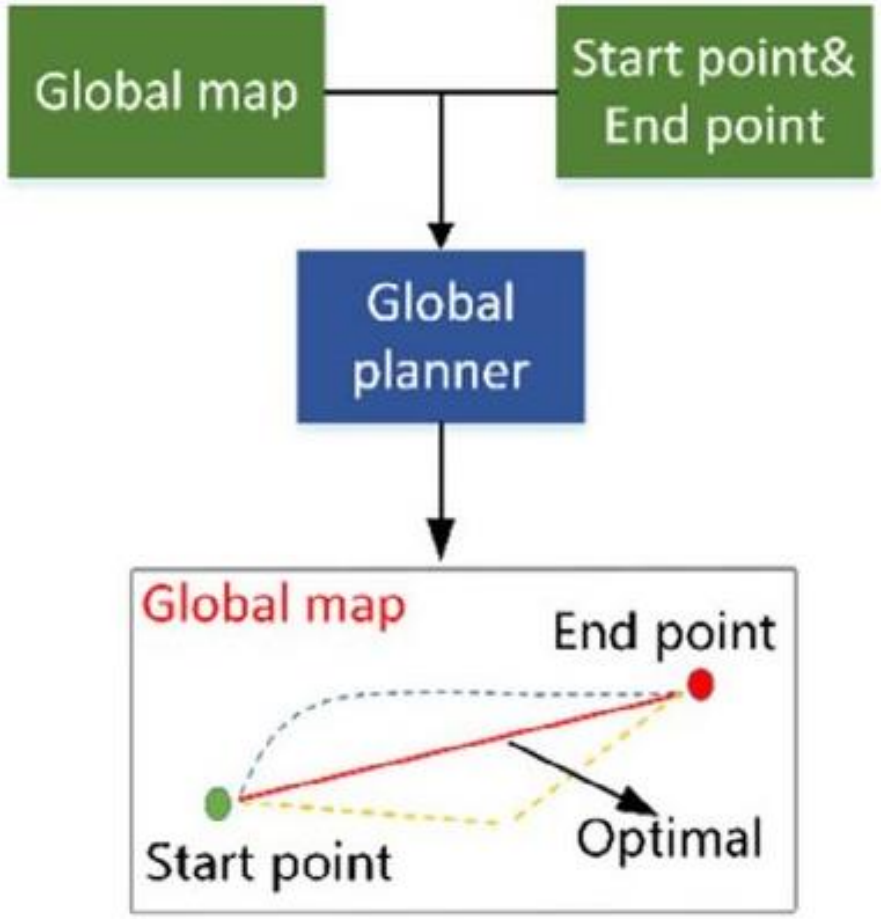
Classic Two-layered Architecture



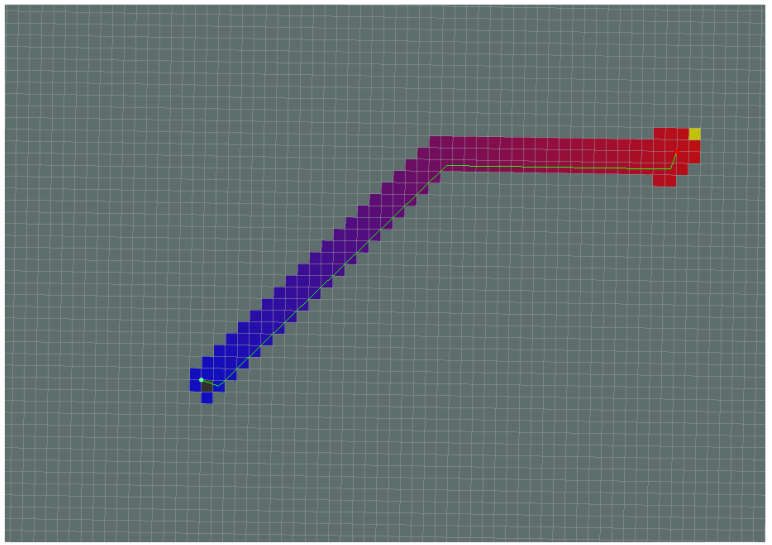
Ref: Introduction to Mobile Robotics (engl.) - Autonomous Mobile System at University of Freiburg

Navigation and Autonomous Driving

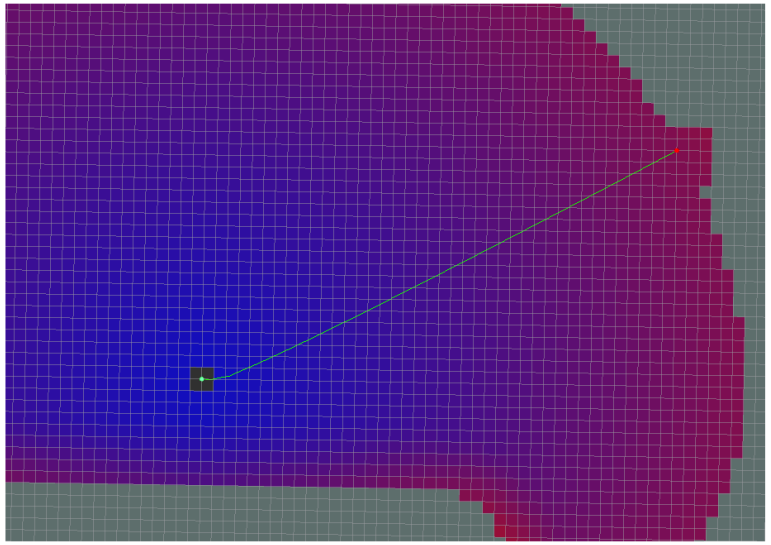
Path Planning – Global Planner



A*

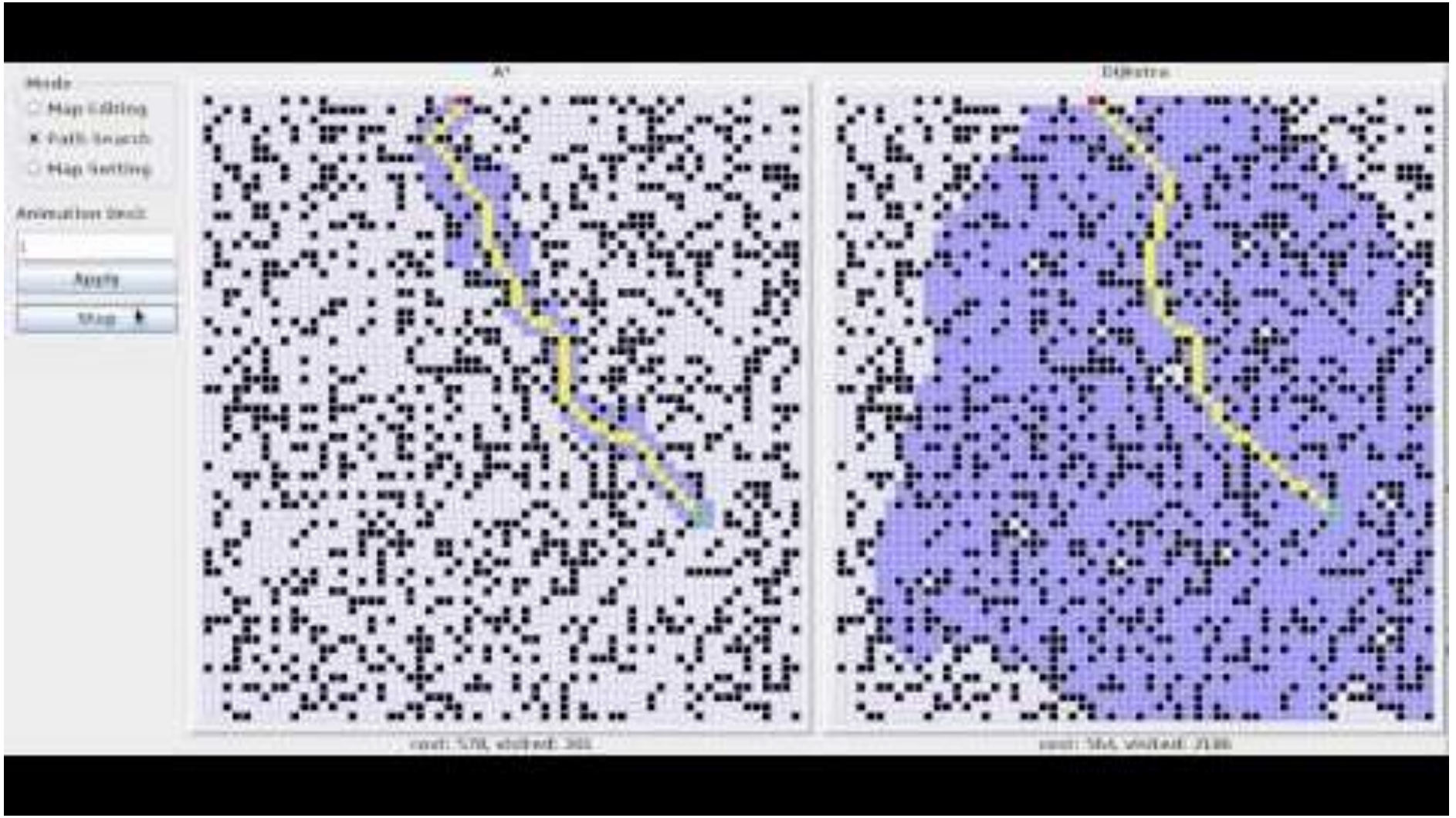


Dijkstra's



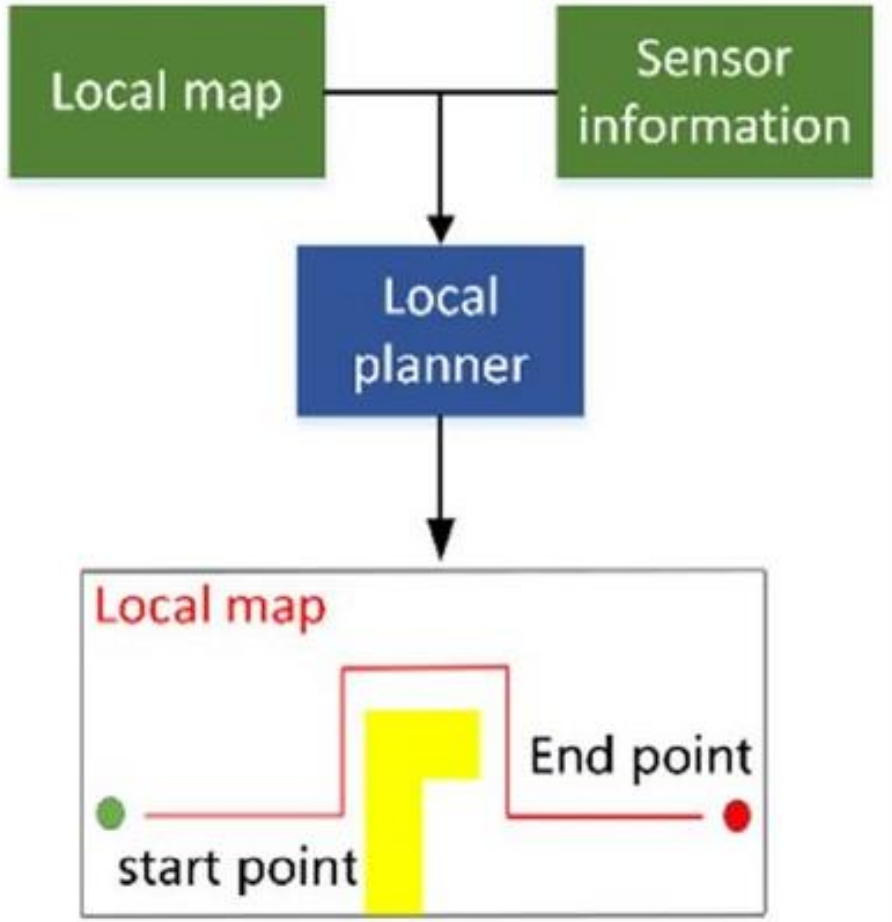
From : Lu, Yuncheng & Zhucun, Xue & Xia, Gui-Song & Zhang, Liangpei. (2018). A survey on vision-based UAV navigation. Geo-spatial Information Science

Navigation and Autonomous Driving



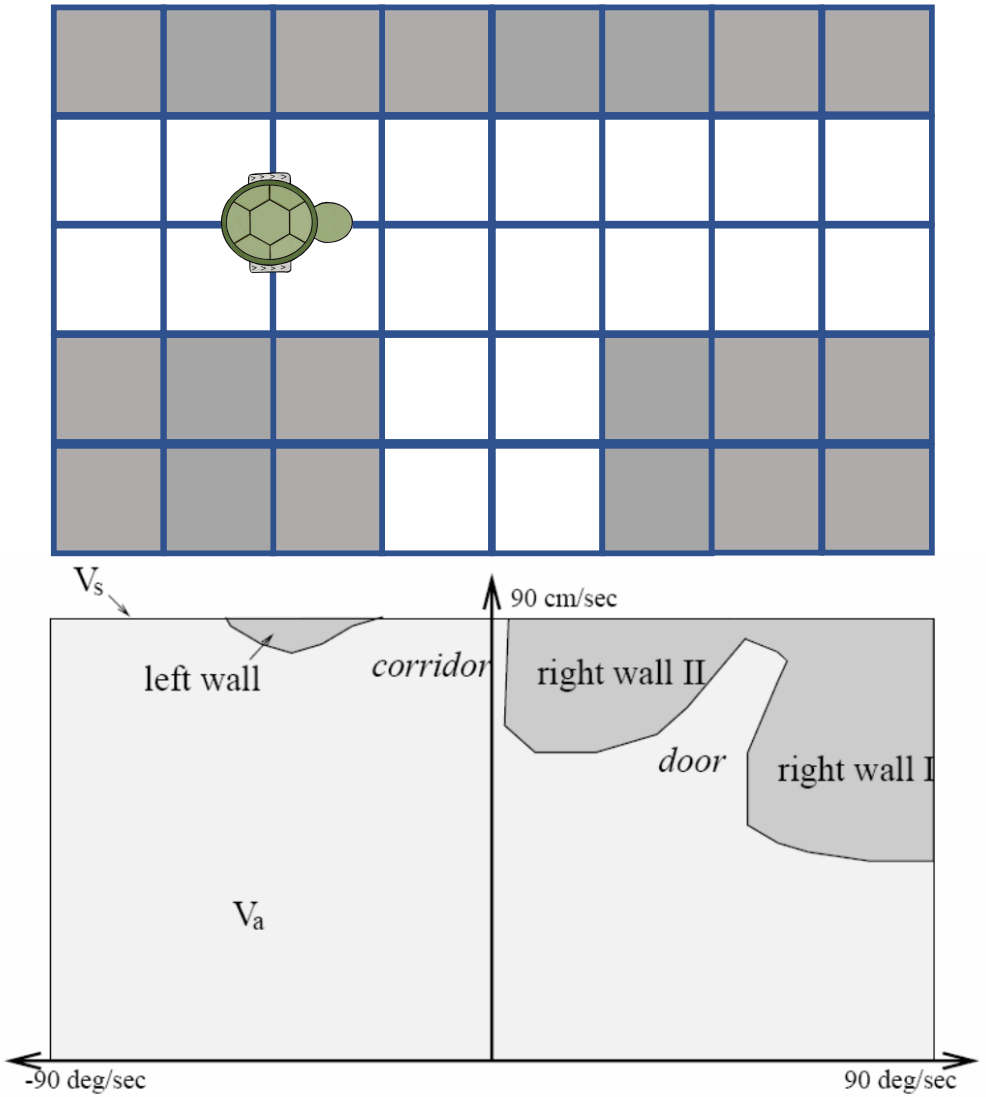
Navigation and Autonomous Driving

Path Planning – Local Planner



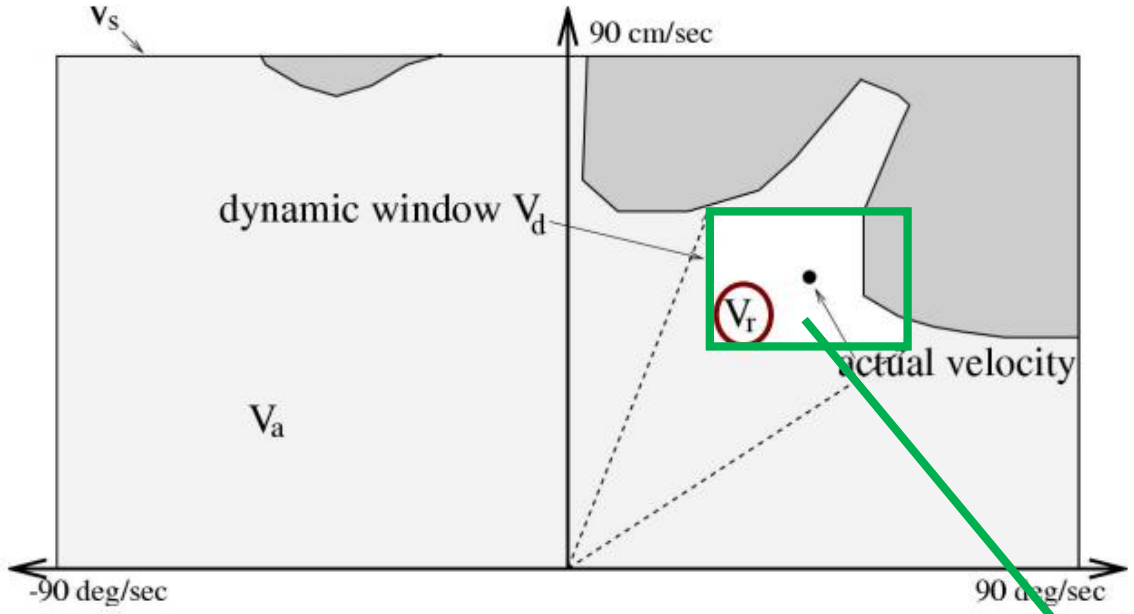
From : Lu, Yuncheng & Zhucun, Xue & Xia, Gui-Song & Zhang, Liangpei. (2018). A survey on vision-based UAV navigation. Geo-spatial Information Science

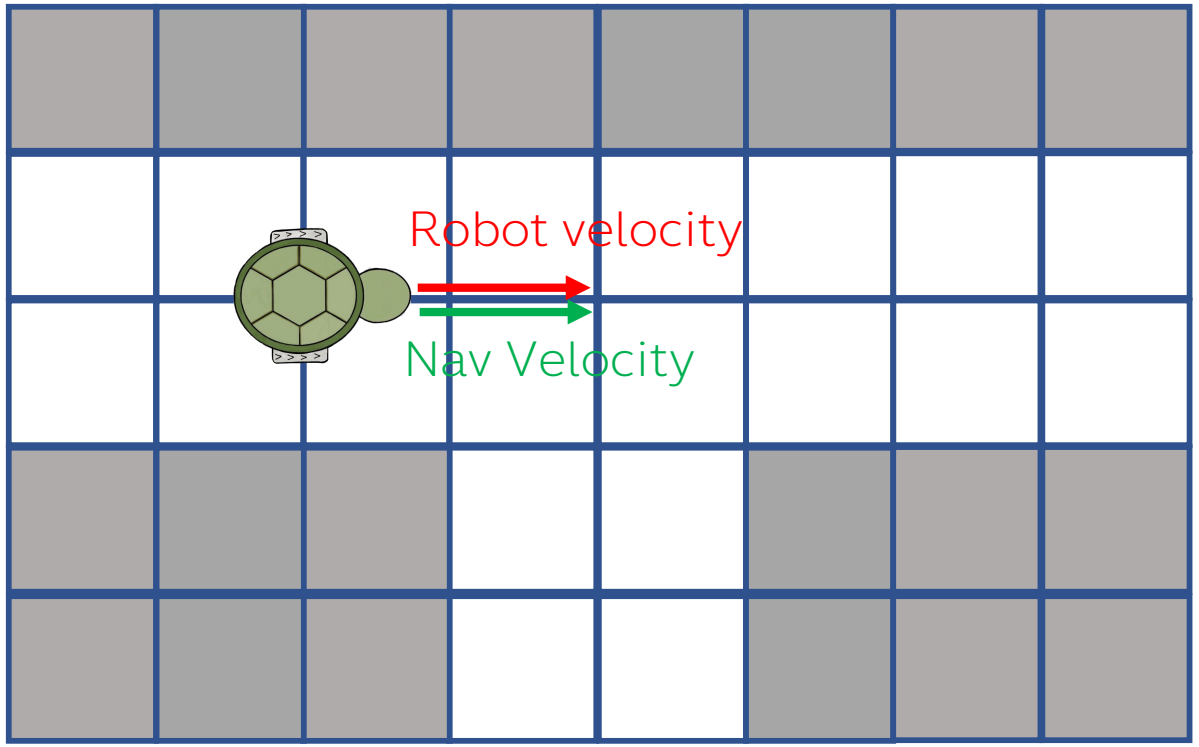
DWA local planer search



Navigation and Autonomous Driving

DWA local planer search





V_s = all possible speeds of the robot.

V_a = obstacle free area.

V_d = speeds reachable within a certain time frame based on possible accelerations.

$$V_r = V_s \cap V_a \cap V_d$$

Maximize velocity

Follows Grid based path (Global)

$$NF = \alpha \cdot vel + \beta \cdot nf + \gamma \cdot \Delta nf + \delta \cdot goal$$

Cost to reach the goal

Goal nearest

Navigation and Autonomous Driving

Run following command On Turtlebot:

Run the AMCL:

```
$ roslaunch turtlebot_navigation amcl_demo.launch map_file:=/tmp/my_map.yaml
```

```
[ INFO] [1589188330.345375072]: Using plugin "static_layer"
[ INFO] [1589188330.353272344]: Requesting the map...
[ INFO] [1589188330.558622889]: Resizing costmap to 32 X 32 at 0.050000 m/pix
[ INFO] [1589188330.658583904]: Received a 32 X 32 map at 0.050000 m/pix
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[ INFO] [1589188330.801454276]: Stopping device RGB and Depth stream flush.
[ INFO] [1589188330.849969357]: Using plugin "obstacle_layer"
[ INFO] [1589188330.854517455]:     Subscribed to Topics: scan bump
[ INFO] [1589188330.931099651]: Using plugin "inflation_layer"
[ INFO] [1589188331.005866802]: Created local_planner dwa_local_planner/DWAPlann
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[ INFO] [1589188331.011846625]: Sim period is set to 0.20
[ INFO] [1589188332.010352631]: Recovery behavior will clear layer obstacles
[ INFO] [1589188332.016616784]: Recovery behavior will clear layer obstacles
[ INFO] [1589188332.079586595]: odom received!
```
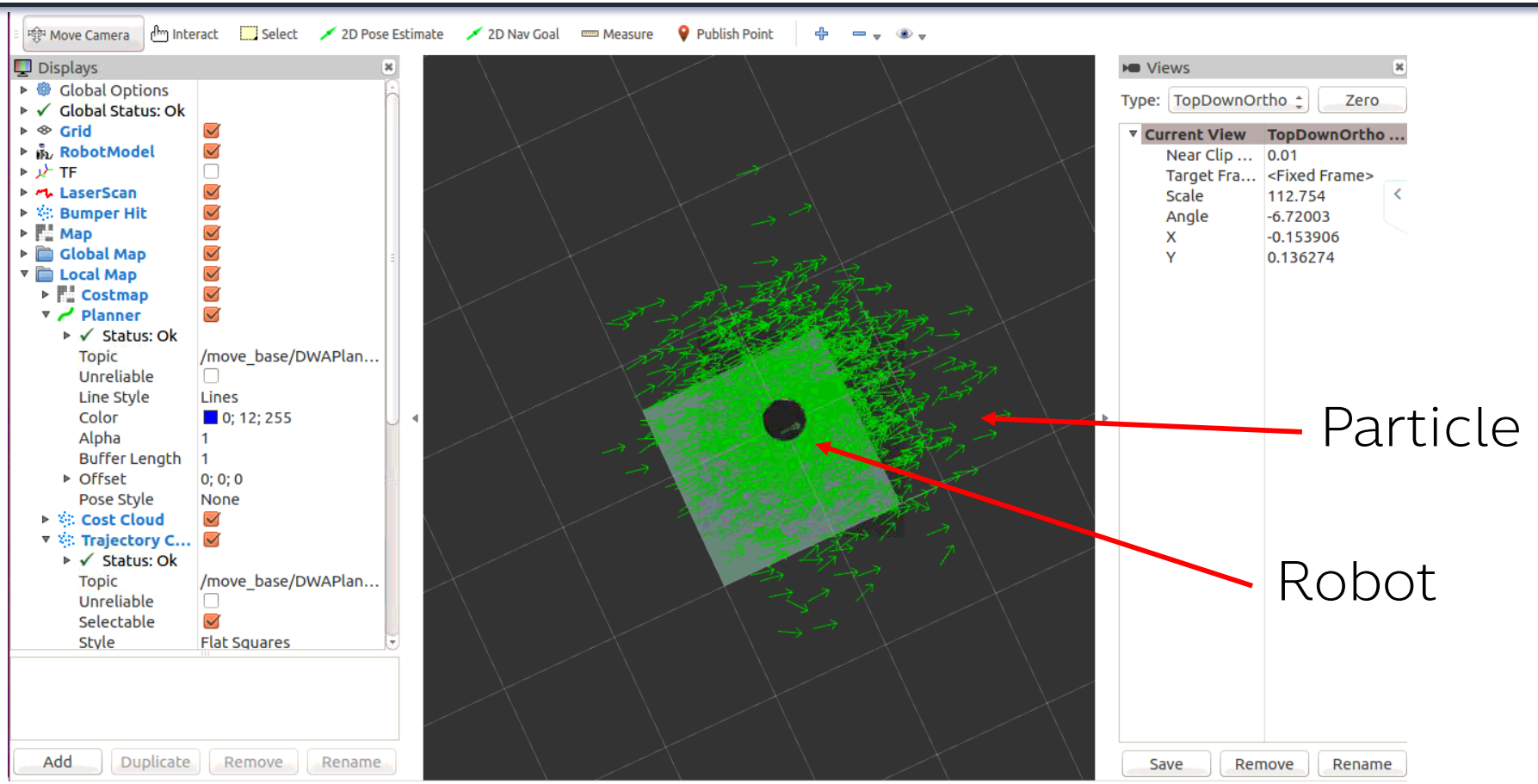

Navigation and Autonomous Driving

Run following command On Workstation:

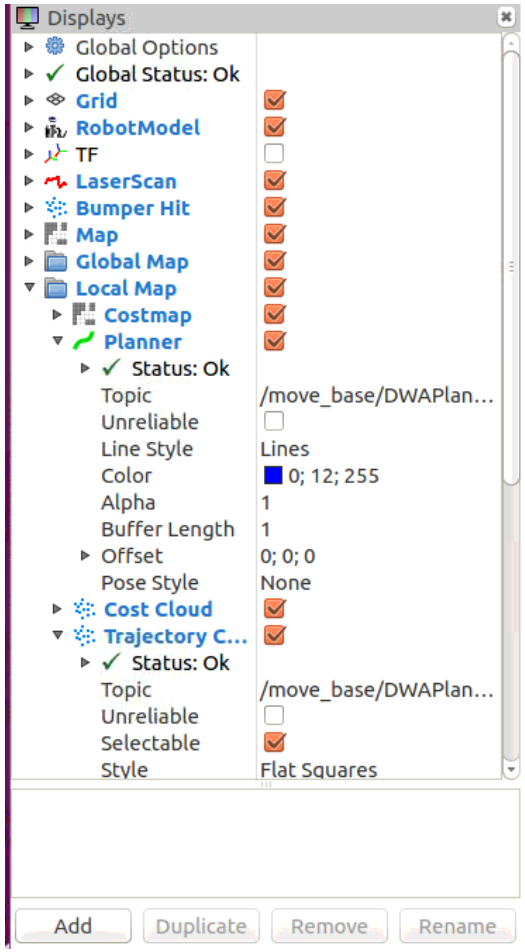
Run the robot visualization to show the map and position of robot:

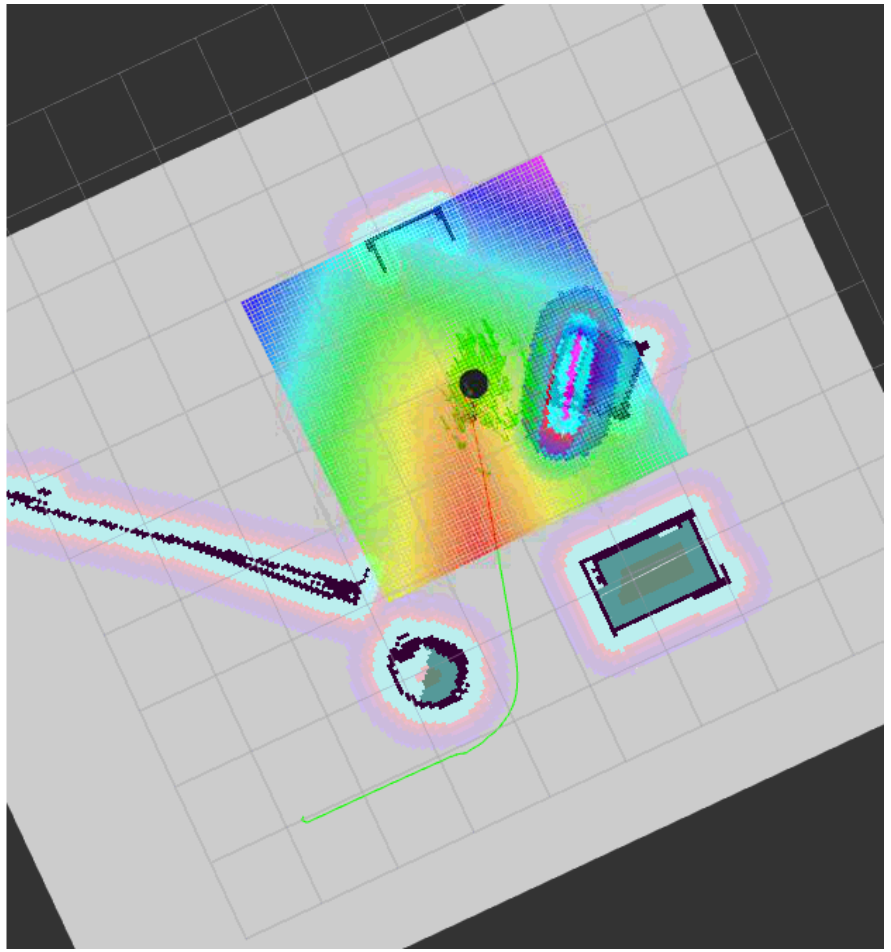
```
$ roslaunch turtlebot_rviz_launchers view_navigation.launch
```



Navigation and Autonomous Driving

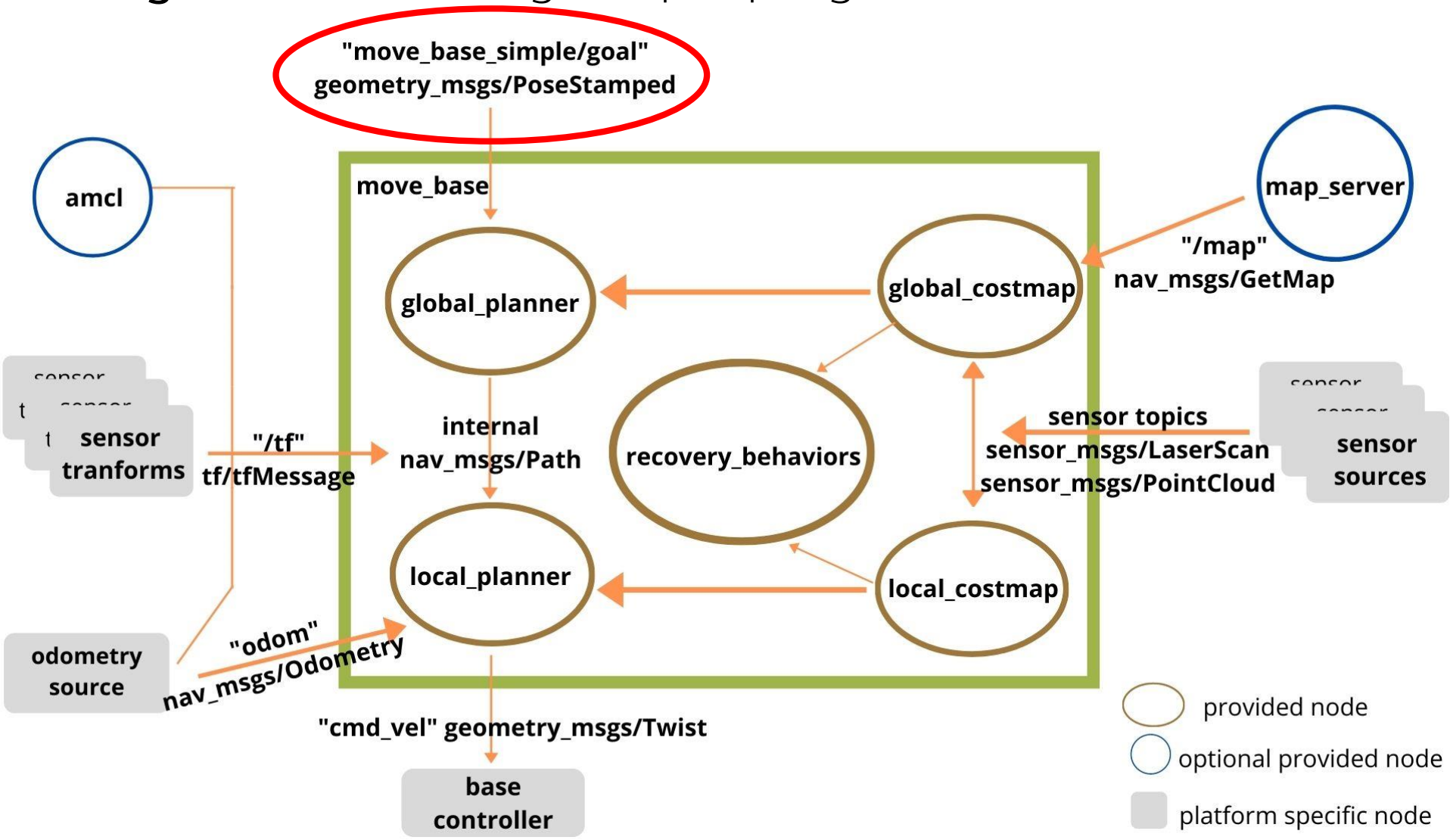
Send Navigation Goal via RViz



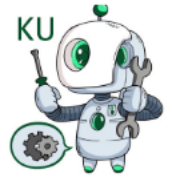


Navigation and Autonomous Driving

Send **Navigation** Goal using simple program



Example 1: Move forward with avoidance



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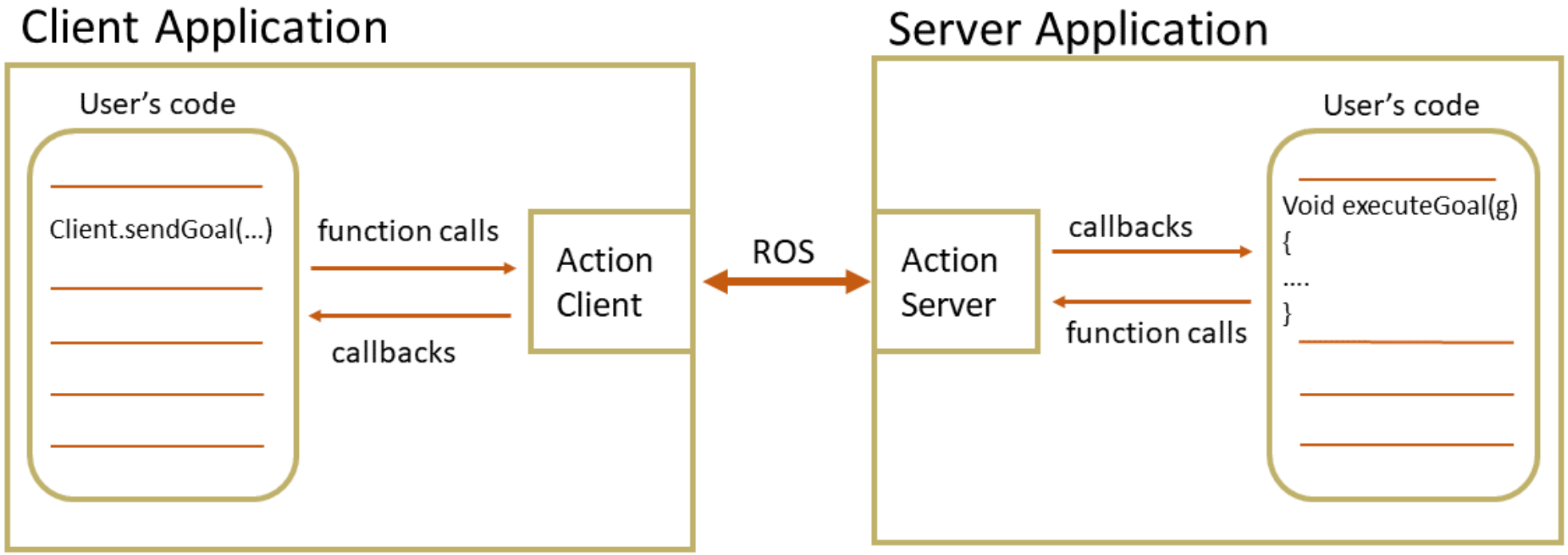
Navigation and Autonomous Driving

Send Navigation Goal via simple program



Navigation and Autonomous Driving

Going Forward and Avoiding Obstacles with Code

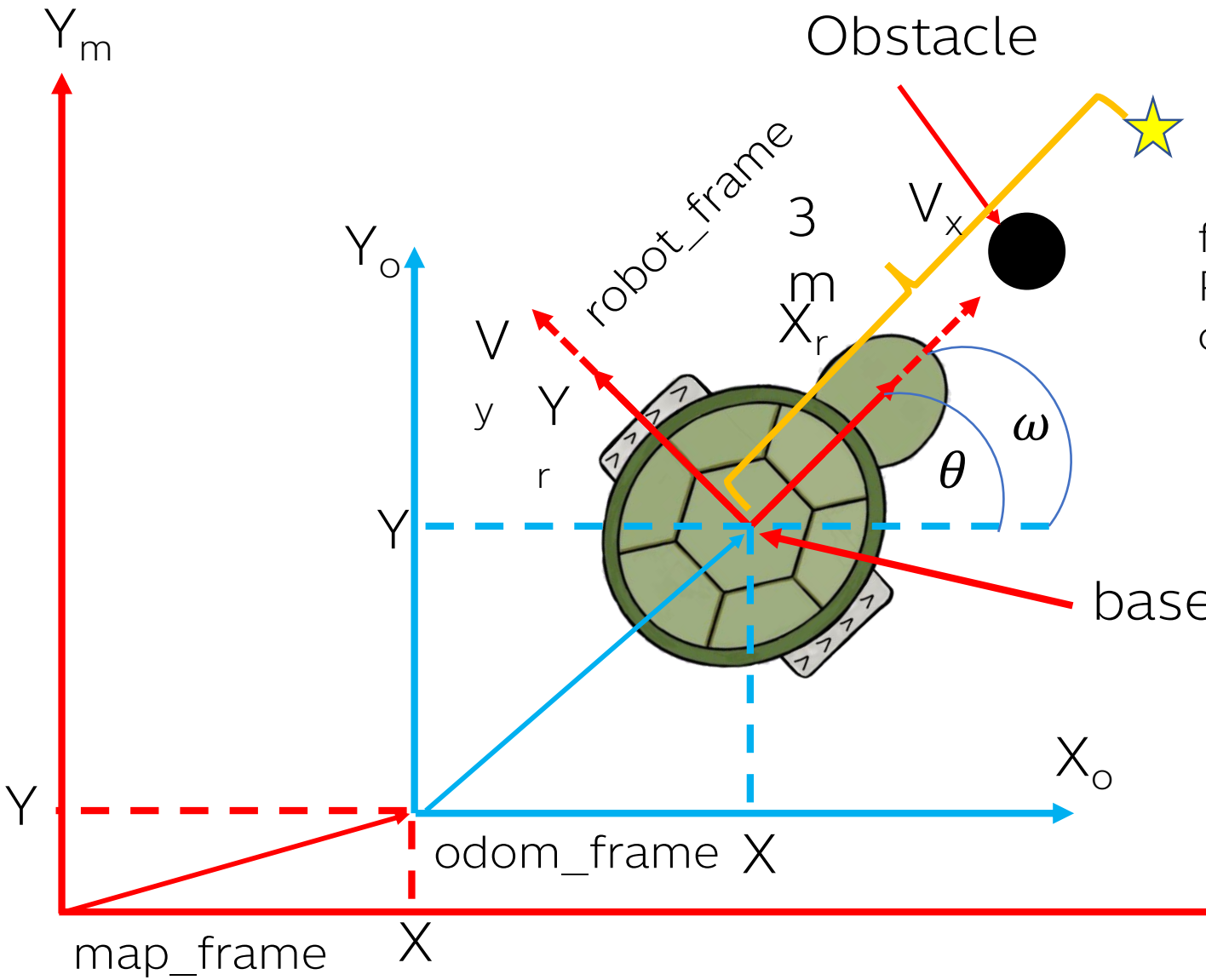

```
#!/usr/bin/env python
import rospy
from move_base_msgs.msg import MoveBaseAction, MoveBaseGoal
import actionlib
from actionlib_msgs.msg import *
if __name__ == '__main__':
    try:
        GoForwardAvoid()
    except rospy.ROSInterruptException:
        rospy.loginfo("Exception thrown")
```

Navigation and Autonomous Driving

```
class GoForwardAvoid():
    def __init__(self):
        rospy.init_node('nav_test', anonymous=False)
        rospy.on_shutdown(self.shutdown)
        #tell the action client that we want to spin a thread by default
        self.move_base = actionlib.SimpleActionClient("move_base", MoveBaseAction)
        rospy.loginfo("wait for the action server to come up")
        #allow up to 5 seconds for the action server to come up
        self.move_base.wait_for_server(rospy.Duration(5))
        #we'll send a goal to the robot to move 3 meters forward
        goal = MoveBaseGoal()
        goal.target_pose.header.frame_id = 'base_footprint'
        goal.target_pose.header.stamp = rospy.Time.now()
        goal.target_pose.pose.position.x = 3.0  #3 meters
        goal.target_pose.pose.orientation.w = 1.0   #go forward
```

Set Goal

Navigation and Autonomous Driving




```
frame_id = 'base_link'
Pose.x = 3.0            # 3 meters
orientation.w = 1.0     # go forward
```

Navigation and Autonomous Driving

```
    #start moving
    self.move_base.send_goal(goal)
    #allow TurtleBot up to 60 seconds to complete task
    success = self.move_base.wait_for_result(rospy.Duration(60))
    if not success:
       self.move_base.cancel_goal()
       rospy.loginfo("The base failed to move forward 3 meters for some reason")
    else:
       # We made it!
       state = self.move_base.get_state()
       if state == GoalStatus.SUCCEEDED:
          rospy.loginfo(“The base moved 3 meters forward")
```

```
    def shutdown(self):
        rospy.loginfo("Stop")
```

Navigation and Autonomous Driving

Run following command On Turtlebot:

Run the AMCL:

```
$ roslaunch turtlebot_navigation amcl_demo.launch map_file:=/tmp/my_map.yaml
```

Run the robot visualization to show the map and position of robot:

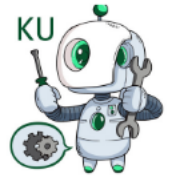
```
$ roslaunch turtlebot_rviz_launchers view_navigation.launch
```

Set the robot position

Run the obstacle avoidance node:

```
$ rosrun <package_name> <program_name>
```

Example 2: Go to Specific location



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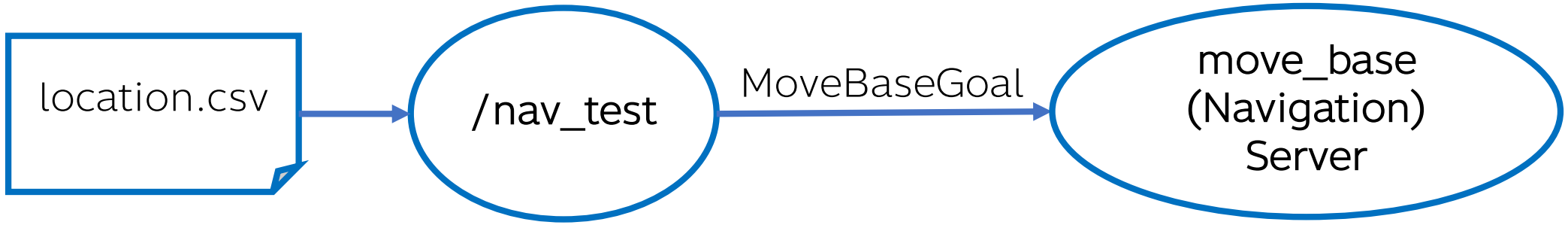
Navigation and Autonomous Driving

Going to a Specific Location on Map




```
#!/usr/bin/env python
import rospy
from move_base_msgs.msg import MoveBaseAction, MoveBaseGoal
import actionlib
from actionlib_msgs.msg import *
from tf.transformations import quaternion_from_euler
if __name__ == '__main__':
    try:
        robot_nav = RobotNavigation()
        robot_nav.go_to_location(“location_name”)
    except rospy.ROSInterruptException:
        rospy.loginfo("Exception thrown")
```

Navigation and Autonomous Driving

```
class RobotNavigation():
    def __init__():
        rospy.init_node('nav_test', anonymous=False)
        rospy.on_shutdown(self.shutdown)
        #tell the action client that we want to spin a thread by default
        self.move_base = actionlib.SimpleActionClient("move_base", MoveBaseAction)
        rospy.loginfo("wait for the action server to come up")
        #allow up to 5 seconds for the action server to come up
        move_base.wait_for_server(rospy.Duration(5))

    def go_to_location(self, position_name):
        x,y,theta = read_position(position_name)
        x,y,theta = float(x), float(y), float(theta)
        #convert euler to quanternion
        q = quaternion_from_euler(0,0,theta)
```

Load position

Navigation and Autonomous Driving

```
        goal = MoveBaseGoal()
        goal.target_pose.header.frame_id = 'map'
        goal.target_pose.header.stamp = rospy.Time.now()
        goal.target_pose.pose = Pose(Point(x, y, 0.000), Quaternion(q[0], q[1], q
[2], q[3]))
        self.move_base.send_goal(goal)
        success = self.move_base.wait_for_result(rospy.Duration(60))
        state = self.move_base.get_state()
        result = False
        if success and state == GoalStatus.SUCCEEDED:
            # We made it!
            result = True
        else:
            self.move_base.cancel_goal()
            self.goal_sent = False
            return result
```

Navigation and Autonomous Driving

```
def read_csv(self):
    thisdict = {}
    with open(“path_to_csv_file”, "r") as csv_file:
        csv_reader = csv.reader(csv_file,delimiter = ',')
        for row in csv_reader:
            thisdict[row[0]] = [row[1], row[2], row[3]]
    return thisdict
```

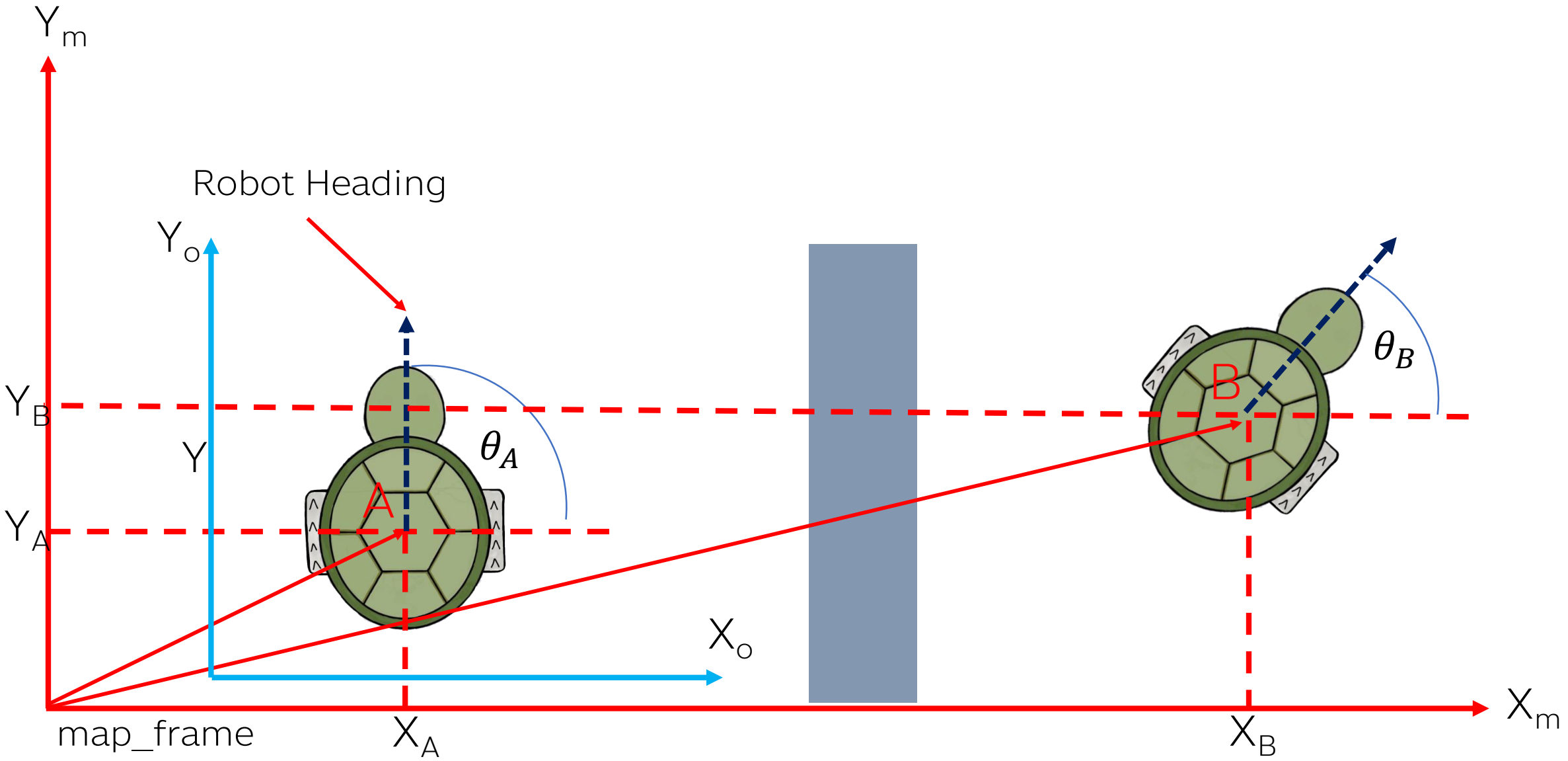
Convert csv to dictionary

```
def read_position(position_name):
    dict_position = read_csv()
    rospy.loginfo(dict_position[position_name])
    return dict_position[position_name]
```

Read Location from csv file

```
def shutdown(self):
    rospy.loginfo("Stop")
```

Navigation and Autonomous Driving



Navigation and Autonomous Driving

Map_file.csv

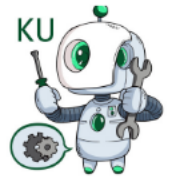
A, X_A , Y_A , θ_A
B, X_B , Y_B , θ_B

Get Turtlebot Position

```
$ rosrun tf tf_monitor /map /base_footprint
```

```
At time 1263248513.809
- Translation: [2.398, 6.783, 0.000]
- Rotation: in Quaternion [0.000, 0.000, -0.707, 0.707]
in RPY [0.000, -0.000, -1.570]
```

ROS TF



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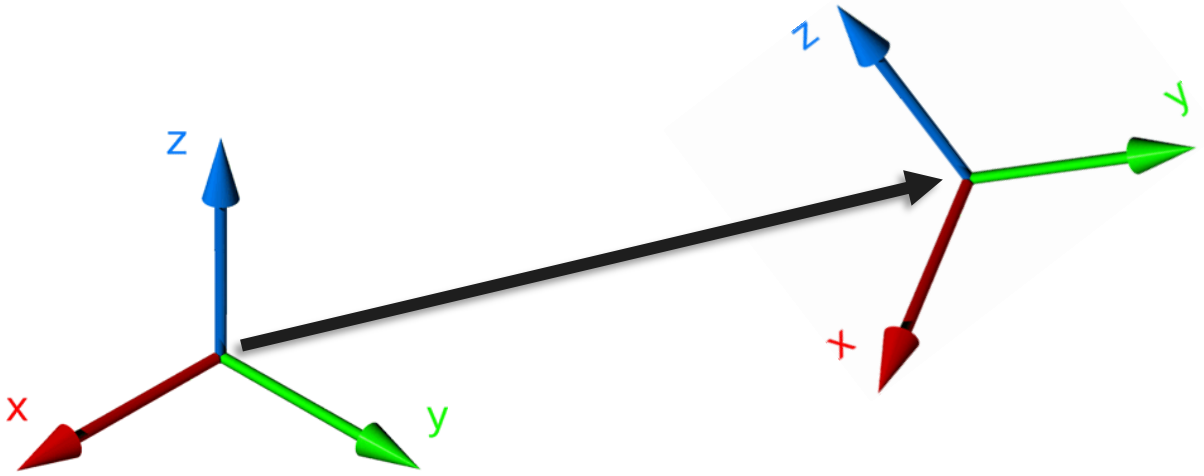
UNIVERSITY

ROS TF

What is tf

tf is a package that lets the user keep tracking multiple coordinate frames overtime.
Transform points, or vectors between two coordinates

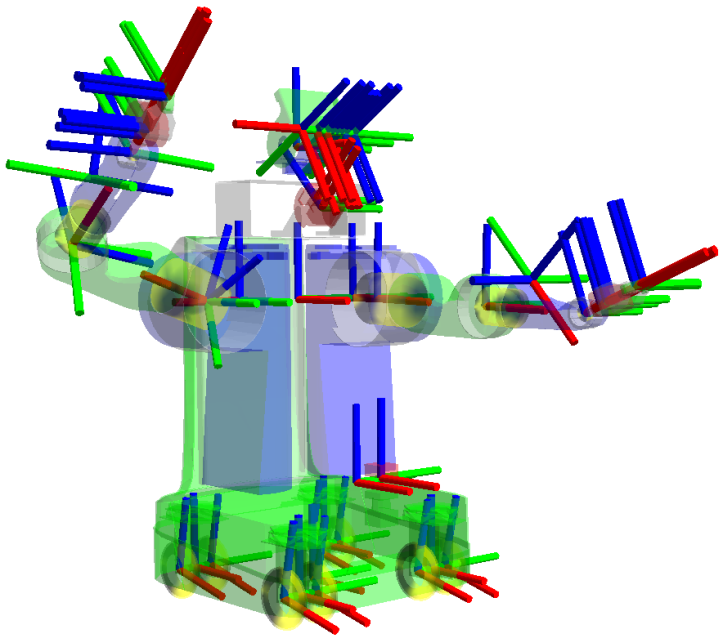


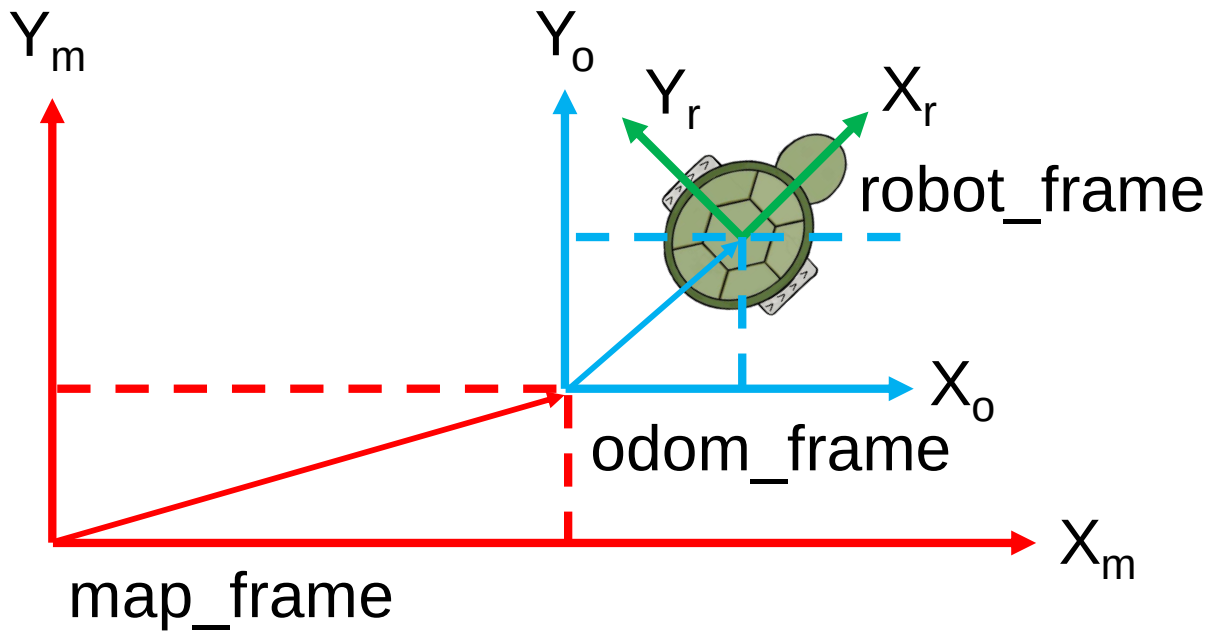
Source: http://wiki.ros.org/tf

ROS TF

Why should I use tf

A robotic system typically has many 3D coordinate frames that change over time, such as a world frame, base frame, gripper frame, head frame, etc. tf keeps track of all these frames over time





ROS TF

ROS tf Command-line Tools

tf_monitor <source_frame> <target_frame>

```
$ rosrun tf tf_monitor /base_footprint /odom
```

tf_echo <source_frame> <target_frame>

```
$ rosrun tf tf_monitor /map /base_footprint
```

ROS TF

Writing a tf listener with Python

```
def get_position(self):
    self.listener = tf.TransformListener()
    rate = rospy.Rate(10.0)
    get_position = False
    while not rospy.is_shutdown() and not get_position:
        try:
            (trans,rot) = self.listener.lookupTransform("/map","/base_link", rospy.Time(0))
            if trans != None:
                get_position = True
                print(trans)

        except (tf.LookupException, tf.ConnectivityException, tf.ExtrapolationException):
            continue
        rate.sleep()
    euler = tf.transformations.euler_from_quaternion(rot)
    return trans[0], trans[1], euler[2]
```

ROS TF

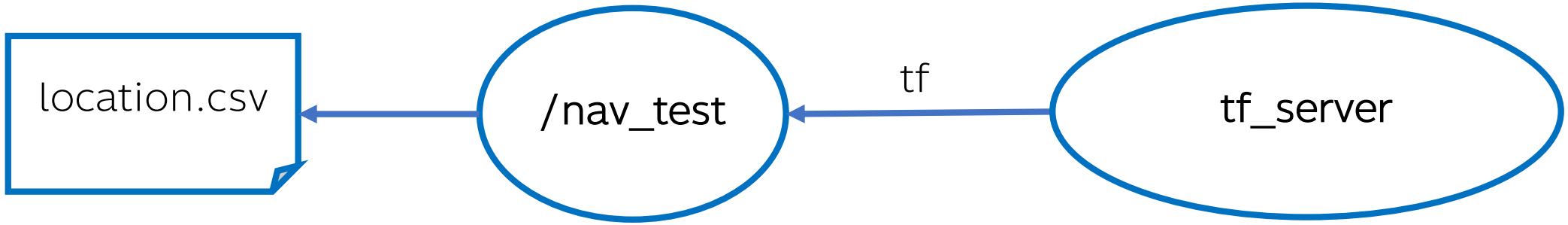
```
def save_position(self, position_name):
    try:
        x,y,theta = self.get_position()
        thisdict = self.read_csv()
        thisdict[position_name] = [x,y,theta]
        thislist = []
        for x in thisdict:
            thislist.append([x,thisdict.get(x)[0],thisdict.get(x)[1],thisdict.get(x)[2]])

        with open("file.csv", "w") as csv_file:
            csv_writer = csv.writer(csv_file,delimiter=',')
            for x in thislist:
                csv_writer.writerow(x)
        return True

    except:
        return False
```

ROS TF

Going to a Specific Location on Map

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THANK YOU