UNIVERSITÄT BONN

Rheinische Friedrich-Wilhelms-Universität Bonn
Prof. Dr. Maren Bennewitz

Institut für Informatik
Abteilung VI
Humanoid Robots Lab
Adresse:
Friedrich-Hirzebruch-Allee 8
53115 Bonn

Cognitive Robotics

Assignment 7

Due Tuesday, December 05th, before class.

7.1) Consider two features f_1 and f_2 extracted from an observation z_t, and a map $m_t = (l_1, l_2, l_3)$ with three landmarks. An assignment Ψ associates each observed feature f_i to a map landmark l_j, or marks it as a false detection or as a new landmark.

(a) Write down all possible assignments for the two observed features f_1 and f_2 and the three map landmarks $l_1 \ldots l_3$. Note that a single landmark cannot be assigned to more than one feature.

6 points

(b) Suppose now that for each assignment from (a), we create a new landmark for every observed feature that we marked as "new landmark" and add it to the map, resulting in m_{t+1}. For each map m_{t+1}, write down all possible assignments for a single feature f_3 extracted from the observation z_{t+1}. Again, each landmark can be assigned to at most one feature.

4 points

7.2) In bearing-only SLAM, the initialization of new landmarks (mean, covariance) is difficult, because the robot can only measure the angle between its orientation and the landmark, but not the landmark distance.
Find a method in the literature that has been proposed to overcome the 'delayed initialization' problem. (Hint: Perform undelayed initialization).

5 points

7.3) Consider EKF SLAM with a 6D robot pose (3 position coordinates, 3 rotation coordinates) and M 3D landmark positions. How many independent variables are needed to represent the state and its uncertainty?

5 points

7.1) Consider two features f_1 and f_2 extracted from an observation z_t, and a map $m_t = (l_1, l_2, l_3)$ with three landmarks. An assignment Ψ associates each observed feature f_i to a map landmark l_j, or marks it as a false detection or as a new landmark.

We have: 3 landmarks
2 features

Feature can be assigned to: 1) Existing Landmark
2) New Landmark
3) No Landmark (False)

(a) Write down all possible assignments for the two observed features f_1 and f_2 and the three map landmarks $l_1 \dots l_3$. Note that a single landmark cannot be assigned to more than one feature.

6 points

$$\boxed{P(n,r) = P(5,2) = \frac{5!}{(5-2)!} = \frac{5!}{3!} = \frac{120}{6} = 20}$$

All possible combinations are:

① $f_1 \to l_1$, $f_2 \to l_2$	② $f_1 \to l_1$, $f_2 \to l_3$	③ $f_1 \to l_2$, $f_2 \to l_1$	④ $f_1 \to l_2$, $f_2 \to l_3$
⑤ $f_1 \to l_3$, $f_2 \to l_1$	⑥ $f_1 \to l_3$, $f_2 \to l_2$	⑦ $f_1 \to$ new, $f_2 \to \emptyset$	⑧ $f_1 \to \emptyset$, $f_2 \to$ new

⑨ $f_1 \to l_1$, $f_2 \to$ new	⑩ $f_1 \to l_1$, $f_2 \to \emptyset$
⑪ $f_1 \to l_2$, $f_2 \to$ new	⑫ $f_1 \to l_2$, $f_2 \to \emptyset$
⑬ $f_1 \to l_3$, $f_2 \to$ new	⑭ $f_1 \to l_3$, $f_2 \to \emptyset$

15 $f_1 \to$ new, $f_2 \to l_1$	16 $f_1 \to \emptyset$, $f_2 \to l_1$
17 $f_1 \to$ new, $f_2 \to l_2$	18 $f_1 \to \emptyset$, $f_2 \to l_2$
19 $f_1 \to$ new, $f_2 \to l_3$	20 $f_1 \to \emptyset$, $f_2 \to l_3$

(b) Suppose now that for each assignment from (a), we create a new landmark for every observed feature that we marked as "new landmark" and add it to the map, resulting in m_{t+1}. For each map m_{t+1}, write down all possible assignments for a single feature f_3 extracted from the observation z_{t+1}. Again, each landmark can be assigned to at most one feature.

4 points

$m_t = \{l_1, l_2, l_3\}$

-> Supposed: No false detections

$m_{t+1} = \{l_1, l_2, l_3, l_4, l_5\}$

↳ new landmarks

Number of permutations (i.e. assignments) is in this case:

$$P(n,r) = P(5,3) = \frac{5!}{(5-3)!} = \frac{120}{2} = 60$$

7.3) Consider EKF SLAM with a 6D robot pose (3 position coordinates, 3 rotation coordinates) and M 3D landmark positions. How many independent variables are needed to represent the state and its uncertainty?

5 points

Each state is RV
It is described with μ and σ

For mean : $\mu = s = [\underbrace{s_x, s_y, s_z, s_\phi, s_\theta, s_\psi}_{\text{Robot pose}}, \underbrace{m_{1x}, m_{1y}, m_{1z}, \ldots, m_{Mx}, m_{My}, m_{Mz}}_{\text{Landmark position}}]^T$

$len(s) = 6 + 3 \cdot M$

For covariance matrix (i.e. uncertainity) we need to know the $\underbrace{\text{same number}}_{6 + 3 \cdot M}$ of variables (in this case standard deviations σ)

(we suppose correlation between states is given or they are uncorrelated)

So, we need $6 + 3M$ random variables (with mean μ and std σ)