Introduction to Robotics

Homework 2

1 What are the two categories of rotatory encoders? And by what way to categorize rotatory encoders? (10)

2 Describe the speed measurement principles with incremental rotatory encoders, and compare. (20)

3 What is the characteristic of grating rules? (5)

4: what are the properties of mechanical gyroscope? Explain them. (15)

5: Regarding laser ranger, explain the transit time method (渡越法)? (5)

6: Regarding acoustic ranger, explain the blind spot and crosstalk (盲区与串扰)? (5)

7 Describe the Bayesian Inference framework for mobile robot localization. (15).

8: Describe the pseudo code of MCL algorithm for mobile robot localization. (15)

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1 What are the two categories of rotatory encoders? And by what way to categorize rotatory encoders? (10)

Incremental Rotatory Encoder and Absolute Rotatory Encoder depending on how the disc is coded, uniformly or diversely.

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2 Describe the speed measurement principles with incremental rotatory encoders, and compare. (20)

M-Method: by counting the impulses from the encoder given time interval. In given time interval T, supposing M_1 impulses are detected, and there are N slits on the disc, then the rotation speed is calulated as $n = \frac{60 M_1}{NT}$ r/min Resolution: $S_m = \frac{60}{NT}$

T-Method: by measuring the time interval between two adjacent impulses $n = \frac{60f}{NM_2}$ r/min

Resolution: $S_t = \frac{60f}{N(M_2-1)} - \frac{60f}{NM_2} = \frac{60f}{NM_2(M_2-1)}$

M/T Method: Combination of M-Method and T-Method $n = \frac{60 M_1 f}{NM_2}$ r/min

Resolution: $S_{mt} = \frac{60 M_1 f}{N(M_2-1)} - \frac{60 M_1 f}{NM_2} = \frac{60 M_1 f}{NM_2(M_2-1)}$

Comparasion: ① M-Method is suitable for high speed measurement, while T-Method is suitable for low speed measurement.

② In low speed, M/T Method works as T-Method

③ In high speed, M/T Method works as M-Method.

④ M/T-Method is capable of precision speed measurement in a broader speed range.

3 What is the characteristic of grating rules? (5)

① Based on optical principle of the grating

② Often used in the closed-loop servo system of CNC machine tools

③ Detection of linear displacement or angular displacement

④ The measurement output signal is digital pulse

⑤ Large detection range, high detection accuracy and fast response speed.

4: what are the properties of mechanical gyroscope? Explain them. (15)

Rigidity: The axis of rotation (spin axis) of gyro wheel tends to remain in a fixed direction in space if no force is applied to it.

Precession: The axis of rotation has a tendency to turn at a right angle to the direction of an applied force.

5: Regarding laser ranger, explain the transit time method (渡越法)? (5)

The distance is determined by transmitting the laser beam to the object under test and receiving the reflected wave of the beam, using the time difference and speed between transmitting and receiving.

6: Regarding acoustic ranger, explain the blind spot and crosstalk (盲区与串扰)? (5)

At the moment of ultrasonic transmission, some sound waves will directly enter the receiving end, producing strong false reflection waves, resulting in crosstalk phenomenon.

In order to avoid crosstalk effectively, software delay processing is needed, which leads to the problem of detection blind spots.

7 Describe the Bayesian Inference framework for mobile robot localization. (15).

Symbols: $Bel(\xi)$ belief by a probability density over all locations $\xi \in \Xi$

$P(\xi|\bar{\xi}, a)$ transition density after the effect of a motion command $a \in A$

$P(s|\xi)$ the probability that $s \in S$ is observed at location ξ

$\sigma: S \to F$ sensor data are projected into a smaller space F

$p(f|\xi)$ relates the sensory features $f = \sigma(S)$ to different locations of the environment.

Robot localization: the robot's belief after executing the $t-1$ th action

$$Bel_{prior}(\xi^{(t)}) = P(\xi^{(t)} | f^{(1)}, a^{(1)}, f^{(2)}, a^{(2)}, \dots f^{(t-1)}, a^{(t-1)})$$

after taking the t-th sensor measurement

$$Bel_{posterior}(\xi^{(t)}) = P(\xi^{(t)} | f^{(1)}, a^{(1)}, f^{(2)}, a^{(2)}, \dots, a^{(t-1)}, f^{(t)})$$

Sensing: According to Bayes' rule,

$$Bel_{posterior}(\xi^{(t)}) = P(\xi^{(t)} | f^{(1)}, \dots, a^{(t-1)}, f^{(t)})$$

$$= \frac{P(f^{(t)} | \xi^{(t)}, f^{(1)}, \dots a^{(t-1)}) P(\xi^{(t)} | f^{(1)}, \dots, a^{(t-1)})}{P(f^{(t)} | f^{(1)}, \dots, a^{(t-1)})}$$

The Markov assumption states that sensor readings are conditionally independent of previous sensor readings and actions given knowledge of the exact location.

$$P(S^{(t)} | \xi^{(t)}) = P(s^{(t)} | \xi^{(t)}, s^{(1)}, a^{(1)}, \dots, a^{(t-1)})$$

Since $f^{(t)} = \sigma(s^{(t)})$, it follows that

$$P(S^{(t)} | \xi^{(t)}) = P(f^{(t)} | \xi^{(t)}, f^{(1)}, a^{(1)}, \dots a^{(t-1)})$$

8: Describe the pseudo code of MCL algorithm for mobile robot localization. (15)

Algorithm MCL(X_{t-1}, u_t, z_t, m):

$\bar{X}_t = X_t = \phi$

for $m=1$ to M do

$x_t^{[m]}$ = sample_motion_model$(u_t, x_{t-1}^{[m]})$

$w_t^{[m]}$ = measurement_model$(z_t, x_t^{[m]}, m)$

$\bar{X}_t = \bar{X}_t + \langle x_t^{[m]}, w_t^{[m]} \rangle$

endfor

for $m=1$ to M do

draw i with probability $\propto w_t^{[i]}$

add $x_t^{[i]}$ to X_t

end for

return X_t