Written Exam in Intelligent Vehicles – MK8005

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Assistant aids:	**Writing tools, calculator and an arbitrary book on formulas (e.g. Beta).**
Date:	**Halmstad, 2012-03-13**
Time limit:	**4 hours**
Answers:	**All answers should be motivated. The answers should be kept as <u>short</u> as possible.**
Language:	**Write your answers in either Swedish or English language.**
Contact:	**Björn Åstrand, 0733 – 121285**
Points and grades:	**Maximum points = 50 [20 – 29.5]p gives grade = 3 [30 – 39.5]p gives grade = 4 [40 – 50.0]p gives grade = 5**
Passing the exam / Final grade:	**You should, to pass the exam, achieve at least the grade 3**

Good luck,

/Björn

1. Assume that the covariance matrix for estimation error of the robot pose [x,y,θ] is given by

$$\begin{pmatrix} 0.05 & 0.01 & 0.02 \\ 0.01 & 0.09 & 0.03 \\ 0.02 & 0.03 & 0.15 \end{pmatrix}$$

What is the standard deviation of the estimation of the y-coordinate?

(2p)

2. Mention something (information, hardware, etc.) that is needed for odometry?

(2p)

3. Mention a problem then using phase difference to measure distance, e.g. laser range scanner?

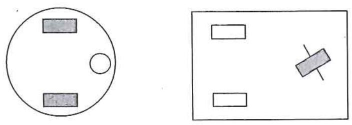
(2p)

4. Mention one advantage and one disadvantage with an active sensor?

(2p)

5. In Exercise 2 we were using two different types of robots: Khepera, a deferential drive robot and Snow-white, a steer-drive robot. Explain how they are controlled and the difference between them regarding how they are controlled, e.g. steering.

(4p)

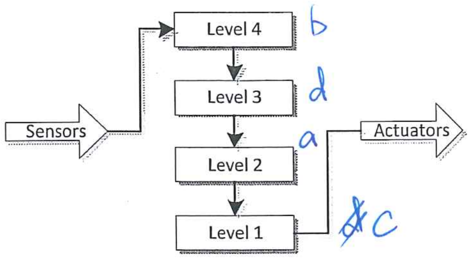


6. What is the difference between local and global path planning?

(2p)

7. Figure below describes the architecture for map-based navigation. Connect following concepts to right level (1-4) in figure below.
   a. Cognition/planning
   b. Perception
   c. Motion control
   d. Localization / map-building

(4p)



8. In Exercise 1 we found that speed estimates using GPS was much better than the position estimate.
   a. Explain why? (4p)
   b. How many satellites are needed for estimating the position and why?

(2p)

9. How will your dead reckoning system estimate differ from the true motion of a differential drive robot if the wheelbase is assumed to be larger than it really is? Motivate by making a rough calculation for a case when we falsely assume that it is 10% larger than the true value.

(4p)

10. **Assume that you measure the distance to an object using a laser range scanner and an ultrasonic sensor. You want to combine these two measurements to a single estimate using a Kalman filter.**

   a. **Under which conditions gives this combination the smallest variance?**

   (2p)

   b. **Derive the expression of the linear combination $\hat{X} = f(X_{laser}, X_{ultasound}, \sigma^2_{laser}, \sigma^2_{untrasound})$ that gives you the smallest variance of the estimated distance $\hat{X}$.**

   (4p) 8

   c. **Derive an expression of the variance of $\hat{X}$ if the variance of the ultrasound sensor is ten times bigger than the laser range sensor.**

   10X $(1+10)X$

   (2p)

11. **The differential drive robot, which was used in exercise 2 and Wang paper, the vehicle's relative movement in between time steps k and k+1 ($\Delta x, \Delta y, \Delta\theta$) can be seen in Equation 2.**

$X_{k+1} = X_k + \Delta X$ there

$$\Delta X = \begin{pmatrix} \Delta x \\ \Delta y \\ \Delta\theta \end{pmatrix} = \begin{pmatrix} \Delta s \cos\left(\theta + \frac{\Delta\theta}{2}\right) \\ \Delta s \sin\left(\theta + \frac{\Delta\theta}{2}\right) \\ \Delta\theta \end{pmatrix} \quad \text{and} \quad \begin{aligned} \Delta s &= \frac{\Delta s_r + \Delta s_l}{2} \\ \Delta\theta &= \frac{\Delta s_r - \Delta s_l}{L} \end{aligned} \qquad \text{(Equation 2)}$$

there $\Delta s_r, \Delta s_l$ are the incremental distance traveled by the robots left and right wheel, $\Delta\theta$ the change of heading, and L the distance between the wheels.

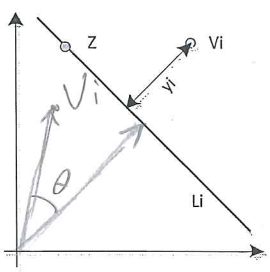
   a. The input signals, Δs and $\Delta\theta$, are not known with absolute certainty. In the Wang paper they assumed random error of odometry and this can be modeled by a parametric distribution. They derived following expression for the variance of change in robots heading, $\sigma^2_{\Delta\theta} = (\sigma_r^2 + \sigma_l^2)/L^2$, and the variance of robot incremental distance traveled, $\sigma^2_{\Delta s} = (\sigma_r^2 + \sigma_l^2)/4$. Calculate the co-variance matrix of X_{k+1}, i.e. the position uncertainty $\Sigma_{X_{k+1}}$, with respect to the uncertainty in the input signals. (You should do all necessary calculations.) (8p)

12. **Briefly explain the main difference between a map-based navigation system and a behavior-based navigation system?**

   (2p) 14

13. **In exercise 3 we used the Cox algorithm for matching range scans. The algorithm tries to minimize the distance of all points to a line map. Explain how the distance between a point and a line, *yi*, is calculated?**

   (4p)



$\begin{bmatrix} \cos\theta & -\sin\theta \\ \sin\theta & \cos\theta \end{bmatrix} (V_i - y_i) + y_i$

$\rho - 0$. App.

$\rho \begin{bmatrix} 0 & -1 \\ 1 & 0 \end{bmatrix} (V_i - y_i) + V_i$

$V_i \cdot N_i = V_i \cos\theta \cdot N_i$