UNIVERSITY OF MORATUWA

Faculty of Engineering

Department of Electronic & Telecommunication Engineering

B.Sc. Engineering

Semester 8 Examination

EN 4562 – AUTONOMOUS SYSTEMS

Time Allowed: 2 hours

Feb 2013

INSTRUCTIONS TO CANDIDATES

1. This paper contains **FOUR (04)** questions on **FOUR (04)** pages.
2. This examination accounts for **60%** of the module assessment. The marks assigned for each question and sections are included in square brackets.
3. This is an **OPEN** book examination. You are allowed to use **ONLY/ANY** written **AND/OR** printed material.
4. Time allowed is 2 hours.
5. Answer **ALL (04)** questions.

1 Autonomous cars have been getting attention since recently. Driving autonomously in urban roads staying in lane, overtaking other vehicles, and following traffic rules at interactions are complex problems for the designers of such vehicles.

a) Describe the problem of lane detection in more details and suggest a sensor system and its functionality for an autonomous car to "stay in lane". [05]

b) Describe the problem of overtaking a car, which is moving slower in the same lane. Propose an appropriate sensor system and control algorithm for an autonomous car to be able to safely overtake another vehicle. [05]

c) Describe the problem of following traffic rules at an intersection (red, amber, green lights, pedestrians and other vehicles). Propose a sensor system and control algorithm for an autonomous car to be able to safely handle this situation. [10]

d) Describe perception and learning problems in autonomous cars. [05]

2 Orientation of an unmanned aerial vehicles is illustrated in Fig. 2, where Earth and UAV co-ordinate frames are represented by fixed frame {xe ye ze}, and moving frame {xb yb zb}, respectively.

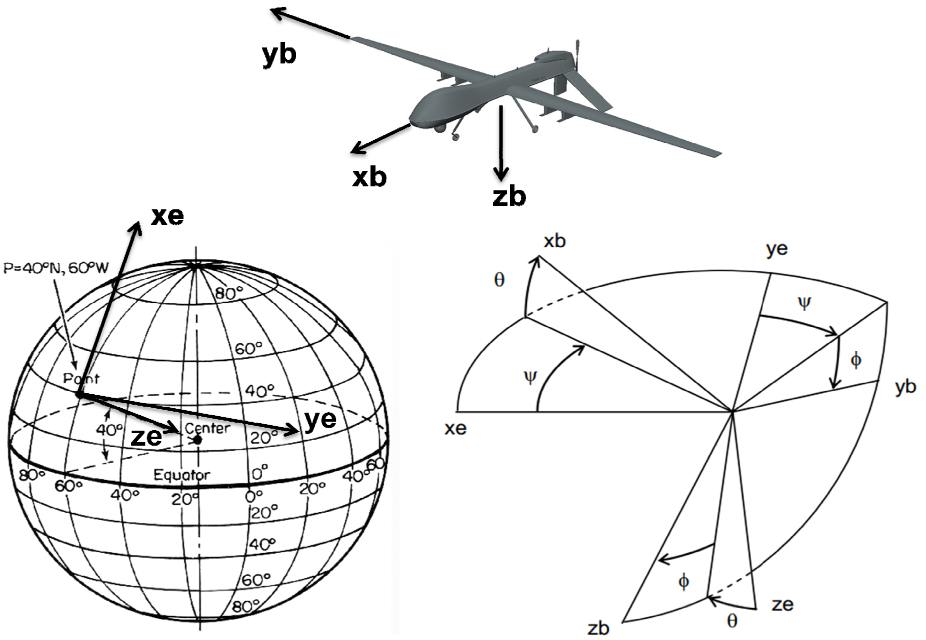

Fig 2. Earth and Body Frames of a Unmanned Aerial Vehicle System

a) At time $t = kT$, the orientation of the UAV is [10]

${}^{E}_{B}\boldsymbol{R}(\boldsymbol{k}) = [\varphi(\boldsymbol{k}), \theta(\boldsymbol{k}), \phi(\boldsymbol{k})] = [10^o\ 5^o\ 30^o]$, and the onboard gyroscope gives angular rate signals as $[\omega_{Bx}(\boldsymbol{k}), \omega_{By}(\boldsymbol{k}), \omega_{Bz}(\boldsymbol{k})] = [-5^o\ 4^o\ -10^o]\boldsymbol{s}^{-1}$. Calculate the following matrices:

1. Orientation matrix of the UAV at $\boldsymbol{t} = \boldsymbol{kT}$.

2. Orientation matrix of the UAV at $t = (k+1)T$.[Assume 20Hz update rate].

b) Perform orthogonality correction of the rotation matrix after being updated, using its first two column vectors. Verify whether orthogonality has been improved after correction. [10]

c) Perform Renormalization of the rotation matrix after update. Verify renormalization accuracy. [10]

3 Fig. 3 shows the vehicle-single landmark system used to establish a SLAM problem. Vehicle state is defined by its position (x, y) and orientation angle (θ). Landmark state is defined by its coordinates (x_l, y_l). Velocity of the vehicle (V) and the steering angle (ϕ) are measured using encoders. L and ρ are the distance measurements as shown in the figure. For localization, IR sensor is used and placed at the center of the axel of the rear wheels. The IR sensor can return only distance measurements (r_l) to the landmark.

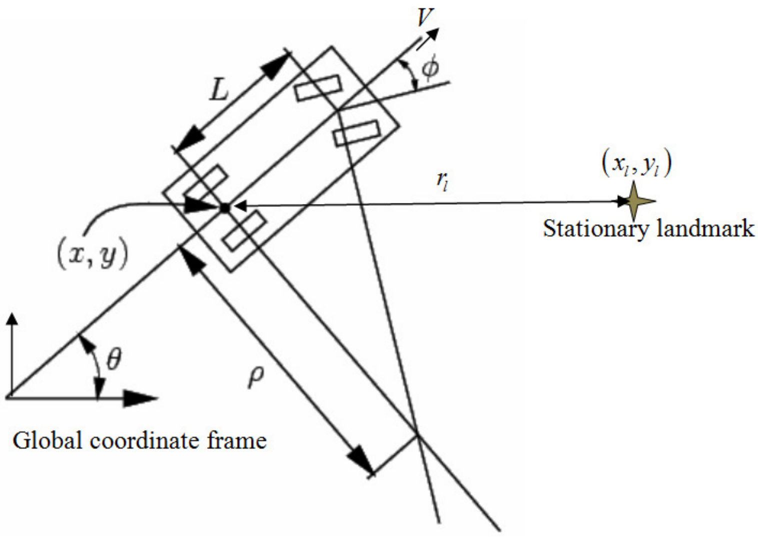

Fig. 3: Vehicle - single landmark system

a) Derive the kinematics equations ($\dot{x}, \dot{y}$ and $\dot{\theta}$) for the vehicle provided $\rho\dot{\theta} = V$ [04]

b) Derive the discrete time motion model of the vehicle using kinematics equations in part (a) above. [02]

c) Obtain the landmark process model. [02]

d) Obtain the augmented process model of the composite system. [02]

e) Obtain the Jacobian matrix of the augmented process model with respect to the state variables of the composite system. [04]

f) Obtain the Jacobian matrix of the augmented process model with respect to the control inputs V and ϕ. [04]

g) Derive the measurement model of the system. [01]

h) Obtain the Jacobian matrix of the measurement model with respect to the state variables. [02]

i) Write down the Kalman filter equations for predicted state estimation and predicted state error covariance. Indicate the dimensions of the each and every matrix in each equation. [04]

4 A fuzzy PD controller with TSK fuzzy rules is sown in Fig. 4. Assume X as the error, Y as the rate of error, and Z as the control input to the actuator.

$X, Y \in [-5, 5]$ ➡ $Z \in [-2, 10]$

R1: if X is small and Y is small then $z = -x + y + 1$
R2: if X is small and Y is large then $z = -y + 3$
R3: if X is large and Y is small **then** $z = -x + 3$
R4: if X is large and Y is large then $z = x + y + 2$

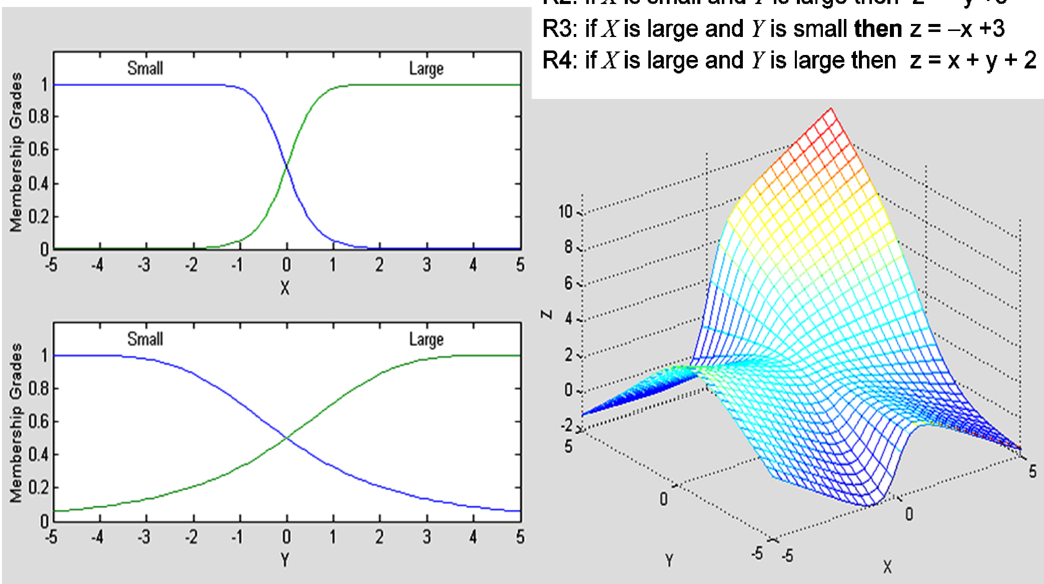

Fig. 4: TSK fuzzy controller

a) Appreciate specific characteristics of this controller comparing it with other linear controllers. [04]

b) Describe how the rules and their coefficients can be determined. [04]

c) At a given moment, the error and error rate were read as -0.5 each. Determine the following: [12]
1. Error memberships.
2. Error rate memberships.
3. Rule outputs and weightages (assuming minimum rule).
4. Calculate the control input to the actuator.

– **End of Paper** –