Kungl Tekniska Högskolan
Autonomous Systems, NADA
Stockholm

Student's Name:

Course Name **Robotics and Autonomous Systems**

Pers. Number:

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The written exam carries 50% of the credit for the course. Questions 1-4 carries 8 point credit each, and Questions 5 carries 18 point credit. Please keep in mind that some questions might take longer than others to complete. For that reason it might be useful to read through the entire test before starting to solve individual problems.

1. What are the main motivations for use of legged and wheel robots, respectively? For what applications would you select a legged implementation and for what applications would you select a wheeled system?

Legged systems have the advantage that their provide a much degree of flexibility in terms of the types of environments that they have handle. Wheeled systems on the other hand are more energy efficient for operation on planar surfaces, Legged systems also have the advantage, with enough legs, that the stability of the platform during motion can be improved more than for wheeled systems. Legged systems are of significant utility in unstructured / non-planar environments, where as wheels are the obvious choice for planar / engineered environments such as on roads and in in-door environments.

2. In the consideration of vehicle control we talk about holonomy and non-holonomy. a) Explain the concept of non-holonomy. b) Is a normal bicycle holonomous? why/whynot? As part of the characterisation of motion for a robot one might talk about instantaneous centre of rotation? What is it and how is it computed?

A holonomous vehicle is a vehicle that has a motion systems that is fully integrable or a system in where the robot is fully controllable for all its physical degrees of freedom, without boundary conditions. A bicycle is not fully holonomous, as the position of the rearwheel only can be moved axially through motion of the entire vehicle. The instantaneous centre of rotation is the point of motion around which the centre of the platform presently rotates. It is computed as

$R = l\,(theta_l + theta_2) / (theta_l - theta_2)$

Where L is the distance between the wheels and $theta_i$ is the velocity of the left/right wheel respectively

3. Sensing is a crucial modality for building mobile platforms. a) Outline 3 methods for estimation of the distance to an object, b) How could such range measurements be combined to generate better results?, c) GPS is used for localisation outdoors. c1) Why can it not be used for indoor localisation? c2) What are the three types of error sources for a GPS system?

a1) time of flight (the time it takes for a pulse to travel from a transmitter to the object and back to a received)

a2) phase differencing. Using a modulated signal and doing continuous transmission. The phase difference on the modulation can be used for estimation of time of travel (modulo the wavelength of the modulation signal)

a3) triangulation: observation of the distortion of a signal as it is reflected of the object. The amount of distortion is typically inverse proportional to the distance to the object.

b) A typical way to combine information is through uncertainty based fusion. Simple weighted averaging is one option, another is Bayesian fusion in which each sensor is modeled as a stochastic signal with a probability distribution and the fusion can be based on estimation of the best estimate. For simple variance based weighting a solution would be

x_fused = (sigma_2^2 * x_1 + sigma_1^2 * x_2) / (sigma_1^2 + sigma_2^2)

c1) GPS uses radiosignals in the 1.4 GHz range which are reflected off most materials and thus the signal cannot penetrate normal building materials and reach an in-door antenna. So the received antenna must have line of sight to the GPS satellites.

c2) The normal categorisation of errors in a GPS systems are according to space segment, atmospheric segment and user segment. Each of these segments have their own contribution to the error. Through use of differential correction the space and the atmospheric disturbances can be reduced or eliminated.

4. Mention 3 methods for localisation for a mobile platform and 2 methods for environment modelling. What are the main differences?

a1) Kalman Based Estimation of Pose

a2) Particle based estimation of pose distribution

a3) Multi-hypothesis estimation of pose from a tree search with Kalman filters.

b1) grid based - a probability grid

b2) feature based models with features such as lines and points

b3) topological graphs

The differences between a1-a3 is the representation of the inherent uncertainty as uni-modal, any distribution or multi-modal gaussian. The differences in representation is either a homogenous grid, a list of features or a graph of the environmental geometry. The updating of the uncertainty based on new sensory data is coupled both to the model of the environment and the associated model for uncertainty in pose.

5. You have been promoted to be the chief engineer for the design of a new generation of vacuum cleaners to be manufactured by "we-suck-more-than-others". The robot is required to

- Operate in in-door environments
- Handle open areas up to 10x10 meters
- Automatically handle obstacles in the environment
- Must be safe so as not to drive down staircases

a) What type of kinematic structure would you choose? why?

b) What sensor would you put on the platform? why?

c) What would you consider to be the hardest problem in the design of the system

This is a general design task so there is no single correct solution, but some hints can be given!

a) to simplify operation in handling of corners it is easiest to have a differential drive robot, which is also the reason why it is used on most commercial systems

b) as the robot must operate in areas up to 10x10 meters than absolute localisation cannot be achieved with sonar only if there are no objects in the room. Consequently there is a need to integrate different sensors. A good combination could be dead-reckoning (wheel encoders/quadrature), inertial sensor package, sonar / IR for local obstacle handling and local mapping, IR sensors for short-range forward/down looking to ensure detection of staircases. Sonar and IR also allow for local mapping so that a simple deterministic search method can be used for avoidance of objects.

c) The hardest problem is cost reduction to bring the entire package into a system that can be manufactured at a price that is acceptable for sales.