Exam in
DD2425 Robotics and Autonomous Systems

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The total time to complete the exam is at most 3 hours. Please read the entire exam before preparing the answers to make sure that you have a good view of the questions to be answered. You need at least 30 points to pass. Good luck!

Do not forget to turn the page!

Short questions, short answers

1. Mention 2 causes for non-systematic errors in odometry. (2p)

   slippage, obstacles on the floor

2. Mention 3 principles to measure the range to unknown objects (we are after the underlying principles and not a specific sensor or a specific way to implement it with, for example, sound) (3p)

   Time of flight, phase difference, triangulation (stereo), intensity

3. One of often talks about SLAM (Simultaneous Localization And Mapping) as a chicken-and-egg problem. Explain briefly? (3p)

   To perform localization you need a map and to build a map you need the position, which comes first? This is the chicken and egg problem and the solution is to perform localization and mapping at the same time.

4. When and why is suspension needed on a wheeled platform? (3p)

   When you have more than 3 wheels you need suspension to make sure that the wheels are in contact with the ground. Suspension is good already from a single wheel to reduce vibrations, improve traction, etc

5. Mention 2 causes for systematic errors in odometry. (2p)

   incorrect wheel radii, incorrect wheel base, misaligned wheels

6. Explain what skid steering is briefly? What are the cons with it? (4p)

   For example, a platform with four fixed wheels or tracks. It cannot turn without the wheels/tracks slipping/skidding on the surface. This makes it hard to predict how the platform actually moves when it turns, hence the odometric performance is typically poor. The wheels also wear down quickly.

Longer questions, longer answers

7. What do you typically measure with an ultrasonic sensor? How is it measured? Mention pros/cons with it. (8p)

   It typically measures distances by time-of-flight of sounds. Sound travels rather slowly in air which gives a quite low sampling rate. The sound propagates in a cone. Pros: relatively cheap, easy to use, used a lot (well studied), ..., cons: large angular uncertainty, specular reflections, soft surfaces absorb most of the sound (difficult to detect), low sampling rate ...

8. If a robot has a differential drive system. What does that mean? Pros/cons? (6p)

   Two independently controlled wheels positioned along the same axis. The direction of the axis is orthogonal to the direction of motion. Pros: easy to implement, easy to control. Cons: Motion limited to forward/back and rotation, ie cannot move sideways.

9. Explain what coordinated linear motion means (4p).

   If you want an arm to describe a linear motion from A to B you need to coordinate the motion of the joints. Each joint will have a value corresponding to being at A and B. If they were to make the change in angle as fast as possible independent of each other the arm would not move along a straight line. Instead one needs to coordinate the joints such that the change in the joint values keep the arm on the line.

10. You have calibrated your camera (set to operate at 320x240) and learned that the focal length is f=380 pixels. Assume that you place the camera 10cm above a flat floor with the optical axis tilting down $\alpha = 10°$.
    a) What is the field of view vertically and horizontally? (4p) b) How far from the camera is the closest point on the floor that you can see in the image (4p)? c) Where in the image would the intersection between floor and wall be if the wall is 1m away from the camera (4p)?

    a) Horizontal field of view $2 \cdot atan(120/380) = 35°$. *Veritical field of view* $2 \cdot atan(160/380) = 46°$.
    b) $10cm/tan(10° + atan(120/380)) = 19.2cm$ *where you need to deal with degrees and radians*
    c) $120 + 380 \cdot tan(atan(0.1/1.0) - 10°) = 91$ *pixels from the top*

11. Recent advances in MEMS technology have made inertial sensors much more affordable and you now find them in many consumer products today. For each of compass, gyro and accelerometer describe (18p)
    What quantity does the sensor measure (be precise!)?
    What is it typically used for and why is it good for that?
    Pros
    Cons

    Compass: *Measures the direction of the (Earth's if we are lucky) magnetic field. Used to estimate the orientation as it does so without drift. Pros: Gives absolute measure of orientation. Cons: Easily disturbed by other magnetic fields.* **Gyro:** *Measures rotational speed around an axis. Used for estimating the rotation speed and often also to get a measure of the angle by integration as it is not affected as much by magnetic fields as compass. Pros: High bandwidth, works really well over short time intervals, Cons: Drifts with time when integrating for angle, bias and cross sensitivity can be*

hard to compensate for. **Accelerometer** *Measures linear acceleration. Used to detect high accelerations (direct measure) in for example car crash detection systems and orientation at low speed by looking at direction of gravity which it can do without drift. Pros: Cheap, high bandwidth Cons: Severe drift when used to get position, bias and cross sensitivity hard to compensate for. Gravity is large and hard to remove if other acceleration are the main focus.*

12. Describe the GPS system. Basic principle? Challenges? Good applications for it? Bad applications for it? Pros? Cons? (8p)

    The GPS system makes use of a set of satellites. The position of a receiver is determined by measuring the time it takes for the signal to go from satellites (transmitter) to the receiver. Time synchronization needs to be very good. Outdoor applications are well suited, especially if the sky is free. Indoor operation does not work wel because of the limited contact with the satallites. Pros: Extremely easy-to-use positioning solution. Affordable. Well known and excepted on the market. Cons: Does not really work indoors.

13. Mention and explain 3 intrinsic camera parameters (9p)

    Principle point: point in image where optical axis goes through it. Focal length: defines field of view. Lens distortion parameters: defines how the lens distorts the view.

14. Explain the basics of an occupancy grid. What is it used for and why? Pros and cons? (8p)

    An occupancy grid is a representation of space (often 2D) where the world is divided into cells, classified as occupied or not (sometimes probabilistically). It is used for building maps and for calculations for path planning algorithms. Pros: Makes few assumptions about the world, easy to use and implement. Cons: Structures smaller than the grid size are reduced to information that there is something there only.