Question 1

Describe how odometry errors on a mobile robot might occur and explain two methods how they could be corrected.

Answer: Odometry errors on a mobile robot can be due to calibration errors and wheel slippage. Calibration errors can be fixed by recalibrating the robot's odometry.
Errors due to slippage can be fixed by obtaining the robot's location by other means, e.g. GPS or via triangulation from sensed beacons or landmarks.

Question 2

With respect to mobile robots:

(a) Explain why IR sensors might be used in preference to sonar sensors.

(b) Explain why sonar sensors might be used in preference to IR sensors.

Answer:

a) IR sensor are better for detecting very close objects 5 to 10 cm.
b) Sonar sensors have longer range than IR sensors. They can also detect glass which may not reflect IR light. They are also unaffected by the Sun.

Question 3

Name 4 sensors discussed in this course that can resolve the range of objects? For each sensor named briefly explain how it works.

Answer:

1. IR Sensor. Has IR emitter and receiver and can detect the distance of close objects by measuring the amount of reflected light.
2. Ultrasonic Sensor. Has sonar emitter and receiver. The emitted sound waves are reflected off objects and detected by the receiver. The time elapsed between emitting and receiving is proportional to the distance of the object.
3. Stereo Disparity Camera: Two cameras are separated and used to measure the disparity (shift) of features in the two images. The greater the shift the further the object is away from the camera.
4. Laser Sensor: Has laser emitter and detector. A pulsed laser beam and a detector is rotated to scan the environment between 180 to 360 deg. The time of flight is measured by a fast electronic circuit. The longer the time of flight the further away the object..

Question 4

Briefly explain the first 4 levels of automation attributed to autonomous vehicles.

Answer

Level 1 (Function-specific automation) Human has complete authority, but cedes limited control to the vehicle in a crash situation. E.g.: electronic stability control.
Level 2 (Combined function automation) Automation of at least two control functions e.g. adaptive cruise control, lane centering control, but driver still responsible for monitoring.
Level 3 (Limited self-driving) Vehicle controls all safety functions under certain traffic and environmental conditions. Vehicle alerts driver to take control if needed.
Level 4 (Full self-driving automation) Vehicle controls all safety functions and monitors conditions for the entire trip.

Question 5

Name thee sensors available for LEGO Mindstorms robots. For each sensor explain its purpose and comment on its capabilities and limitations.

Answer

1. Touch sensor: Switches on (or off) when pressed by an object. Good for bump sensing. Needs button to be pressed in one direction or it won't activate.
2. Colour sensor: Indicates the colour or light intensity of a nearby object. Can be active or passive. Can be affected by other light sources.
3. Sonar sensor: Measures or responds to the distance of nearby objects. Can fail to detect surfaces that are at an angle to the sensor.

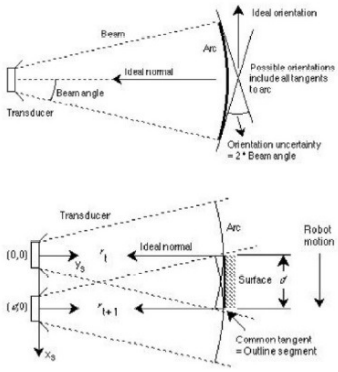
Question 6

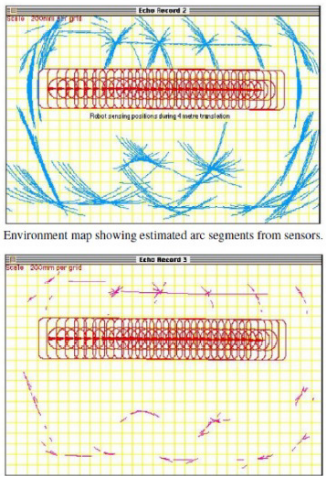
Two methods for acquiring a map of the environment using odometry are outline segments and an occupancy grid. With the aid of diagrams explain these methods.

Answer

Both outline segments and occupancy grids uses range sensors and odometry to detect objects in the environment and acquire a map of the environment.

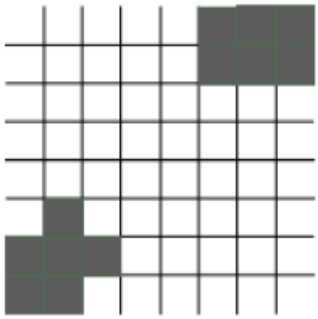
Outline Segments: By combining sensor readings over time the intersections of the arcs indicate where the objects are located as shown below.





Environment map showing estimated arc segments from sensors.

Arc Segments



Occupancy grid

Occupancy grid: By using the direction of sensors and the distance of detected objects, squares in a grid are incremented or decremented based on their correspondence with objects or free space. A threshold is used to indicate objects, as shown above.

Question 7
State one advantage an outdoor mobile robot has over an indoor mobile robot when navigating the environment? State one disadvantage an outdoor mobile robot has over an indoor mobile robot when navigating the environment?
Answer:
Advantage: An outdoor mobile robot can use GPS and a compass to navigate the environment.
Disadvantage: Loose and uneven terrain means odometry loses its accuracy. The sun can also affect the operation of IR sensors and cameras.

Question 8
Briefly explain how a robot pool cleaner might go about navigating its environment.
Answer
Since the pool is a confined space the pool cleaning robot can first clean the floor perimeter of the pool by following the walls with bump or sonar sensors and at the same time map the floor using odometry. The robot can then use its odometry to clean the floor by using a scan traversal pattern of the floor. The robot can then climb the walls and perform a similar scan if necessary.

Question 9
Explain the difference between a mobile robot control systems that reacts to the environment and one that works by planning a path through the environment. List one advantage and one disadvantage of each of these controllers.
Answer
The reactive robot is simpler and faster to react but can be difficult to program to do complex tasks. A path planning robot is capable of negotiating cluttered environments but needs a map and a reliable means of plotting its position to avoid getting lost.

Question 10
In terms of sensing and control, explain how a bookmobile robot can navigate the inside of a library building.
Answer
The bookmobile robot can use sonar sensors for collision avoidance and a light stripe vision system for navigating the corridors. A digitised corridor map, odometry, a barcode scanner and barcodes placed on the walls can be used for localization.

Question 11
What is meant by the piano mover problem? What type of robots does this apply to? Describe two ways how this problem can be overcome.
Answer
The piano mover problem occurs with robots that have rectangular shaped bodies and Ackerman steering. The robot could get stuck in a dead end or have difficulty negotiating tight bends in corridors. This problem can be overcome by fitting omidirectional wheels to the robot or by using a round robot with central differential drive wheels to spin the robot when it detects a dead end or needs to make a sharp turn.

Question 12
What is meant by supervised learning, unsupervised learning and learning by demonstration? Give an example for each learning paradigm.
Answer
Supervised learning: Learn by examples. e.g. being given input-output patterns and learning a mapping between them.
Unsupervised learning : no desired output pattern is given in this case. Data clustering is used instead to group the data into categories or classes.
Learning by demonstration: in this case the human teaches a robot to how react with the environment. This can be done with gestures or with a motion capture suit.

Question 13
Briefly explain the difference between reacting control systems and deliberative control systems.
Answer
In a reactive control system, the robot's sensors are directly used to control the actuators, e.g. light seeking robot can use the left light sensor to stimulate the right wheel and the right light sensor to stimulate the left wheel. In a deliberative control system, the robot uses all of the available sensory information and all of the internally stored knowledge to reason about what actions to take next. The control system is usually organised using a functional decomposition of the decision-making processes and usually consists of a sensory processing module, a modelling module, a planning module, a value judgement module and an execution module.

Question 14
In terms of localization and mapping explain how a mobile robot could navigation the environment with the use of:
a) Continuous landmarks
b) Non continuous landmarks
Answer
(a) **Continuous landmarks:** The robot could perform wall (or corridor) following combined with distance measures to reach its destination.
(b) **Non continuous landmarks:** Robot could start by scanning the environment for beacons or a known landmark. The robot could then use dead reckoning to work out its position and plot a path to its destination.

Question 15
What is the credit assignment problem with respect to mobile robots? You may use a diagram to explain your answer?
Answer
The credit assignment problem concerns the difficulty in knowing what action to assign positive or negative credit to when a reinforcement signal is received. For example, when a robot collides with an object, it is difficult for the robot to decide how long ago it made the wrong action.

Question 16
Name 4 sensors discussed in this course and discuss their function and limitations?
Answer

Sensor Name	Function	limitation
Ultrasonic Sensor	measure the distance to an object by using sound waves	Angular surfaces difficult to measure
IR Sensor	to detect a select light wavelength in the Infra-Red (IR) spectrum	Cannot detect glass, mirrors or objects in sunlight.
Laser Sensor	used to measure distance via TOF of laser beam	Laser beams can suffer from reflection, scattering or absorption on some surfaces.
Vision Sensor	Obstacle detection, feature recognition	The big disadvantage is lighting variations. Also difficult to process visual information.

Question 17
What is an occupancy grid? How might you devise an occupancy grid that can cope with odometry errors?
Answer
An Occupancy Grid is a 2D grid used to represent the environment and show obstacles and free space. It works by detecting obstacles with range sensors. Grid elements are incremented where obstacles are detected and decremented where free space is detected. A threshold is used to determine the existence of objects.

Question 18
In terms of sensing and control briefly explain how an indoor mobile could be devised to find its charging bay.
Answer
The charging bay is equipped with an IR beacon and the robot is equipped with an IR sensor for detecting the IR beacon. When the battery power gets low, the robot starts looking for the infrared signal emitted by the charging bay. Once it finds it, the robot heads for the signal and docks with the charging bay using its other sensors (e.g. bump or sonar sensors).
.

Question 19
Is the light sensor used on LEGO Mindstorms robots a passive sensor or an active sensor? Explain your answer.
Answer
The light sensor used on LEGO Mindstorms robots can be either a passive sensor or an active sensor, depending on how it is setup. In passive mode the light sensor detects the amount of ambient light reflected off a surface. In active mode a light emitting diode (LED) mounted in the sensor emits light that is reflected off the target surface. This reflected light is then detected by the light sensor.

Question 20
Why might a simulator be used to assist with the development of a mobile robot control system? What special considerations need to be taken into account when devising a mobile robot simulator?
Answer
Simulators are set up to execute and test robot code quickly in a simulated environment before running the code on the real robot in the real environment. The simulator needs to be devised to run the robot's code and must have the physics of the robot's sensors and motion closely simulated. The simulator can also be divised to be a discrete time simulator, where the user can watch the simulated robot move, or a discrete event simulator, where the simulated robot jumps from event to event.

Question 21
What is the main difference between a *local variable* and a *global variable* in labview?
Answer:
A Local Variables can only be accessed via the block diagram of the VI on which it is declared. A Global Variable can be accessed via the block diagrams of all the VIs and sub-VIs in the program.

Question 22
Why is LabVIEW a *data flow* programming language?
Answer:
The flow of data through nodes on the block diagram determines the execution.

Question 23
Two methods for accessing an indicator on the front panel are *local variables* and *property nodes*. Explain the main difference between a *local variable* and a *property node*.
Answer:
A local variable can only be used to access the value of the indicator. A property node can be used to access the value and other properties of the indicator (e.g. the label, visibility, etc).

Question 24
Draw by hand the block diagram for a Labview program that flashes a boolean LED light ON for 0.5 seconds and OFF for 1 second continuously until the user pushes a stop button.

Answer: