8823 – 6906M

Diploma Programme
Programme du diplôme
Programa del Diploma

Markscheme

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Computer science

Higher level

Paper 3

10 pages

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Subject details: **Computer science HL paper 3 markscheme**

Mark allocation

Candidates are required to answer **all** questions. Total 30 marks.

General

A markscheme often has more specific points worthy of a mark than the total allows. This is intentional. Do not award more than the maximum marks allowed for that part of a question.

When deciding upon alternative answers by candidates to those given in the markscheme, consider the following points:

- Each statement worth one point has a separate line and the end is signified by means of a semi-colon (;).
- An alternative answer or wording is indicated in the markscheme by a "/"; either wording can be accepted.
- Words in (…) in the markscheme are not necessary to gain the mark.
- If the candidate's answer has the same meaning or can be clearly interpreted as being the same as that in the markscheme then award the mark.
- Mark positively. Give candidates credit for what they have achieved and for what they have got correct, rather than penalizing them for what they have not achieved or what they have got wrong.
- Remember that many candidates are writing in a second language; be forgiving of minor linguistic slips. In this subject effective communication is more important than grammatical accuracy.
- Occasionally, a part of a question may require a calculation whose answer is required for subsequent parts. If an error is made in the first part then it should be penalized. However, if the incorrect answer is used correctly in subsequent parts then **follow through** marks should be awarded. Indicate this with "**FT**".
- Question 4 is marked against markbands. The markbands represent a single holistic criterion applied to the piece of work. Each markband level descriptor corresponds to a number of marks. When assessing with markbands, a "best fit" approach is used, with markers making a judgment about which particular mark to award from the possible range for each level descriptor, according to how well the candidate's work fits that descriptor.

General guidance

Issue	Guidance
Answering more than the quantity of responses prescribed in the questions	• In the case of an "identify" question read all answers and mark positively up to the maximum marks. Disregard incorrect answers. • In the case of a "describe" question, which asks for a certain number of facts *eg* "describe two kinds", mark the first two correct answers. This could include two descriptions, one description and one identification, or two identifications. • In the case of an "explain" question, which asks for a specified number of explanations *eg* "explain two reasons …", mark the first two correct answers. This could include two full explanations, one explanation, one partial explanation *etc*.

1. (a) *Award **[2] max***

*Award **[1]** for definition and **[1]** for devices/data*
A technique to navigate and map an unknown environment in real-time;
using visual input from cameras /using sensor data, such as odometry or IMU;

A technique for the robot to locate itself/orientate within an area;
using cameras and data like IMU or odometry.

(b) *Award **[2] max***

The environment being indoors or underground;
Signal strength insufficient to penetrate/no GPS booster present;

Overhead obstructions, such as buildings or terrain;
Prevent the line-of-sight connection;

Interference from other electronic devices or sources;
Increases noise that weakens/distorts the GPS signal;

The GPS device being damaged or malfunctioning;
There's no working GPS receiver (unless failover system/second GPS receiver);

Reflective surfaces on buildings;
Causing diffraction, or scattering of signals in urban environments;

Multi-path interference from buildings;
Creating duplicate signals (which confused the receiver).

Atmospheric conditions, such as ionospheric/tropospheric/heavy rain;
Refraction or scattering the signal.

2. (a) *Award **[4] max***

*Award **[1]** for combining data, **[1]** for synchronization, **[1]** for filtering, **[1]** for weighting, and **[1]** for decisions in real-time. Also **[1]** max for identifying two sensors, and **[1]** for stating how they work or why they are needed.*

Combines data from multiple sensors to detect obstacles/paths (through smoke)/not reliant on a camera;
Synchronizes data at a specific time/ensures all inputs are associated with the same moment.
Filters data to smooth and refine sensor data (e.g. reducing noise);
Applies weighting each sensor's input (based on reliability/situation);
Combined sensor data is used to make informed decisions in real-time.

Sensor explanation
Uses IMU Data for Stability;
Maintain balance, control movement, and determine orientation;
Thermal Sensor Data;
To create a temperature map (identify hot spots);
Radar Data;
Using radio waves for object detection/rebounds radio waves to calculate distance;
LiDAR data;
Using laser pulses for object detection (rebounds light to calculate distance);

Data from Ultrasonic sensors;
Object detection (rebounds soundwaves);
Fuses gas sensors;
To detect toxic levels and avoid hazardous areas;
Uses odometry data;
Provides data on how far and in which direction the robot has traveled;

(b) *Award* ***[4 max]***
Award ***[1]*** *for each point,*
The vSLAM system recognizes that it has lost track of its position (poor visual data or significant drift);
Searches for recognisable features/landmarks (previously stored);
Matches the identified features to pinpoint location;
Recalculates its position (pose) and orientation/relocalizes itself on the map;
Initiates the resumption of vSLAM (once confirmed);

Award any relevant marks above if the candidate is describing the process of loop closure since it's a recognised mechanism within relocalization.

3. *Award **[6 max]***
*Award **[5]** max if there is no final appraisal*

*Reasons to use Rescue Robots **[3]** max*
Saves human lives by reducing the need for human rescuers to enter dangerous environments;
Can reach difficult-to-access areas / extreme conditions;
Can work longer and without breaks;
Can carry out repetitive or monotonous tasks with precision (less error);
Can be equipped with sensors to detect hazards (heat, gas);
Can be remotely operated, allowing rescuers to control them from a safe distance;
Can be deployed quickly, potentially reducing response times;

*Reasons not to use Rescue Robots **[3]** max*
Robots may not be able to access certain areas due to size and terrain limitations;
Robots may not be able to perform certain tasks that require human dexterity and judgement;
Robots may malfunction or break down in dangerous situations, putting human lives at risk;
Victims may be uncomfortable with robots and prefer human interaction;
Robots cannot provide emotional support to victims in distress;
Robots may not have the ability to make life and death decisions in complex situations;
Robots may not have the same level of communication skills as human rescuers;
Robots may not be able to provide the same level of medical assistance as human rescuers;
Robots have a limited battery life so cannot search for as long as a human.

*Appraisal **[1]** max for a reasoned appraisal (for example)*
Robots to assist with the search but human teams to treat/rescue the survivors.

4. *Award* ***[12 max]***

Introduction

- The robot has some essential functions such as sensing and moving, but the choice of technology to achieve these may depend on factors such as:
- The environment (Equipment must suit conditions like smoke, dust, water, or rubble).
- The robot’s primary purpose (e.g., locating survivors, clearing debris) will determine necessary sensors and tools, like thermal cameras for search or manipulator arms for removing obstacles.
- Power constraints affect the choice of high-energy equipment like LiDAR or radar, as extended missions require efficient power usage.
- Compact, lightweight components are preferred to ensure mobility in tight spaces and challenging terrain (e.g. shock-resistant components).
- High-tech equipment (e.g., advanced AI, radar) can be expensive, so budget limitations may prioritise essential over advanced features.
- Equipment must withstand harsh conditions, so durable and reliable components are essential, especially in debris-filled or wet environments.
- The robot may require specialised communication systems (e.g. Edge) to transmit data back to rescuers, especially if working in areas with weak signals.

Necessary technologies

- Mobility devices to move across various terrains and obstacles, e.g., tracks, wheels, legs, or hybrid designs.
- Communication equipment to transmit and receive data, voice, or video signals to/from human operators, other robots, or central systems, to coordinate tasks, share information, or call for help.
- Mapping and localization to create and update a 3D map of the environment, as well as to estimate the robot's own position and orientation relative to the map (see below for details).
- Manipulation ability to interact with objects and tools, e.g., using arms, grippers, drills, saws, or extinguishers, to clear debris, open doors, search for victims, or extinguish fires.
- High-durability frame and components for withstanding debris and impacts in disaster zones.
- Sensors with the ability to perceive the environment through various modalities

Necessary sensors

- LiDAR: Crucial for mapping and navigation in low-visibility areas (e.g., smoke, debris). LiDAR provides accurate 3D maps but may be costly.
- Thermal Cameras: Useful for detecting survivors based on heat signatures, especially in smoke-filled environments where visibility is limited.
- IMU (Inertial Measurement Unit): Helps maintain stability and orientation, crucial for navigating uneven or unstable surfaces without tipping over.
- Radar: Works well through smoke and fog, offering reliable detection over long distances.
- Gas Sensors: Necessary for detecting toxic gases in hazardous environments, enabling the robot to avoid dangerous areas.

vSLAM

- Real-Time Mapping: vSLAM enables the robot to create a map of the environment for navigating complex or unpredictable terrains, such as rubble or collapsed structures.
- Localization in GPS-Denied Environments: Many rescue scenarios occur indoors, underground, or in dense rubble where GPS signals are blocked.
- Obstacle Detection and Avoidance: vSLAM can identify and track obstacles in the terrain, enabling the robot to make real-time adjustments to avoid hazards.
- Relocalization: If the robot loses track of its position due to terrain challenges (e.g., sudden drops or blockages), vSLAM’s relocalization features help it regain its location on the map.

- Efficient Path Planning: vSLAM provides a continuously updated map, enabling the robot to plan the most efficient path through complex terrain, avoiding obstacles and navigating narrow spaces.

Pose estimation
- Accurate Navigation: Knowing its precise pose helps the robot navigate complex terrains and avoid obstacles effectively,
- Stability on Uneven Terrain: Pose estimation, often supported by sensors like IMUs, allows the robot to adjust its balance and movement to maintain stability on rough or sloped surfaces.
- Efficient Mapping with vSLAM: Pose estimation is fundamental to vSLAM, as it continuously updates the robot’s location on the map. Accurate pose data ensures that the map remains consistent and reliable in real time.
- Precise Object Interaction: For tasks like clearing debris or rescuing survivors, precise pose estimation allows the robot to approach and interact with objects or individuals accurately without causing harm or disruption.
- Improved Relocalization: In case of tracking loss, accurate pose estimation helps the robot realign itself with the map quickly by providing an updated, precise reference of its location.

Impractical or Prohibitively Expensive Technologies
- Ultrasonic Sensors: Limited range and effectiveness in noisy environments; LiDAR or radar could be more effective for object detection.
- High-Resolution Visual Cameras: While useful, these may be less effective in smoke-filled environments. Thermal cameras might be more practical.
- Advanced AI for Emotional Recognition: Not directly beneficial for physical rescue operations; simpler AI for navigation and detection could be prioritised.
- GPS: May be unreliable in indoor or underground environments. Odometry and SLAM could be more useful for position tracking.
- Communication Systems with High Data Transfer: High-bandwidth communication might be impractical in areas with weak signals; basic, reliable communication is more essential.
- Artificial intelligence or machine learning: while useful for some tasks, these techniques may require large datasets, training, and validation, which may not be feasible or reliable in dynamic and unpredictable environments.
- High-level autonomy or decision-making: while useful for reducing human workload and response time, these features may also introduce new risks, such as misinterpretation of data or unexpected behaviours, that could lead to errors or accidents.

Environmental Factors which might prevent sensors being effective (e.g.):
- In extremely cold environments, batteries can lose their charge quickly, limiting the use of rescue robots.
- Dusty and sandy environments can interfere with sensors such as lidar, reducing their effectiveness.
- In situations with high levels of electromagnetic interference, GPS and other radio frequency-based sensors may not function correctly.
- In heavily wooded or cluttered environments, sensors such as lidar or cameras may be obstructed, making mapping and object detection difficult.

Evaluation
- Specialisation for Varied Environments: Different types of robots can be designed to excel in specific environments—e.g., wheeled robots for flat terrain, tracked robots for rough ground, flying drones for aerial reconnaissance, and underwater robots for flooded areas.

- Collaborative Teams: A team of robots with complementary skills can work together to complete complex tasks. For example, a flying drone can scout and map an area from above, while a ground robot follows with detailed inspections or debris removal.
- Division of Tasks: Robots can be assigned specialized roles based on their capabilities. For instance, one robot may focus on locating survivors using thermal imaging, while another focuses on structural assessment using LiDAR.
- Redundancy for Reliability: Having multiple types of robots ensures redundancy; if one robot type fails (e.g., a ground robot gets stuck in debris), another type (e.g., a drone) can continue the mission.
- Optimising Resources and Battery Life: Different robots can rotate roles or substitute for one another to manage power effectively.
- Rapid Adaptability: When unexpected challenges arise, a team of robots with varied abilities can adapt quickly. If a ground robot encounters water, an amphibious or underwater robot can take over, allowing adaptation in real-time.

Marks	Level descriptor
No marks	• No knowledge or understanding of the relevant issues and concepts. • No use of appropriate terminology.
Basic 1–3 marks	• Minimal knowledge and understanding of the relevant issues or concepts. • Minimal use of appropriate terminology. • The answer may be little more than a list. • No reference is made to the information in the case study or independent research.
Adequate 4–6 marks	• A descriptive response with limited knowledge and/or understanding of the relevant issues or concepts. • A limited use of appropriate terminology. • There is limited evidence of analysis. • There is evidence that limited research has been undertaken.
Competent 7–9 marks	• A response with knowledge and understanding of the related issues and/or concepts. • A response that uses terminology appropriately in places. • There is some evidence of analysis. • There is evidence that research has been undertaken.
Proficient 10–12 marks	• A response with a detailed knowledge and clear understanding of the computer science. • A response that uses terminology appropriately throughout. • There is competent and balanced analysis. • Conclusions are drawn that are linked to the analysis. • There is clear evidence that extensive research has been undertaken.