F20RO/F21RO
Coursework (CW)

This assessment is worth 50% of your course mark

Overview

This assessment aims to increase your understanding and use of robot simulators and software tools to support the creation of intelligent controllers for robots using advanced bio-inspired techniques, which are covered in the course. It involves using a well-known robot simulator, creating specific environment configurations and applying bio-inspired algorithms to create intelligent controllers for robots, analysing the resultant robot behaviours and drawing conclusions from it.

For this assessment, you are being formed into groups of **three** or **four** people. Each group will develop controllers for a robot to perform given tasks by the deadline set @ CANVAS.

You will be **randomly matched** with other CW partners.

Please note that **you are only allowed to collaborate with students within your group.**

Groups will be communicated at most by 28/10/2023 (Friday) via CANVAS, with the subject: "F20RO - 2023 - UG Group Allocation" for UG students and "F21RO - 2023 - PG Group Allocation" for PG students including both names and surnames. Once you receive the allocation, please contact your CW partners immediately to start working on your CW assessment. Each group will have a **named "Group Leader"**, who will be responsible for coordinating and **submitting on CANVAS the final CW files for assessment.**

Each group will develop its own robot controllers (in any programming language(*)) for a set of tasks using the Webots simulator software.

(*) we strongly advise you to use the Python language.

PLEASE CONTACT Prof Patricia A. Vargas (p.a.vargas@hw.ac.uk) in Edinburgh
or Talal Shaikh(t.a.g.shaikh@hw.ac.uk) IF THERE ARE PROBLEMS IN YOUR GROUP.

Declaration of Contribution and Authorship

Each group should download and sign the “Coursework Group Signing Sheet” and the **named Group Leader** should upload it (in PDF format) together with the other assessment material @CANVAS.

The “Coursework Group Signing Sheet” is a document containing a declaration of authorship and the actual contribution to this assessment. It should be signed by each member of the group.

NOTE: Your work will not be marked if a fully signed copy of this sheet is not included with your group’s coursework submission.

Please read through these other important points before you begin:

● **You do not need to wait until we have covered all the related topics in the lectures to start working on your coursework**.
● We endeavour to give you **feedback** on an average of 15 working days from submission.

This is assessed coursework. You are allowed to discuss this assignment with students, but you should not copy their work, and you should not share your own work with other students unless they are from your own group. We will be carrying out automated plagiarism checks on both code and text submissions.

Special note for reusing existing code. If you are reusing code that you have not yourself written, then this must clearly be indicated, making clear which parts were not written by you and clearly stating where it was taken from. If your code is found elsewhere by the person marking your work, and you have not mentioned this, you may find yourself having to go before a disciplinary committee and face grave consequences.

Plagiarism. It is the act of taking the ideas, writings or inventions of another person and using these as if they were your own, whether intentionally or not. Plagiarism occurs where there is no acknowledgement that the writings, or ideas, belong to or have come from another source (Heriot-Watt University Plagiarism Policy).
• Students must never give hard or soft copies of their coursework reports or code to another student outside their CW group.
• Students must always refuse any request from a student from another CW group for a copy of their report and/or code.
• Sharing a coursework report and/or code with a student from another CW group is collusion, and if detected, this will be reported to the School's Discipline Committee. If found guilty of collusion, the penalty could involve voiding the course.
• Plagiarism will be treated extremely seriously as an act of academic misconduct which will result in appropriate student discipline. All students should familiarise themselves with the university policies around plagiarism which can be found here:
https://www.hw.ac.uk/students/studies/examinations/plagiarism.htm

Late submission and extensions. Late submissions will be marked according to the university's late submissions policy, i.e. a 30% deduction if submitted within 5 working days of the deadline, and a mark of 0% after that.

The deadline for this work is not negotiable. If you are unable to complete the assignment by the deadline due to circumstances beyond your control (e.g. illness or family bereavement), you should complete and submit a mitigating circumstances application: https://www.hw.ac.uk/students/studies/examinations/mitigating-circumstances.htm

Detailed Description

Mars Rover Navigation with Satellite-Assisted Beacons

Suppose we want to advance Mars exploration with a Mars Rover that uses satellite-assisted surface beacons for navigation. This concept synergizes the precision of decision-making and guided navigation (i.e., path following) with the expansive data analysis and communication capabilities of satellites.

The operational framework of the Mars rover navigation system could be described as follows:

Satellite Path Charting: Satellites chart paths on the Martian surface, using the beacons for communication and considering various factors like terrain type, dust storms, dust devils (or mini tornados), obstacles, and most importantly potential soil collection zones (or reward zones).

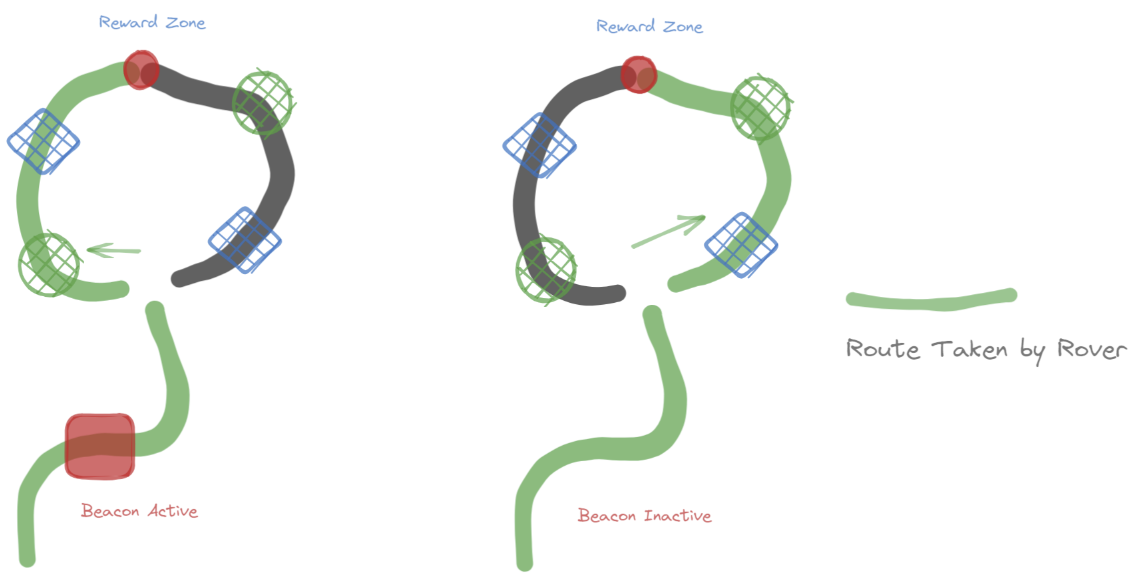
Path Following: Equipped with path-following algorithms, the rover could follow the path with precision, making necessary adjustments to maintain alignment with the path and final destination.

Obstacle Detection and Avoidance: While following the path, the Mars rover utilizes its sensors to autonomously detect and avoid any unforeseen obstacles, ensuring a smooth and uninterrupted journey towards the collection zones (or reward zones).

Surface Beacons: The satellites control the beacons on the surface of the planet to inform the Mars rovers of real-time path adjustments and refinements. The satellite could change the status of a surface beacon to inform the Mars rover to change its path. Therefore, the path chosen by the rover directly corresponds to the status of each surface beacon.

PROBLEM

Suppose we need to create a simplified test bed for the proposed Mars rover navigation system. Our Mars rover must head towards a designated area to collect soil specimens. It needs to reach this collection/reward zone quickly while avoiding any obstacles in its path. The possible paths are highlighted by a line on the surface of the arena. There are two possible paths to this collection zone: **Route A** and **Route B**. The Mars rover's choice of route is determined by a surface beacon's status. Due to potential dust storms in the immediate area, the Mars rover can only rely on this beacon's status for direction. If the beacon is activated (i.e., lights turned ON) by a satellite, the Mars rover should take **Route A**. If the surface beacon is deactivated by a satellite (i.e., lights turned OFF), **Route B** should be taken.



Route A　　*Route B*

Given the above scenario you have to develop robot controllers for the Mars rover using two approaches: Behaviour-Based Robotics (BBR) and Evolutionary Robotics (ER).

TASK 1: Create a Behaviour-Based Robotics (BBR) approach robot controller to control a single "Mars rover" that is able to solve the **PROBLEM** stated above. You should train and test your robot using the arena (i.e., World file) for both **Route A** and **Route B.** The template World file is provided to you @ CANVAS.

TASK 2: Create a robot controller using the Evolutionary Robotics (ER) approach to control a single "Mars rover" that is able to solve the **PROBLEM** stated above. You should train and test your robot using the arena (i.e., World file) for both **Route A** and **Route B.** The template World file is provided to you @ CANVAS.

TIP: For these tasks, you can refer back to the code provided for your labs. For instance, for **TASK 2**, you can check in Lab 4 how the evolutionary controller was created for training and testing the ER robot controller for the T-maze problem.

For both Task 1 and Task 2, you should aim to create the quickest "Mars rover", i.e. the "Mars rover" that could explore the line following path in less time while moving towards the reward zone. Therefore you should record the time spent to find and stop at the REWARD ZONE at **Route A** and **Route B**, on the average of three runs for your best BBR and ER controllers. You should fill in the following Table accordingly and add it to your final report.

Marks on all Tasks are awarded for creativity and performance as well.

Table 1: Statistics.

	Time in Minutes			
	First Run	**Second Run**	**Third Run**	**Average Time**
Task 1 Route A				
Task 1 Route B				
Task 2 Route A				
Task 2 Route B				

The Basic Rules are the following:

1. You must use the **e-puck** robot as your "Mars rover". The e-puck is available in the Webots simulator together with the given World file.
2. You should **NOT** move any fixed objects in the arena or try to change the World.
3. The dimensions of the arena, line path and obstacles **should not be changed**.
4. The maximum time to perform any of the tasks is 5 min for each part of the coursework. After that, the simulation should be stopped and 5 min should be added to that specific group as the time spent, irrespective if the robot(s) have completed the task or not.

Activities for each Task

Activity 1*

~~Create a coursework folder and add the respective files given @ CANVAS under Coursework.~~

Activity 2*

Prepare the arena (i.e., world file) to train and test your robot controller for each Task in both **Route A** and **Route B**.

Activity 3*

Create a robot controller for each task and add the robot controller to the e-puck robot.
Train and test the robot controller to perform each Task described.

Activity 4*

Record a short video (no more than 3 minutes) for each Task showing the final best robot behaviour in both **Route** A and **Route B**. The video **should be narrated** by one of the group members (*please identify yourself at the beginning of the recording*), explaining what is being shown in the video.

Activity 5*

Collect relevant data from the Webots robot simulator that would illustrate the corresponding final robot behaviour for each Task. This data should be included in your Research Report.

Collect statistics for each run for each Task.

NOTE: Remember that you can **refer to past lab activities in order to have some guidance on how to** create/code your own robot controller for the CW tasks. You can reuse the code that you worked on from your lab materials as long as you highlight which part is your own contribution to the code, using comments in the code.

What you are asked to do:

1. Implement a robot controller for each Task.
2. Train and Test your controller for each Task in both **Route A and Route B**.
3. Make a short **narrated video** (no more than 3min) of the final desired behaviour for each Task in both **Route A** and **Route B**.
4. Write a research report.
5. Fill in and Sign the "Coursework Group Signing Sheet"
6. The named '**Group Leader**' should submit the research report (in PDF format), short video(s) (in .zip format), the code (in .zip format), and the "Coursework Group Signing Sheet" (in PDF format) to CANVAS.

NOTE: Your CODE **should not** be uploaded as a PDF, as we need to be able to run your code. If we can NOT run your controller, your CW will not be marked, and you will receive 0 marks.

REPORT, VIDEOS and CODE (Undergraduate Students): Write a research report and submit the report, the code, video(s) and signing sheet @ CANVAS

Your Research Report should:

● Be between 2,500 and 3,000 words

NOTE: Make sure you add the final **Word Count** to the header of the document, excluding figures, tables and references.

● Describe your implementations of the bio-inspired algorithms, noting any interesting aspects.

● Your report should contain the following sections:
- Introduction
- **For each Task Implemented:**
    - Design and Implementation Rationale
    - Results and Analysis
- Discussion and Conclusion
- References

● Report the results of your experimental investigation. For instance, you might want to use tables, figures, graphs and plots to illustrate your results. Please refer to your lab material on how to save the data to create figures and graphs from the robot's data on Webots.

● Referring to these results, discuss which decisions you made that might have affected the performance of your implementations, and say why you think this is the case.

● Prepare a discussion and conclusion addressing the difference between the development of a controller using the BBR approach and the Evolutionary Robotics approach.

● Include useful references to the wider literature. To enhance the credibility and depth of your work, please include references from the wider literature. Please cite relevant books, papers, and articles that can justify the implementation choices made, or use them to compare and contrast your findings with existing results. It is mandatory to include at least **6 relevant references.** Use the **Harvard Referencing Style** for all citations.

The named '**Group Leader**' should submit the report (as a **.pdf** file), the "Coursework Group Signing Sheet" signed by all members of the group (as a **.pdf** file), short videos (in a **.zip** file) and the code (in a **.zip** file) to CANVAS using the links provided.

NOTE: Your CODE **should not** be uploaded as a PDF, as we need to be able to run your code. If we can NOT run your controller, your CW will not be marked, and you will receive 0 marks.

Grading will use the assessment criteria given in the table below.

Marking scheme for F20RO Coursework

Please note that all tasks will be assessed following the corresponding criteria below.

Criteria	Weight	A (70-100%)	B (60-69%)	C (50-59%)	D (40-49%)	E/F (<40%)
Implementation *(i.e. code for Tasks, and evaluation, comments and documentation)*	45%	Creative implementations of each Task that exceed the basic requirements. Correct evaluation code. Easy to read and well structured.	Correct implementations of the basic requirements. Generally good coding, structure and documentation.	Some significant issues in terms of correctness, structure, coding practice and documentation.	Major issues in terms of correctness, structure, coding practice and documentation.	Critical errors: for example, the code does not compile and/or run, or inappropriate algorithms have been implemented.
Experimental study *(i.e. choice and validity of experiments performed, presentation of results, including short video)*	25%	Robot behaviours investigated are well motivated and the rationale for choices made are well elaborated. Suitable results have been collected and are clearly presented and meaningful.	Some minor issues in terms of the motivation or description of resultant robot behaviours, the experiments performed, or the presentation of results.	Some significant issues in terms of the motivation or description of of resultant robot behaviours, the experiments performed, or the presentation of results.	Some major issues: experiments do not make sense, have invalid results, or the Tasks and studies are not adequately described.	Some critical issues: experimental study is nonsensical or missing, the experiments are inappropriate, or the description of the studies are uninformative.
Wider discussion *(i.e. intro, interpretation of results, conclusions, use of the wider literature)*	20%	Clear, insightful discussion that shows a good understanding of BBR (behaviour based robotics) and ER (evolutionary robotics) and includes well chosen references to the wider literature.	Generally clear and insightful, but shows some misunderstanding of BBR (behaviour based robotics) and ER (evolutionary robotics) . Adequate use of the wider literature	The discussion is limited in terms of the depth or volume of understanding it demonstrates. Little or no use of the wider literature.	Some major issues in terms of depth or volume of understanding. No use of the wider literature.	No real demonstration that the subject matter has been understood, or very limited in its scope.
Report *(i.e. structure, language, referencing etc.)*	10%	Report is well structured and divided into sections; good use of language; consistent use of font Arial, size 12; perfect use of Harvard referencing style	Report is suitably structured and divided into sections; mostly good use of language; use of font Arial, size 12; use of Harvard referencing style	Report is structured but not divided into sections; language issues that affect readability; inconsistent use of fonts and sizes; mixed use of referencing styles	Report is poorly structured; substantial language issues that affect readability; use of different fonts and sizes; no referencing style	Report has a nonsensical structure; language issues make it very hard to read; use of different fonts and sizes; no referencing style

REPORT, VIDEOS and CODE (Post Graduate Students): Write a research report using an IEEE paper format and submit the report, the code, video(s) and signing sheet @ CANVAS

Your Research Report should:

● Use the IEEE paper template available on CANVAS

● Be between 4,000 and 5,000 words

NOTE: Make sure you add the final **Word Count** to the header or footer of the document, excluding figures, tables and references.

● Describe your implementations of the bio-inspired algorithms, noting any interesting aspects.

● Your report should contain the following sections:
- Introduction
- **For each Task Implemented:**
    - Methods and Implementation Rationale
    - Results
- Discussion and Conclusion
- References

● Report the results of your experimental investigation. For instance, you might want to use tables, figures, graphs and plots to illustrate your results. Please refer to your lab material on how to save the data to create figures and graphs from the robot's data on Webots.

● Referring to these results, discuss which decisions you made that might have affected the performance of your implementations, and say why you think this is the case.

● Prepare a **thorough discussion** and **conclusion** addressing the difference between the development of a controller using the BBR approach and the Evolutionary Robotics approach. As a postgraduate student, you must present a **thorough discussion** of both methods and also **make comparisons with other methodologies** used to create intelligent robot controllers.

● Include useful references to the wider literature especially when comparing your implementations with other possible methodologies (see above). Additionally, you might also use references to books, papers and articles to justify particular implementation choices, or you could compare your findings to those reported elsewhere. It is mandatory to include at least **8 relevant references.** Use the standard referencing style of the provided IEEE template for this.

The named '**Group Leader**' should submit the report (as a .**pdf** file), the "Coursework Group Signing Sheet" signed by all members of the group (as a .**pdf** file), short videos (in a .**zip** file) and the code (in a .**zip** file) to CANVAS using the links provided.

NOTE: Your CODE **should not** be uploaded as a PDF, as we need to be able to run your code. If we can NOT run your controller, your CW will not be marked, and you will receive 0 marks.

Grading will use the assessment criteria given in the table below.

Marking scheme for F21RO Coursework

Please note that all tasks will be assessed following the corresponding criteria below (*)

(*) Please ignore the requirement for Harvard Referencing Style when using the IEEE template.

Criteria	Weight	A (70-100%)	B (60-69%)	C (50-59%)	D (40-49%)	E/F (<40%)
Implementation *(i.e. code for Tasks, and evaluation, comments and documentation)*	40%	Creative implementations of each Task that exceed the basic requirements. Correct evaluation code. Easy to read and well structured.	Correct implementations of the basic requirements. Generally good coding, structure and documentation.	Some significant issues in terms of correctness, structure, coding practice and documentation.	Major issues in terms of correctness, structure, coding practice and documentation.	Critical errors: for example, the code does not compile and/or run, or inappropriate algorithms have been implemented.
Experimental study *(i.e. choice and validity of experiments performed, presentation of results, including short video)*	25%	Robot behaviours investigated are well motivated and the rationale for choices made are well ellaborated. Suitable results have been collected and are clearly presented and meaningful.	Some minor issues in terms of the motivation or description of resultant robot behaviours, the experiments performed, or the presentation of results.	Some significant issues in terms of the motivation or description of of resultant robot behaviours, the experiments performed, or the presentation of results.	Some major issues: experiments do not make sense, have invalid results, or the Tasks and studies are not adequately described.	Some critical issues: experimental study is nonsensical or missing, the experiments are inappropriate, or the description of the studies are uninformative.
Wider discussion *(i.e. intro, interpretation of results, conclusions, use of the wider literature)*	25%	Clear, insightful discussion that shows a good understanding of BBR (behaviour based robotics) and ER (evolutionary robotics) and includes well chosen references to the wider literature.	Generally clear and insightful, but shows some misunderstanding of BBR (behaviour based robotics) and ER (evolutionary robotics) . Adequate use of the wider literature.	The discussion is limited in terms of the depth or volume of understanding it demonstrates. Little or no use of the wider literature.	Some major issues in terms of depth or volume of understanding. No use of the wider literature.	No real demonstration that the subject matter has been understood, or very limited in its scope.
Report *(i.e. structure, language, referencing etc.)*	10%	Report is well structured and divided into sections; good use of language; consistent use of font Arial, size 12; perfect use of Harvard referencing style	Report is suitably structured and divided into sections; mostly good use of language; use of font Arial, size 12; use of Harvard referencing style	Report is structured but not divided into sections; language issues that affect readability; inconsistent use of fonts and sizes; mixed use of referencing styles	Report is poorly structured; substantial language issues that affect readability; use of different fonts and sizes; no referencing style	Report has a nonsensical structure; language issues make it very hard to read; use of different fonts and sizes; no referencing style