Module Specification

Robot Learning and Teleoperation

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Contents

Part 1: Information

Module title: Robot Learning and Teleoperation

Module code: UFME7R-15-M

Level: Level 7

For implementation from: 2023-24

UWE credit rating: 15

ECTS credit rating: 7.5

College: College of Arts, Technology and Environment

School: CATE School of Engineering

Partner institutions: None

Field: Engineering, Design and Mathematics

Module type: Standard

Pre-requisites: None

Excluded combinations: None

Co-requisites: None

Continuing professional development: No

Professional, statutory or regulatory body requirements: None

Part 2: Description

Overview: This new optional module will bring students state of the art robotic learning knowledge for teleoperation to satisfy students' need to learn up-to-date robotic knowledge.

Features: Not applicable

Educational aims: Teleoperation has been playing an important role for modern robotic applications. Nowadays learning based technologies are more popularly used than conventional control-based methods. This new optional module will bring students state of the art robotic learning knowledge for teleoperation to satisfy students' need to learn up-to-date robotic knowledge.

Outline syllabus: Part 0: Introduction
1: Dynamic Systems
1.1 Background and Significance of Robot Skill Learning and Teleoperation
This course provides an overview of the background and significance of robot skill learning and teleoperation. Students will explore the motivations behind the development of robot skill learning techniques and understand the role of teleoperation in robotic systems.
1.2 Course Introduction and Credits, Examinations, etc.
Students will be introduced to the course structure, learning objectives, and evaluation methods. The course credit system, examination formats, and grading criteria will also be discussed to familiarize students with the course requirements.
1.3 Summary

Part 1: Theoretical Basis
2: Dynamic Systems
2.1 Autonomous Dynamic Systems
This course delves into the study of autonomous dynamic systems, which is the fundamental to understanding robot behavior. Students will learn about the principles and mathematical models used to describe autonomous systems and their dynamics.
2.2 Non-autonomous Dynamic Systems
This course will explore non-autonomous dynamic systems. Students will learn the behaviors and characteristics of the non-autonomous systems, including dynamics and mathematical models in robot skill learning.
2.3 Stability Analysis Method
Stability analysis is crucial in understanding the performance of the dynamic systems. This course introduces various stability analysis methods used in the study of dynamic systems. Students will learn how to assess the stability of robot control systems and analyze their robustness.
2.4 Summary

3: Probabilistic Systems (Part 1)

3.1 Multidimensional Gaussian Distribution

Probability theory plays a vital role in robot skill learning and teleoperation. This course focuses on the multidimensional Gaussian Distribution, a fundamental probabilistic model used in robotics. Students will learn about its properties, statistical inference, and applications in robot systems.

3.2 Gaussian Mixture Model and EM Optimization

Expanding on the Gaussian distribution, this course introduces the Gaussian mixture model (GMM) and the expectation-maximization (EM) optimization algorithm. Students will understand how GMMs can be used to model the complex data distributions and learn about EM optimization for parameters.

3.3 Summary

4: Probabilistic Systems (Part 2)

4.1 Gaussian Mixture Regression

This course explores Gaussian mixture regression (GMR), which is a powerful tool for modeling and predicting robot trajectories. Students will learn how GMR combines the capabilities of GMMs and regression analysis to capture complex relationships between variables.

4.2 Gaussian Process

Gaussian processes provide a flexible and non-parametric framework for modeling and inference. This course will introduce Gaussian process models and their applications in robot learning and control. Students will understand the concepts of kernel functions, hyperparameters, and Bayesian inference.

4.3 Summary

Part 2: Robot Teaching and Learning

5: Dynamic Movement Primitives

5.1 Learning and Generalization of Dynamic Movement Primitives

Dynamic movement primitives (DMPs) are essential for robot skill learning. In this course, students will explore the principles and techniques used to learn and generalize DMPs. They will understand how DMPs are expressed human demonstrations and how to generate robot motions using DMPs.

5.2 Dynamic Movement Primitives for Obstacle Avoidance

This course focuses on the application of DMPs for obstacle avoidance tasks. Students will learn how to integrate DMPs with obstacle detection to enable safe and efficient robot navigation in a complex environment.

5.3 Summary

6: Gaussian Mixture Models

6.1 Gaussian Mixture Model Learning and Generalization

This course explores Gaussian mixture models (GMMs) in the context of robot skill teaching and learning. Students will learn advanced techniques for GMM learning and generalization, including parameter estimation, model selection, and adaptation.

6.2 Gaussian Mixture Model Based on Dynamic Motion Primitives

Building upon Course 6.1 and Course 5, this course focuses on the integration of Gaussian mixture models with dynamic motion primitives. Students will understand how GMMs can enhance the adaptability and expressiveness of robot motions learned from demonstrations.

6.3 Summary

7: Generalized Gaussian Mixture Models

7.1 Generalized Gaussian Mixture Models

Generalized Gaussian mixture models (GGMMs) provide a powerful framework for modeling complex data distributions. This course introduces GGMMs and their applications in robot teaching and learning. Students will learn about the advantages of GGMMs over traditional GMMs and their use in capturing higher-order statistics.

7.2 Autonomous Dynamical Systems Based on Gaussian Mixture Models

This course will explore the application of GGMMs in developing autonomous dynamical systems. Students will understand how GGMMs can be used to model and control complex robot behaviors, enabling autonomous decision-making and adaptation.

7.3 Summary

8: Other Primitive Models

8.1 Probabilistic Motion Primitive Learning and Generalization

This course introduces probabilistic motion primitive models, which will extend the capabilities of DMPs and GMMs. Students will learn about advanced techniques for probabilistic motion primitive learning and generalization, including probabilistic inference and model adaptation.

8.2 Gaussian Process Learning and Generalization

Building upon Course 4, this course will explore Gaussian process models in the context of robot teaching and learning. Students will understand how Gaussian processes can be used for non-parametric learning and trajectory generation, enabling adaptive and flexible robot behaviors.

8.3 Hidden Semi-Markov Model Learning and Generalization

Hidden semi-Markov models (HSMMs) provide a framework for capturing temporal dependencies in robot behavior. In this part, students learn about HSMM learning and generalization techniques, including the Baum-Welch algorithm and Viterbi algorithm.

8.4 Summary

9: Application of Robot Teaching and Learning

9.1 Stiffness-Adaptive Skill Transfer based on Surface EMG Signals

In this course, students will make a comprehensive study about the state-of-the-art application of robot learning techniques. The first part focus on exploring the transfer of skills based on surface electromyography (EMG) signals, enabling stiffness-adaptive control and safe interaction between humans and robots.

9.2 Transfer of Writing Skills based on Generalized Gaussian Mixture Model

The second part focuses on the transfer of writing skills from a human to a robot using generalized Gaussian mixture models. Students will learn that how to apply the generalized Gaussian mixture models in robot learning and replicating human-like writing behaviors.

9.3 Summary

Part III: Robot Teleoperation Technology

10: Fundamentals of Robotic Teleoperation Technology

10.1 Introduction to Teleoperation System

This course provides an introduction to teleoperation systems in robotics. Students will learn about the fundamental concepts, components, and architectures of teleoperation systems, as well as the challenges and considerations in designing and implementing them.

10.2 Composition and Application of Teleoperation System

Base on Course 10.1, this course explores composition and practical applications of teleoperation systems. Students will understand the roles and interactions between different components, such as haptic devices, communication interfaces, and control algorithms, in achieving effective robot teleoperation.

10.3 Summary

11: Teleoperation Control

11.1 Basic Principles of Teleoperation Control

This course focuses on the fundamental principles of teleoperation control. Students can learn different control architectures and strategies, and communication protocols used in teleoperation systems to ensure stability, transparency, and safety.

11.2 Remote Operation Control based on Position Feedback

Building upon Course 11.1, this course delves into remote operation control techniques based on position feedback. Students will explore the design and implementation of position-based control algorithms for teleoperated robotic systems.

11.3 Stability Criterion for Teleoperation System

Stability is a critical aspect of teleoperation systems. This course introduces stability criteria and analysis methods specific to teleoperation systems. Students will learn how to assess the stability of teleoperation control systems and ensure reliable human-robot interaction.

11.4 Summary

12: Robot Teaching and Learning based on Teleoperation

12.1 Simulation of Teleoperation System based on MATLAB

In this course, students will engage in a comprehensive project focusing on the simulation of a teleoperation system using MATLAB. In the course, the teacher will present the modelling process using Matlab and Simulink. As the coursework, the students will develop models, algorithms, and simulations to explore the dynamics, control, and learning aspects of teleoperated robotic systems.

12.2 Robot Behavior Learning based on Teleoperation Teaching
This course explores the application of teleoperation-based teaching for robot behavior learning. Students will develop algorithms and techniques to enable the robot to learn and adapt behavior based on human teleoperation demonstrations. This will be the final course work as well.
12.3 Summary

Part 3: Teaching and learning methods

Teaching and learning methods: The teaching and learning method involves a combination of theoretical knowledge and practical implementation to enhance students' understanding of robot learning and teleoperation concepts. The teacher will be presented with teacher presentations and discussions with students. The students will complete coursework and make group discussions and presentations. By incorporating hands-on experimentation and practice, students gain state-of-the-art theoretical knowledge of robot learning as well as practical skills, problem-solving abilities, and a deeper understanding of the challenges and opportunities of robot learning and teleoperation. This teaching and learning method encourages active engagement, critical thinking, and application of theoretical knowledge in real-world applications.

Module Learning outcomes: On successful completion of this module students will achieve the following learning outcomes.

MO1 Examine the fundamental concepts and principles of robot learning and teleoperation, including their roles and significance in robotics.

MO2 Evaluate different robot learning methods and teleoperation techniques, including Dynamic Systems, Probabilistic Systems, Dynamic Movement Primitives, and Gaussian Mixture Models and considering their strengths, limitations, and applicability to real-world scenarios.

MO3 Apply robot learning algorithms to teach robots new skills and behaviours, enabling them to adapt and generalize from training data.

MO4 Design and implement teleoperation systems for safe and efficient human-robot interaction, with considerations of control architectures, communication protocols, and user interfaces.

Hours to be allocated: 150

Contact hours:

Lectures = 12 hours

Total = 12

Reading list: The reading list for this module can be accessed at readinglists.uwe.ac.uk via the following link https://rl.talis.com/3/uwe/lists/3924ABAC-957B-CF56-115A-5A95093E1998.html?lang=en&login=1

Part 4: Assessment

Assessment strategy: The assessment strategy for this course aims to accomplish several objectives:
1)Provide a measurement of students' achievement and certify their learning outcomes.
2)Develop and refine the course by incorporating feedback from students.
3)Evaluate students' learning skills in the practical application of robotics.

Here are the details of the assessment strategy:
We will employ two methods to assess students' learning achievements:

a)Online exam: Students will be required to complete an online exam for assessment of accomplishment of LO1 and LO2.

b)Coursework project: LO3 and LO4 will be evaluated based on the performance and outputs in coursework completed project.

There are three main achievements for the student learning.
1)Achieving the basic knowledge of robot skill learning and teleoperation which

involves conducting a review of current research on the topic and integrating the knowledge gained from the courses. The relevant assessment will measure the students' understanding and application of the taught concepts.
2)Acquisition of several robot skill learning methods, such as the Gaussian Mixture Model and Dynamic Movement Primitives, students are required to complete an independent coursework simulation using MATLAB. The relevant assessment will focus on evaluation of implementation of robot skill learning using the aforementioned methods.
3)Acquiring knowledge of the teleoperation system and basic control methods for robot teleoperation. This coursework will integrate robot teleoperation with robot skill learning to achieve robot learning through teleoperation. The relevant assessment evaluates the students' ability to apply concepts effectively in robotics research.
4)Additionally, to supplement the course achievement assessment, attendance would be taken into account when calculating the final score.

Plagiarism measures: We will employ anti-plagiarism software to detect any instances of plagiarism after the work is submitted. Additionally, we will conduct thorough investigations of each submission to ensure that it is the original work of the candidate.

Resit strategy: The course offers a resit option, including completing an independent coursework and passing an additional examination.

Assessment tasks:

Examination (Online) (First Sit)
Description: Online exam (3 hours)
Weighting: 50 %
Final assessment: Yes
Group work: No
Learning outcomes tested: MO1, MO2

Project (First Sit)

Description: Coursework project

Weighting: 50 %

Final assessment: No

Group work: No

Learning outcomes tested: MO3, MO4

Examination (Online) (Resit)

Description: Online exam (3 hours)

Weighting: 50 %

Final assessment: Yes

Group work: No

Learning outcomes tested: MO1, MO2

Project (Resit)

Description: Coursework project

Weighting: 50 %

Final assessment: No

Group work: No

Learning outcomes tested: MO3, MO4

Part 5: Contributes towards

This module contributes towards the following programmes of study:

Robotics {Joint Award}[Frenchay] MSc 2023-24