



人工智能时代下的机器人设计

Artificial Intelligence and Robots Design



#1. 课程背景及简介



人工智能学科，是一个以计算机科学为基础，由计算机、心理学、哲学等多学科交叉融合交叉学科、新兴学科，研究、开发用于模拟、延伸和扩展人的智能的理论、方法、技术及应用系统的一门新的技术科学，企图了解智能的实质，并生产出一种新的能以人类智能相似的方式做出反应的智能机器，该领域的研究包括机器人、语言识别、图像识别、自然语言处理和专家系统等。

如今人工智能已变成了一个无所不包的术语，很多用来执行在过去需要人工输入的复杂任务的应用（例如与客户在线沟通或下棋）都可以被称作人工智能。在现实中，人工智能也经常与它的子领域互换使用，例如机器学习和深度学习。然而，它们之间是有区别的，例如机器学习侧重于构建能够基于自身使用的数据学习或改进性能的系统。换句话说，所有的机器学习都是 AI，但不是所有的 AI 都是机器学习。为了充分发挥 AI 的价值，如今许多企业正加大对数据科学团队的投入。人工智能不是人的智能，但能像人那样思考，也可能超过人的智能。

本课程向学生介绍机器人学习领域的最新发展。一般来说，机器学习侧重于构建可以根据所使用的训练数据学习或提高性能的系统。人工智能 (AI) 使用机器学习来实现人类认知过程。过去许多用于执行需要人工输入的复杂任务（例如与客户在线交流或下棋）的应用程序都可以称为 AI。为了充分发挥 AI 的价值，现在很多公司都在加大对数据科学团队的投入，以实现机器人学习。本课程首先概述相关子领域的背景材料，包括计算机视觉、机器学习、机器人技术和控制理论。该课程将涵盖有关机器人导航的案例研究并解释在使用人工智能设计和实施机器人时需要学习或考虑的各种重要观点。

#2. 学习目标



本课程将解决许多挑战，如：

- ★ 学习描述典型机器人管道的各种组件
- ★ 解释认知机器人与其他机器人分支的区别
- ★ 使用 ROS 编写发布者、订阅者和服务
- ★ 对机器人机械手进行编程以执行拾取和放置任务
- ★ 识别认知架构的几个例子并描述它们是如何工作的。
- ★ 描述马尔可夫决策过程 (MDPs)
- ★ 探索如何使用上述学习技术来解决机器人导航和操作中的问题

#3. 任课教师信息



Prof. J C F

教授目前是纽约大学计算机科学学院硕士研究生项目的副教授，也就职于纽约



大学柯朗数学科学研究所，在众多相关行业的垂直领域拥有 37 年的实战经验，并拥有超过 27 年的教学和培训经验。他曾在大型美国公司担任行政职务，并且是多个行业标准委员会的审查员，早年间在科罗拉多大学博尔德分校，丹佛 大学，哥伦比亚大学等知名学府的研究所任助教。教授的教学和研究兴趣包括 信息安全、数据库系统、通讯工程、云计算、软件工程等，重点是大规模软件体系结构和业务解决方案。

4. 课程设置

PBL

周期	时间	课程设置内容	课时
第一周 学习指南 教授及助教辅导	1 月 28 日 周六	什么是 PBL 教学方法	1
		PBL 教学的常见形式	1
	1 月 29 日 周日	教授课-1 交叉学科 PBL 课程设计及知识点学习 学习目标：认知机器人概述 1.1 定义 1.2 人工智能机器人的运行 1.3 行业要求 1.4 软件开发环境	3
	1 月 30 日 周一	助教课-1 知识点查漏补缺	2
	1 月 31 日 周二	教授课-2 制定小组项目方向 学习目标：移动机器人 2.1 机器人导航的挑战 2.2 相对位置估计和运动学 2.3 绝对位置估计 2.4 闭环控制和 PID 控制 2.5 Go-To-Position 和 Go-To-Pose 问题 2.6 地图中最短路径的识别 2.7 案例研究	3
	2 月 1 日 周三	助教课-2 知识点查漏补缺	2
	2 月 2 日 周四	教授课-3 交叉学科课程知识点学习 学习目标：机械手 3.1 机器人编程 3.2 物体姿态规范	3



第二周 教授及助教辅导		3.3 基于帧的任务规范 3.4 多任务学习 3.5 Pick-and-Place 示例实现 3.6 高级运动学 3.7 案例研究	
	2月3日 周五	助教课-3 知识点查漏补缺& 跟进学生个人作业进度	2
	2月4日 周六	教授课-4 互动与项目设计跟进答疑	1.5
	2月6日 周一	助教课-4 跟进学生个人作业进度	2
	2月7日 周二	教授课-5 交叉学科课程知识点学习 学习目标：机器人视觉 4.1 计算机视觉 4.2 OpenCV 简介 4.3 细分 4.4 图像分析与特征提取 4.5 分类器 4.6 透视变换	2
第三周 教授及助教辅导 未来展望	2月8日 周三	助教课-5 跟进学生个人作业进度	2
	2月9日 周四	教授课-6 交叉学科课程知识点学习 学习目标：人工认知系统 5.1 认知主义范式 5.2 涌现和混合范式 5.3 学习与发展 5.4 记忆与展望 5.5 内部模拟 5.6 交互与社会认知 5.7 认知架构简介 5.8 求解马尔可夫决策过程 (MDP) 5.9 认知科学和心理学的教训 5.10 现代深度强化学习与经典控制	2
	2月10日 周五	助教课-6 知识点查漏补缺& 指导学生个人作业成果展示	2
	2月11日	教授课-7	1.5



	周六	教授点评学生个人作业	
	2 月 12 日	升学与就业方向展望	1
	周日	个人规划及发展建议	1
总课时	32		

#5. 阅读材料



- ★ Robotic Systems. Kris Hauser.
- ★ O’Kane, J. M. (2018). A Gentle Introduction to ROS.
- ★ Modern Robotics: Mechanics, Planning, and Control. Frank C. Park, Kevin M. Lynch. Cambridge University Press.
- ★ Corke, P. (2017). Robotics, Vision and Control, 2nd Edition, Springer.
- ★ Computer Vision: Algorithms and Applications 2nd Edition. Richard Szeliski, Microsoft Research.
- ★ Reinforcement Learning: An Introduction. Richard S. Sutton and Andrew G. Barto. Second Edition, MIT Press, Cambridge, MA, 2018.

#6. 项目主题



本课程使用 PBL 教学法，PBL 即项目式学习，是一种以学生为中心的教学方法，教师提供关键素材构建学习环境，学生通过在此环境里解决一个开放式项目的经历来学习。以下为本课程可选的项目主题：

- 最近的文献中选择一篇论文，实施并对该论文中描述的方法进行压力测试。描述它在哪里起作用，在哪里不起作用。追求可以改进方法的扩展。
- 获取一些公开可用的代码，将其应用于有趣的不同问题，并探索各种扩展和修改。
- 针对您感兴趣的问题设计并实施解决方案。可以在模拟或真实硬件（例如 LoCoBots）上完成。

英文版教学大纲



Course Title	Artificial Intelligence and Robot Design
Credit Hours	32 (one credit hour is 45 minutes)
Course Objectives	<p>This class will address challenges such as:</p> <ul style="list-style-type: none">★ Describe, at a high-level, the various components of a typical robotics pipeline★ Explain what differentiates cognitive



	<p>robotics from other branches of robotics</p> <ul style="list-style-type: none">★Write publisher, subscriber, and services using ROS★Program a robot manipulator to perform pick-and-place tasks★Identify several examples of cognitive architectures and describe how they work.★Describe Markov Decision Processes (MDPs).★ Describe how the aforementioned learning techniques can be used to tackle problems in robotic navigation and manipulation.
Course Description	<p>This course introduces students to the most recent developments in the area of robot learning. In general, machine learning focuses on building systems that can learn or improve performance based on the training data used. Artificial Intelligence (AI) uses machine learning to implement human cognitive processes. Many applications used to perform complex tasks that required human input in the past (such as communicating with customers online or playing chess) can be called AI. In order to give full play to the value of AI, many companies are now increasing their investment in data science teams to implement robot learning. The goal of this course is to give students an understanding of what is involved in the design of a cognitive robot and give them the knowledge and skills to produce working</p>



	<p>implementations for simple instances of cognitive fetch and place tasks. The course introduces the general area of robotics and relevant subfields of cognitive robotics including computer vision, machine learning, robotics and control theory. Students will learn how to develop software using ROS (Robot Operating System) and they will learn the principles of robot manipulation and task level robot programming, including the mathematical tools required to specify the position and orientation of robots and objects in the robot environment. Students will be introduced to the main topics in artificial cognitive systems, including the different paradigms of cognitive science and cognitive architectures. This will lead to explaining various perspectives that are important to learn from or consider when using artificial intelligence to design and implement robots. As time and student interest allow, the course may cover advanced techniques (i.e., model-free reinforcement learning with function approximators, model learning, model-based reinforcement learning with learned models, imitation learning, inverse reinforcement learning, self-supervised learning, and exploration, hierarchies) that will be delved into via a review of recent research papers that</p>
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	develop and validate them. The course may also cover case-studies on robotic navigation, and manipulation from recent papers. Project work as part of the course will include research in this evolving area.
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Brief introduction of the course

Nowadays, Artificial Intelligence has become an all-encompassing term. Many applications used to perform complex tasks that required human input in the past (such as communicating with customers online or playing chess) can be called AI. In reality, Artificial Intelligence is often used interchangeably with its sub-fields, such as machine learning and deep learning. However, there are differences between them. For example, machine learning focuses on building systems that can learn or improve performance based on the data they use. In other words, all machine learning is AI, but not all AI is machine learning. In order to give full play to the value of AI, many companies are now increasing their investment in data science teams. Artificial intelligence is not human intelligence, but being able to think like humans may also exceed human intelligence.

	Topics
Module 1	Objective: Overview of Cognitive Robotics 1.1 Definitions 1.2 Operation of an Artificially Intelligent Robot 1.3 Industrial Requirements 1.4 Software Development Environment
Module 2	Objective: Mobile Robots 2.1 Challenges of Robot Navigation 2.2 Relative Position Estimation and Kinematics 2.3 Absolute Position Estimation 2.4 Closed-Loop-Control and PID Control 2.5 Go-To-Position and Go-To-Pose Problems 2.6 Identification of Shortest Path in a Map 2.7 Case Studies
Module 3	Objective: Robot Manipulators 3.1 Robot Programming 3.2 Object Pose Specification 3.3 Frame-Based Task Specification



	3.4 Task-Level Robot Programming Example 3.5 Pick-and-Place Sample Implementation 3.6 Advanced Kinematics 3.7 Case Studies
Module 4	Objective: Robot Vision 4.1 Computer Vision 4.2 Introduction to OpenCV 4.3 Segmentation 4.4 Image Analysis and Feature Extraction 4.5 Classifiers 4.6 Perspective Transformation
Module 5	Objective: Artificial Cognitive Systems 5.1 Cognitivist Paradigm 5.2 Emergent and Hybrid Paradigms 5.3 Learning and Development 5.4 Memory and Prospection 5.5 Internal Simulation 5.6 Interaction and Social Cognition 5.7 Introduction to Cognitive Architectures 5.8 Solving Markov Decision Processes (MDPs) 5.9 Lessons from Cognitive Science and Psychology 5.10 Modern Deep RL vs. Classical Control
Module 6	Objective: Project Discussion Description: a live session to discuss students' projects
Module 7	Objective: Project Presentation Description: a live session where students present their projects

Required Readings

- ★ Robotic Systems. Kris Hauser.
- ★ O’Kane, J. M. (2018). A Gentle Introduction to ROS.
- ★ Modern Robotics: Mechanics, Planning, and Control. Frank C. Park, Kevin M. Lynch. Cambridge University Press.
- ★ Corke, P. (2017). Robotics, Vision and Control, 2nd Edition, Springer.
- ★ Computer Vision: Algorithms and Applications 2nd Edition. Richard Szeliski, Microsoft Research.
- ★ Reinforcement Learning: An Introduction. Richard S. Sutton and Andrew G. Barto. Second Edition, MIT Press, Cambridge, MA, 2018.

Suggested list of the topics for the final project

- 1.Select a paper from recent literature, implement and stress-test the



approach described in that paper. Characterize where it works, where it does not. Pursue extensions that can improve the approach.

2. Take some publicly available code, apply it to an interesting different problem and explore various extensions and modifications.

3. Design and implement a solution to a problem that interests you. Be sure to formulate a clear short-term goal and desired outcome for the course project. Projects can be done in simulation, or on real hardware.

Criteria

Homework: 50%

Project: 50%

Class Expectation

I would like to share with you, the student who is reading this syllabus, some of my experience to make this course most beneficial for you. I have found many times that students are reluctant to speak and raise questions in class. This is due to shyness or other reasons. Especially, when you think your question is not a clever one, you are intimidated by what other students, or the professor will think about you. So, I want to make it clear! The more questions you have, the more I will value you as a student and the more I can adapt my teaching to you. My role is to help you from whatever starting point you are. So please, ask many questions in class. Not asking questions, is an obstacle for learning.