Carnegie Mellon University Africa
Certificate Program in AI and Machine Learning in Africa

Course AIML01: Artificial Intelligence – Past, Present, and Future

Module 3: Example Applications
Lecture 2: AI Applications in Robotics

Welcome to Lecture 2 of Module 3, the second of four lectures that look at the applications of artificial intelligence. This lecture focusses on robotics.

In this lecture, we explain how the robots today fall well short of the robots that are portrayed in science fiction movies. We identify the many uses of AI in robotics. We provide an overview of the many types of robot and application domains. As an example, we look at robot-enhanced therapy for children with autism spectrum disorder (ASD). Finally, we mention the field of cognitive robotics and explain its goals and the challenges it faces in achieving these goals. We will finish up by summarizing what we have covered and identifying the articles that you should read to consolidate what you have learned.

We have three learning objectives, so that, after studying the material covered in this lecture, you should be able to do the following.

1. Provide examples of contemporary robots and explain how their capabilities fall well short of the robots in science fiction movies.

2. Highlight the main features of AI-enabled robotics, sometimes referred to as cognitive robots.

3. Identify one of the goals of cognitive robotics and explain the associated technical challenges.

Slide 1 Welcome to Lecture 2 of Module 3, the second of four lectures that look at the applications of artificial intelligence. This lecture focusses on robotics.

Slide 2 Robots feature prominently in the general public's perception of AI

This is due in part to the way they are portrayed in science fiction movies as machines that can think and move freely around the world, sometimes with super-human intelligence and mobility.

Slide 3 From cute robots such as Johnny 5 in Short Circuit

Slide 4 and WALL·E.

Slide 5 To more threatening robots such as the Skynet Terminator,

Slide 6 Sonny in I, Robot,

Slide 7 and Chappie.

Slide 8 There is a long way to go before we can build robots that are capable of what we see in science fiction movies.

Even so, there has been impressive progress in mechatronics and control over the past ten years.

Slide 9 For example, consider the mobility displayed by Atlas from Boston Dynamics.

Slide 10 [Play video]

Slide 11 And Spot, also from Boston Dynamics.

Slide 12 [Play video]

Slide 13 Or the dexterity of the Shadow Hand.

Slide 14 [Play video]

Slide 15 There have also been recent advances in cognition-enabled robot manipulation in everyday activities

Such as setting a table, preparing a simple meal, and clearing up afterwards.

Here is an example from the Everyday Activity Science and Engineering EASE interdisciplinary research center.

Slide 16 [Play video]

Slide 17 Robotics remains a key element of the domain of AI,

and AI tools and techniques play a central role in achieving the robust performance that are required of robots,

especially when they are operating in environments that are not engineered to facilitate their operation.

Slide 18 AI is used in robotics for many purposes, including autonomous navigation, task planning, task execution, object detection, object grasping and manipulation, inspection & surveillance, and social human-robot interaction (or HRI).

HRI involves several AI techniques, such as natural language processing, face recognition, sentiment analysis, gesture understanding, and intention recognition.

Slide 19 AI is also used in an extensive range of robots.

The IEEE robots website features over two hundred robots of many different types:
wheeled,
legged,
tracked,
airborne,
underwater, and
humanoid,
targeting consumers,
entertainment,
education,
research,
medicine and health care,
disaster response,
service & industrial,
aerospace,
military & security applications,
telepresence,
self-driving cars,
and agriculture.

Here's a sample.

Slide 20 This is the Pepper social robot, a humanoid robot designed to be a companion for humans in the home and help customers in shops.

Slide 21 Nao is a small humanoid robot designed to interact with people.

It is used in research, education, and healthcare.

Slide 22 The iCub is a child-sized humanoid robot which can crawl, manipulate objects, and interact with people.

It was designed as an open-source platform for research in robotics, AI, and cognitive science.

Slide 23 Armar is a robot created to be a helper in industrial environments. Its humanoid form lets it use human tools such as power drills and hammers.

Slide 24 HRP-4 is one of the world's most advanced humanoids. It was designed to collaborate with humans.

Slide 25 The PR2 is one of the most advance research robots ever built. It can do things like clean up tables, fold towels, and fetch things from the fridge.

Slide 26 Sawyer is an industrial collaborative robot designed to help with manufacturing tasks and work alongside humans.

You can teach it new tasks by demonstrating what to do using the robot's own arm.

Slide 27 Atlas, which we met earlier, is the most agile humanoid robot in existence. It uses whole-body skills to move quickly and balance dynamically.

It can lift and carry objects like boxes and crates.

Slide 28 Aquanaut is an unmanned underwater vehicle that can transform itself from a submarine to a half-humanoid robot capable of carrying out complex manipulation tasks.

It can inspect undersea oil and gas infrastructure, open and close valves, and use tools.

Slide 29 ANYmal is a rugged, autonomous four-legged robot designed for inspection and manipulation tasks.

It can operate in rain, snow, wind, waterlogged rooms, and dusty environments.

Slide 30 AlphaDog is a quadruped robot the size of a mule.

It's powered by a hydraulic actuation system and is designed to assist soldiers in carrying heavy gear over rough terrain.

Slide 31 Spot, which we also met earlier, is a compact, nimble four-legged robot that can trot around your office, home, or outdoors

Slide 32 Aibo is a robotic dog whose personality and behavior evolves over time.

It can recognize its owner's face, detect smiles and words of praise, and learn new tricks.

Slide 33 Keepon is a social robot that interacts with people and dances when music is playing.

It's used to engage with children in autism research.

A toy version, My Keepon, is designed for general audiences.

Slide 34 Paro is a robotic baby harp seal designed as a therapeutic tool for use in hospitals and nursing homes.

Slide 35 Salamandra robotica II is an amphibious robot inspired by the salamander's anatomy and nervous system.

It's used to study robot locomotion and test neurobiological models in real environments.

Slide 36 Meca500 is the world's smallest, most compact six-axis industrial robot arm. It's also one of the most precise.

Slide 37 Universal Robots cobots are versatile, lightweight collaborative robotic arms designed to work safely alongside humans.

Slide 38 The da Vinci is a surgical robot designed for minimally invasive procedures.

It has four arms equipped with surgical instruments and cameras that a physician controls remotely from a console.

Slide 39 The Shadow Dexterous Hand, again a robot we met earlier, is one of the most advanced robot hands in the world.

It's designed to replicate as much of the functionality, dimensions, and range of motion of the human hand as possible.

Slide 40 Roomba is an autonomous vacuum and one of the most popular consumer robots in existence.

It navigates around clutter and under furniture cleaning your floors, and returns to its charging dock when finished.

Slide 41 This is the Create 2, a low-cost version of the Roomba for education.

It doesn't have the vacuum cleaning function but can be controlled by a remote computer.

Slide 42 Picker Robots are mobile machines designed to autonomously retrieve and carry products in a warehouse.

The robots are directed through AI-powered software that identifies the most efficient paths for them to pick, replenish, return, and count goods.

Slide 43 Freight is an autonomous mobile base for use in warehouses to transport materials from point A to point B.

Slide 44 Boss is the world's smartest Chevy Tahoe. Created by Carnegie Mellon University, in 2007, it won the DARPA Urban Challenge for autonomous vehicles.

Slide 45 Google's self-driving car is a modified Toyota Prius that can autonomously drive in city traffic and on highways.

Slide 46 Versatrax is a mobile robot designed for hazardous environments.

It allows users to locate, inspect, and safely remove dangerous materials from any site faster than by conventional means.

Slide 47 Kobra is a rugged, remote control robot designed to search for explosives and carry out reconnaissance missions.

It rolls on tank-like treads, and its manipulator arm can lift heavy payloads.

Slide 48 Beam is a telepresence robotic system that can "teleport" you to a remote location, allowing you to move around and interact with people.

Slide 49 The Global Hawk is an unmanned aerial vehicle that's used for high-altitude, long-duration surveillance.

Slide 50 Zipline is an autonomous fixed-wing aircraft drone used to carry blood and medicine from a distribution center to wherever it's needed.

And here is a Zipline drone in action, dropping packs of blood to a clinic in the rural south of Rwanda.

Slide 51 [Play video]

Slide 52 One of the main goals of AI in robotics is to create a collaborative robot,

That is, a robot that can share a common goal with a human

and share the human's intentions to achieve that goal,

acting jointly with the human,

paying attention to what the human is doing, and, crucially,

anticipating any help the human might need to complete whatever tasks she or he is working on.

Slide 53 The overlap between robotics and AI is a good illustration of the manner in which the scope of AI has expanded to embrace many techniques in computer science and engineering, for example,

control theory
machine learning
signal processing,
and computer vision

Slide 54 In addition, drawing from insights in the cognitive and biological sciences,

AI techniques are used to support the core cognitive abilities of

perception (i.e., the interpretation of sensed data),
attention,
action selection,
memory,
learning,
reasoning,
metacognition,
and prospection.

This field of robotics and AI is sometimes called cognitive robotics.

Slide 55 One example of AI in robotics is robot-enhanced therapy where robots assist a psychotherapist working with children with autism spectrum disorder.

Slide 56 Under the guidance of clinical practitioners, this project developed interactive capabilities for social robots that allowed them to engage a child in clinically derived exercises.

Slide 57 The robot can operate autonomously for limited periods under the supervision of a psychotherapist.

Slide 58 AI plays a major part in the success of this application, specifically in its cognitive ability to interpret body movement and appearance-based cues of emotion.

This allows the robot to assess the child's actions by learning to map them to therapist-specific classes of behavior.

In turn, the robot also learns to map these child behaviors to appropriate robot responses, again as specified by the therapists.

Slide 59 One of the challenges of cognitive robotics is for humans to be able to give a robot some task to perform by stating that task in the same terms they would use if they were talking to another human being,

Conveying just the essence of the goal without having to specify exactly how the task is the be carried out

The image shows a PR2 robot in the process of pouring popcorn from a saucepan during a demonstration of cognition-enabled robot manipulation using the CRAM cognitive architecture (Beetz et al. 2010).

To summarize:

1. Real robots don't yet have the abilities of the robots that we see in science fiction movies.

2. But great progress is being achieved through the use of advanced control and artificial intelligence.

3. There are many different types of robot, each designed for a wide variety of application domains.

4. The intersection of the fields of robotics, artificial intelligence, and cognitive science has given us the field of cognitive robotics which aims to develop robots that can interact naturally with people, and carry out tasks for people without having to be told exactly how to perform each step in the task.

Recommended Reading

Here is some recommended reading.

Cao, H.-L., Gomez Esteban, P., Baxter, P., Belpaeme, T., Billing, E., Cai, H., Coeckelbergh, M., Costescu, C., David, D., De Beir, A., Hernandez Garcia, D., Kennedy, J., Liu, H., Matu, S., Mazel, A., Kumar Pandey, A., Richardson, K., Senft, E., Thill, S.,Van de Perre, G., Vanderborght, B., Vernon, D., Wakanuma, K., Yu, H., Zhou, X., Ziemke, T. (2019). Robot-Enhanced Therapy: Development and Validation of a Supervised Autonomous Robotic System for Autism Spectrum Disorders Therapy, IEEE Robotics and Automation Magazine, Vol. 26, No. 2, pp. 49-58.
http://vernon.eu/publications/19_Cao_et_al.pdf

Sandini, G., Sciutti, A. and Vernon, D. (2021). Cognitive Robotics. In M. Ang, O. Khatib, and B. Siciliano (Eds.), Encyclopedia of Robotics. Springer.
http://vernon.eu/publications/2021_Sandini_et_al.pdf

References

Here are the references cited to support the main points in what we covered today.

Beetz, M., Mösenlechner, L., & Tenorth, M. (2010). CRAM – A cognitive robot abstract machine for everyday manipulation in human environments. In IEEE/RSJ International Conference on Intelligent Robots and Systems, pp. 1012–101, Taipei, Taiwan.

Murphy, R. (2019) Introduction to AI Robotics. Cambridge, MA: MIT Press. https://mitpress.mit.edu/books/introduction-ai-robotics-second-edition

Vernon, D. (2022), Cognitive Architectures, in Cognitive Robotics, Cangelosi, A. and Asada, M. (Eds.). Cambridge, MA: MIT press, 2022. http://vernon.eu/publications/2022_Vernon.pdf