Artificial Intelligence

- **Intelligence**
  - “Capacity to solve new problems through the use of knowledge”
- **Artificial Intelligence**
  - “Science concerned with building intelligent machines, that is, machines that perform tasks that when performed by humans require intelligence”
Autonomous Agents

- **Traditional Definition:**
  “Computational System, situated in a given environment, that has the ability to perceive that environment using sensors and act, in an autonomous way, in that environment using its actuators to fulfill a given function.”

Robotic and Human Agents

- **Agent:**
  - Perceive its environment using sensors and executes actions using its actuators
  - Sensors:
    - Eyes, ears, nose, touch, ...
  - Actuators:
    - Legs, Arms, hands, vocal cords, ...

- **Robotic Agent:**
  - Sensors:
    - Cameras, sonar, infra-red, microphone
  - Actuators:
    - Motors, wheels, manipulators, speakers
Multi-Agent System (MAS)

• Composed by **multiple agents** that:
  – Exhibit **autonomous behavior**
  – **Interact** with the other agents in the system

Agents and Multi-Agent Systems

• To build individual autonomous intelligent agents is important
• However:
  – Agents don’t leave alone…
  – Necessary to work in group…
  – Multi-Agent Applications!
  – Robotic Agents: Body, Complex Environment
  – Coordination in necessary: **“To Work in Harmony in a Group”**
Intelligent Robotics

- **Robotics**
  - Science and technology for projecting, building, programming and using Robots
  - Study of Robotic Agents (with body)
  - Increased Complexity:
    - **Environments**: Dynamic, Inaccessible, Continuous and Non Deterministic!
    - Perception: Vision, Sensor Fusion
    - Action: Robot Control
    - Robot Architecture (Physical / Control)
    - Navigation in unknown environments
    - Interaction with other robots/humans
    - Multi-Robot Systems

Definition of Robot

- Notion derives from 2 strands of thought:
  - Humanoids --human-like
  - Automata --self-moving things
- “Robot” --derives from Czech word *robořa*
  - “Robota”: forced work or compulsory service
  - Term coined by Czech playwright Karel Capek
- Current notion of robot:
  - Programmable
  - Mechanically capable
  - Flexible
- Best Definition of robot:
  - Physical agent that generates “intelligent” connection between perception and action
Definition of Robot

• Robot “Robota” in Czech
  – “Robota”: forced work or compulsory service
  – Karel Capek (1920)

• General definitions:
  – Simple: “Machine that is similar to humans in shape or function”,
    “Machine that operates autonomously”…
  – “Physical Agent capable of establishing an (intelligent) connection
    between Perception and Action”
  – “Mechanical device capable of moving and that may perform
    physical tasks”
  – “Mechanical creature that may operate in an autonomous mode”
  – “Agent with Body!”

Control, Shape and Locomotion of Robots

• Control:
  – Directly by a human (space-shuttle robotic arm)
  – Autonomous based on its perceptions and decision methods
    (soccer playing robot in RoboCup)

• Locomotion:
  – Wheels (2, 4, etc.)
  – Legs (Bipeds, quadrupeds, hexapods)
  – Snakes
  – Static (Manipulators)

• Shapes:
  – Humanoids (shape and movement similar to humans)
  – Mobile robots (autonomous vehicles)
  – Industrial manipulators (shape depends on function)
  – Reconfigurable (change shape)
Utilization of Robots

• Used to Perform:
  – Dangerous or difficult tasks to be performed directly by humans
  – Repetitive tasks that may be performed more efficiently (or cheap) than when performed by humans (for example automobile assembling)

• Robot Types (use):
  – Domestic Robots (Pets – AIBO, vacuum cleaners)
  – Entertainment robots (social robots)
  – Industrial robots
  – Medical robots (lab robots)
  – Surveillance robots
  – Military robots
  – Intelligent buildings
  – Intelligent vehicles (Cars, Submarines, Airplanes) and AGVs
  – Educational robots

Current State of Robotics

• Moving from manufacturing, industrial manipulators to:
  – Entertainment robotics
  – Personal service robots
  – Medical robots
  – Industrial applications beyond factory (e.g., mining, agriculture)
  – Hazardous applications (e.g., military, toxic cleanup, space)
  – Multi-Robot Applications
Robotic Teams (Utilization)

- Multi-Robot Applications
  - Surveillance or Safety
  - Search and Rescue
  - Spatial Exploration
  - Housekeeper Robots in Intelligent buildings
  - Autonomous vehicle teams
  - War robots
  - Robotic Soccer

Robots: Hollywood vs. Real-World

- Hollywood Robots:
  - Human-like capabilities
  - “Sense all, know all”!

- Real-World Robots:
  - Insect or simple animal capabilities
  - “Sense little, know little”!
Visions: Dangers and Fears

• Books:
  – Frankenstein – 1818: Machine (monster) turns against its “creator”…
  – Work of Isaac Asimov about Robots and their interaction with society – IRobot (Asimov’s laws of Robotics)

• Old Movies:
  – Metropolis (1926)
  – The Day the Earth Stood Still (1951)
  – Forbidden Planet (1956)

Visions: Dangers and Fears

• Classical Movies:
  – 2001 Space Odyssey (1968)
  – Star Wars (1977)
  – Blade Runner (1982)

• Recent Movies:
  – Matrix (1999)
  – Artificial Intelligence (2001)
Asimov’s Robotic Laws

- The Three Laws of Robotics are a set of three rules written by Isaac Asimov, which almost all Robots appearing in his fiction must obey. Introduced in his 1942 short story "Runaround", although foreshadowed in a few earlier stories:
  - Law 0) A robot may not injure humanity or, through inaction, allow it.
  - Law 1) A robot may not injure a human being or, through inaction, allow a human being to come to harm.
  - Law 2) A robot must obey orders given to it by human beings, except where such orders would conflict with the First Law.
  - Law 3) A robot must protect its own existence as long as such protection does not conflict with the First or Second Law.

Robotic Competitions

- DARPA Grand-Challenge
- Intelligent Ground Vehicle Competition
- AAAI Grand Challenges
- RoboCup (Robotic Soccer World Championship)
- Robotic Soccer FIRA
- First Lego-League
- RoboOlympics
- Manitoba Robot Games
- Robotic Fight: BattleBots, RobotWars, Robot-Sumo
- Portuguese Competitions:
  - Festival Nacional de Robótica – Portuguese Robotics Open (including autonomous driving)
  - Micro-Mouse / Ciber-Mouse (Micro-Rato / Ciber-Rato)
  - Firefighting Robots
Robot Composition

• Sensors
  – Used to perceive the world
• Effectors and actuators
  – Used for locomotion and manipulation
• Controllers for the above systems
  – Coordinating information from sensors
  – Commanding the robot’s actuators
• Robot:
  – **Autonomous** system which exists in the physical world, can **sense** its environment and can **act** on it to achieve some goals

Challenges in Robotics

• Perception
  – Limited, noisy sensors
• Actuation
  – Limited capabilities of robot effectors
• Thinking
  – Time consuming in large state spaces
• Environments
  – Dynamic, fast reaction times needed
  – Inaccessible, thing about sensing
  – Continuous, huge state space
  – Non-Deterministic, no guarantee of success
Uncertainty

- Uncertainty is a key property of existence in the physical world
- Environment is stochastic and unpredictable
- Physical sensors provide limited, noisy, and inaccurate information
- Physical effectors produce limited, noisy, and inaccurate action
- Models are simplified and inaccurate
- Errors in perception, action and movement

Uncertainty

- A robot cannot accurately know the answers to the following questions:
  - Where am I?
  - Where are my body parts, are they working, what are they doing?
  - What did I just do? Was my action successful? Am I capable to do X? What will happen if I do X?
  - Who/what/where are you? What are you doing?
Classical activity decomposition

• Locomotion (moving around, going to places)
  – factory delivery, AGVs, Mars Pathfinder, vacuum cleaners...
• Manipulation (picking and handling objects)
  – factory automation, robotic arms, production lines, automated surgery...
• Division of robotics into two basic areas
  – mobile robotics (move around)
  – manipulator robotics (static)
• But these areas are together in domains like robot pets, robotic soccer and humanoid robots

Intelligent Robotics

• Intelligent Robotics Focus:
  – “Mobile Robotics”! (not manipulator robotics)
  – Intelligent Software! (not robotic hardware)
  – Cooperative Robotics
  – Designing Algorithms that allow robots to perform cooperatively, complex tasks, autonomously, in unstructured, dynamic, partially observable, non-deterministic and uncertain environments
Software for Intelligent Robots

- Software enabling autonomous mobile robots to perform, cooperatively, complex tasks, in unstructured, dynamic, partially observable, and uncertain environments:
  - Autonomous: robot makes majority of decisions on its own; no human-in-the-loop control (as opposed to teleoperated)
  - Mobile: robot does not have fixed based (e.g., wheeled, as opposed to manipulator arm)
  - Unstructured: environment has not been specially designed to make robot’s job easier
  - Dynamic: environment change while robot is “thinking”
  - Partially observable: robot cannot sense entire state of the world (i.e., “hidden” states)
  - Uncertain: sensor readings are noisy; effector output is noisy
  - Complex Tasks: Tasks are not easy (such as follow a straight line)
  - Cooperatively: Robot needs to cooperate with other robots/humans to be able to do the task

Not Covered in IR

- Kinematics and dynamics: covered in mechanical engineering
- Teleoperated systems: covered in mechanical / electrical engineering
- Traditional robotic control theory: covered in electrical engineering
- Theory of mind, cognitive systems: covered in psychology, cognitive science…
- Focus on computer science issues adapted to MIEIC and PRODEI: algorithm development, artificial intelligence, software architecture, etc.
Objectives

• To understand the basic concepts of Robotics and the context of Artificial Intelligence in Robotics
• To study methods of perception and sensorial interpretation (emphasizing computer vision), which allow to create precise world states and mobile robots’ control methods
• To study the methods which allow mobile robots to navigate in familiar or unfamiliar environments using Planning and Navigation algorithms
• To study the fundamentals of cooperative robotics and of the robots teams construction
• To analyze the main national and international robotic competitions, the more realistic robot simulators and the more advanced robotic platforms available

Tools - Simulators

• Mobile Robotics Simulator:
  – Cyber-Mouse (Univ. Aveiro)
• Robotic Soccer Simulator:
  – Soccer Server (RoboCup)
• Humanoid Simulator
• Microsoft Robotics Studio
• Rescue Simulator
Tools – Robotic Platforms

- Eco-Bes Robots from Citizen (2x1x1cm)
- Lego Mindstorms (NXT)
- Robotic Quadruped Platform
  - AIBO from Sony (ERS7 e ERS210)
- Middle-Size, Small-Size:
  - FEUP / UA
  - 5DPO and CAMBADA Teams
- RoboNova - Humanoid Robot

Challenges

- Robotic Soccer
  - Simulation (2D, 3D Humanoids, Coach, PV-League, Nanogram, Microsoft Robotics
  - Robots Small-Size
  - Robots Medium-Size
  - Legged Robots (Aibo Dogs - Sony)
  - Humanoid Robots
- Search and Rescue
  - Simulation, Virtual, Robotic
- Robots @ Home
- Autonomous Driving
- Navigation and Planning
- Human-Robot Interaction
Cooperative Robotics - RoboCup

• Emphasize cooperative robotics and application in a domain where the proponents are known as lead world researchers:
  – RoboCup – Robotic Soccer
  – RoboCup – Search and Rescue
  – More than 25 awards in International Competitions
    • Teams FC Portugal, 5DPO and Cambada

Selected Competitive Results

2000 1st place in the 2D Simulation League, RoboCup 2007
2001 3rd place in the 2D Simulation League, RoboCup 2001
2002 1st place in the Coach Competition, RoboCup 2002
2004 2nd place in the Coach Competition, RoboCup 2004
  1st place in the 2D Simulation League, Portuguese Open
2005 1st place in the 2D Simulation League, Portuguese Open
2006 1st place in the 3D Simulation League, RoboCup 2006
  1st place in the 3D Simulation League, Dutch Open
  1st place in the Rescue Simulation League, Dutch Open
  2nd place in the 2D Simulation League, Dutch Open
2007 1st place in the 3D Simulation League, German Open
  2nd place in the Physical Visual. League, RoboCup 2007
Associated R&D Projects

- **FC Portugal – New Coordination Methodologies in the Simulation League**
  - FCT POSI/ROBO/43910/2002, 18 Months, 27800€
- **CAMBADA: Cooperative Autonomous Mobile Robots with Advanced Distributed Architecture**
  - FCT POSI/ROBO/43926/2002, 24 Months, 90000 €
- **5DPO – Small-Size and Middle-Size RoboCup Teams**
- **Portus – A Common Framework for Cooperation in Mobile Robotics**
  - FCT POSI/SRI/41315/2001, 30 Months, 20000€
- **LEMAS – Learning in MAS using RoboCup Sony Legged League**
  - FCT POSI/ROBO/43926/2002, 18 Months, 32908€
- **Rescue: Coordination of Heterogeneous Teams in Search and Rescue Scenarios**
  - FCT POSC/EIA/63240/2004, 24 Months, 32800€
- **ABSES - Agent Based Simulation of Ecological Systems**
  - FCT/POSC/EIA/57671/2004, 30 Months, 75000€
- **ACORD – Adaptative Coordination of Heterogeneous Robotic Teams**
  - FCT PTDC/EIA/34241/2006, 24 Months, 95000€
- **IntelWheels – Intelligent Wheelchair for helping cerebral palsy and quadriplegic handicapped people**

Selected Research Contributions

- **Coordination Strategic Layer**

- **SBSP - Situation Based Strategic Positioning**
Detailed Program (1)

1) Introduction
   - Artificial Intelligence
   - Basic concepts of Robotics
   - Artificial Intelligence in Robotics
   - History, Evolution, and Current Trends in Intelligent Robotics

2) Architectures for Robotic Agents
   - Reactive, Deliberative, Hybrid
   - Belief, Desire and Intentions (BDI)
   - Cooperative Architectures

3) Perception and Sensorial Interpretation
   - Proximity sensors: Sonar or ultrasonic, infrared (IR), touch, light and feel sensors
   - Computer Vision: CCD cameras, Digital Image, Colour Models, Image Processing, Image Analysis
   - Odometry, Rotation and Compass Sensors
   - Sensor Fusion Techniques

Detailed Program (2)

4) Localization and Mapping
   - Creation, representation and updating of World States.
   - Markov and Gaussian Localization
   - Grid and Monte-Carlo Localization
   - Mapping: Occupancy Grid and SLAM
   - World Exploration

5) Mobile robots control: locomotion and action
   - Gears, Speed, Torque
   - Robot locomotion simulation

6) Plan Automatic Generation
   - Means-Ends Analysis, Linear, non-linear
   - Planning and Learning: Plan generality

7) Navigation
   - Algorithms of navigation in known/unknown environments
   - Voronoi diagrams, A*/D* algorithms, cellular decomposition
Detailed Program (3)

8) Cooperative Robotics
   - Cooperation between robots for teamwork
   - Joint Intentions, TAEMS, Role-Based, Social Rules
   - Communication and Mutual Modeling
   - Locker-Room, Strategical Coordination, Partial Hierarchical

9) Applications
   - National and International Robotic Competitions:
     • RoboCup, RoboOlympics, Fira Cup, DARPA Grand-Challenge, Portuguese Robotics Open, Autonomous driving, Micro-Mouse (Micro-Rato) and fire fighting Robots
   - Robotic simulators:
     • Soccerserver 2D and 3D, RoboCup Rescue, Virtual Rescue, Ciber-Mouse
   - Robotic Platforms:
     • MindStorms, ERS210A e ERS-7 (Sony Aibos): Hardware, Software Architectures and Robotic Programming Languages.

Learning Outcomes

• Acquire knowledge of current state and trends in Robotics
• Demonstrate understanding of the problems of intelligent robotics, particularly by selecting appropriate techniques to model and solve them
• Have a broad critical understanding of how Artificial Intelligence may be applied generally to Intelligent Robotics
• Appreciate the problems associated with designing and programming intelligent robots and multi-robot systems for different problems
• Develop research work, demonstrate the origins of the ideas by referencing sources used in the context of intelligent robotics, being aware of the best projects/research works in this area around the world
Teaching Methods

- Challenging students to **Higher Level Learning** as appropriate in a PhD/MSc program. Of course low level learning, i.e., comprehending and remembering basic information and concepts is important. However emphasis will be on **problem solving, decision making** and **creative thinking/design**
- **Use Active Learning.** Exposition will be made mostly with **interaction** in theoretical classes. Use of **appropriate materials/simulators/platforms/problems**
- Use simple but **structured sequence of different learning activities** (lectures, demos, reading, analysis, writing, oral pres., design, experiment.)
- **Opening classes** and assignments about basic principles to lay the foundation for **complex and high level learning tasks** in **later, complex classes** and assignments
- **Detailed feedback** given to students about the quality of their research work and learning process. High level, active learning require to know whether they are “doing it correctly!”
- **High-level teaching method** enable to **increase skills** in research in all other **areas** related to **informatics** and computer science

Evaluation System

- **Research discipline**, intended first to teach state of the art in intelligent robotics and then to do a **simple project** and a **paper of publishable quality** in an international conference
- **Evaluation** based on:
  - Analysis of **a scientific paper** about robotics
  - Oral presentation of a **new trend** on Robotics
  - **Practical Project** based on **simple weekly assignments**, with final demonstration, **oral defense** and production of a publishable **scientific paper**
  - Final Exam if needed...
Summary

- Programme:
  - Intelligent Robotics and Simulation
  - Perception/Decision/Action
  - Navigation and Planning in Robotics
  - Cooperative Robotics
- Emphasis on Programming Intelligent Machines
- Practical Knowledge Application with:
  - Simulators / Robotic Platforms
- Not needed:
  - Electronics + Digital Systems + Electricity + Control
- Programming “Competitive” Robots / Robotic Teams
  - Participation in National/International Robotic Competitions:

Scientific Content
- Collaboration in R&D Projects
- Write and Analyze Scientific Papers
- Collaboration with PhD Students

Assignment 1

Oral Presentation about an “Intelligent Robotic New Trend”

Groups: 1/2 students
10 – 15 Minutes Oral Presentation
15 – 20 Slides (including appropriate images and videos)
4/6 Presentations in the 3rd lesson!
Assignment 1 - Subjects

- Tema 1: Robôs Humanóides: Asimo, Cog, QRIO
- Tema 2: O Kit NXT (Lego MindStorms)
- Tema 3: Kits Robóticos e Lojas On-line de Material Robótico e Plataformas Robóticas.
- Tema 4: Domótica vs Robótica
- Tema 5: Mascotes Robóticas ("Robotic Pets"): Tamagotchi, Furby, Techno, Poo-Chi, Furby2 e Outros
- Tema 6: Automóveis Robóticos Inteligentes, Condução Autónoma e o DARPA Grand Challenge
- Tema 7: RoboOlympics, Manitoba Robot Games e Eventos Semelhantes
- Tema 8: Robots de Combate (Battlebots RobotWars e Outras Competições Robóticas Semelhantes)
- Tema 9: Competições de Futebol Robótico FIRA

Assignment 1 – Subjects

- Tema 10: Membros Robóticos (Braços/Pernas)
- Tema 11: Captura/Imitação de Movimento Humano
- Tema 12: Simuladores de Robótica Móvel
- Tema 13: UAVs - Unmanned Aircraft Vehicle
- Tema 14: Robótica Submarina
- Tema 15: Cadeiras de Rodas Robóticas
- Tema 16: Robôs reconfiguráveis
- Tema 17: Robôs na Exploração de Marte
- Tema 18: Swarming Robotics
- Tema 19: MicroRobótica e NanoRobótica
- Tema 20: Microsoft Robotics Studio
- Tema 21: Novos sensores em Robótica
- Tema 22: Visões de Filmes e Livros sobre a Robótica no Futuro
Assignment 1 – Content

• Presentations must include:
  – 15/20 slides (topics+images)
  – 3/5 short Videos (Youtube?)
  – Introduction and Conclusions
  – Short description of 2/3 related projects
  – References: 5/10 appropriate links/sites, 3/5 conference/journal papers

More Information

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