POLITECNICO DI MILANO



DIPARTIMENTO DI ELETTRONICA, INFORMAZIONE E BIOINGEGNERIA



Artificial Intelligence and Robotics @ Politecnico di Milano

Presented by Marcello Restelli

What is Artificial Intelligence?

«The field of theory & development of **computer systems** able to perform tasks normally assumed to require **human intelligence** to be performed»

In short, how to make machines «**smart/intelligent**» :

- Model, represent, and reason on knowledge and data
- **Decide** the best course of **actions** given a situation
- Learn models and adapt artificial systems to the reality they are facing
- Design and study multi agent systems

Studying AI: What for?

It's in any «smart/intelligent» device

 videogames, security, finance, information systems, robots, appliances, ...



When it is difficult or impossible to define a **model**

• data mining, sensor data interpretation, control, market prediction, deep learning on big data, ...

Because you need to **adapt** the application behaviour

• to the users, the environment, the situation, ...

What is (Autonomous) Robotics?

«The study of **autonomous robots**, i.e., robots (and devices) that interact physically with the environment performing tasks with a high degree of **autonomy**»

In short, how to make «autonomous devices»

- Make vehicles **navigate** autonomously
- Make robots **interacting** with humans
- Develop novel **control** architectures
- Allow **unmanned** operation (e.g., search & rescue by drones, space exploration, driverless cars)

Studying Robotics: What for?

A new market in **rapid expansion** 100

 In 2005 robots outside factories started to be more, and more valuable than those inside factories



Expand your knowledge/expertise beyond computing

 Signal interpretations, computer vision, automation and control, interaction design

Because **computers** need to **interact** with the **world**

 Smart objects, robot assistants, environmental sensing & control, unmanned vehicles, ...

Who's Hiring in AI & Robotics?

Google

List of mergers and acquisitions by Google (2013)

From Wikipedia, the free encyclopedia

122	February 6, 2013	Channel Intelligence	Product ecommerce	USA	\$125,000,000	Google Shopping
123	March 12, 2013	DNNresearch Inc.	Deep Neural Networks	CAN	_	Google, Google X
124	March 15, 2013	Talaria Technologies	Cloud computing	USA		Google Cloud
125	April 12, 2013	Behavio	Social Prediction	USA 📑		Google Now
126	April 23, 2013	Wavii	Natural Language Processing	USA	\$30,000,000	Google Knowledge Graph
127	May 23, 2013	Makani Power	Airborne wind turbines	USA 📑		Google X
128	June 11, 2013	Waze	GPS navigation software	💼 ISR	\$966,000,000	Google Maps
129	September 16, 2013	Bump	Mobile software	💻 USA		Android
130	October 2, 2013	Flutter	Gesture recognition technology	USA	\$40,000,000	Google, Android, Google X
131	October 22, 2013	FlexyCore	DroidBooster App for Android	FRA	\$23,000,000	Android
132	December 2, 2013	SCHAFT, Inc.	Robotics, humanoid robots	JPN		Google X
133	December 3, 2013	Industrial Perception	Robotic arms, computer vision	USA		Google X
134	December 4, 2013	Redwood Robotics	Robotic arms	USA		Google X
135	December 5, 2013	Meka Robotics	Robots	USA		Google X
136	December 6, 2013	Holomni	Robotic wheels	USA		Google X
137	December 7, 2013	Bot & Dolly	Robotic cameras	USA		Google X
138	December 8, 2013	Autofuss	Ads and Design	USA 📰		Google X
139	December 10, 2013	Boston Dynamics	Robotics	USA		Google X
140	January 4, 2014	Bitspin	Timely App for Android	🚹 СНЕ	_	Android



Robotics

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From Wikipedia, the free encyclopedia

January 4, 2014	Bitspin	Timely App for Android	+ CHE	—	Android
January 13, 2014	Nest Labs, Inc	Home automation	USA	\$3,200,000,000	Google
January 15, 2014	Impermium	Internet security	USA	_	Google
January 26, 2014	DeepMind Technologies	Artificial Intelligence	NK	£242,000,000	Google X
February 16, 2014	SilckLogin	internet Security	• ISR	_	Google
February 21, 2014	spider.io	Anti ad-fraud	NK UK	-	DoubleClick, Adsense
March 12, 2014	GreenThrottle	Gadgets	USA	-	Android
April 14, 2014	Titan Aerospace	High-altitude UAVs	USA	—	Project Loon
May 2, 2014	Rangespan	E-commerce		_	Google Shopping
May 6, 2014	Adometry	Online advertising attribution	USA	—	Google
May 7, 2014	Appetas	Restaurant website creation	USA	—	Google
May 7, 2014	Stackdriver	Cloud computing	USA	—	Google Cloud
May 7, 2014	MyEnergy	Online Utility Usage Monitor	USA	—	Nest Labs
May 16, 2014	Quest Visual	Augmented Reality	USA	—	Code Project, Google Translate
May 19, 2014	Divide	Device ivianager	USA	_	Android
June 10, 2014	Skybox Imaging	Satellite	USA	\$500,000,000	Google Maps, Project Loon
June 19, 2014	mDialog	Online advertising	CAN	_	DoubleClick
June 19, 2014	Alpental Technologies	Wireless Technology	USA	—	Google
June 20, 2014	Dropcam	Home Monitoring	USA	\$555,000,000	Nest Labs
June 25, 2014	Appurify	Mobile Device Cloud, Testing Services	USA	—	Google Cloud
July 1, 2014	Songza	Music streaming	USA	_	Google Play, Android TV
July 23, 2014	drawElements	Graphics compatibility testing	FIN	—	Android
August 6, 2014	Emu	IM client		_	Google Hangouts, Google Now
August 6, 2014	Director	Mobile video	USA	_	YouTube, Android
August 17, 2014	Jetpac	Artificial intelligence, image recognition	USA		Google X
August 23, 2014	Gecko Design	Design	USA	—	Google X
August 26, 2014	Zync Render	Visual Effects Rendering	USA	_	Google Cloud Platform
September 10, 2014	Lift Labs	Liftware	USA	—	Life sciences division of Google X
September 11, 2014	Polar	Social Polling	USA	_	Google+
October 21, 2014	Firebase	Data Synchronization	USA	_	Google Cloud Platform
October 23, 2014	Dark Blue Labs	Artificial Intelligence	NK UK	£tens of millions	Google DeepMind
October 23, 2014	Vision Factory	Artificial Intelligence	NK UK	£tens of millions	Google DeepMind
October 24, 2014	Revolv	Home Automation	USA USA		Nest Labs
November 19, 2014	RelativeWave	App Development	USA		Material Design
December 17, 2014	Vidmaker	Video Editing	USA		YouTube

Who's hiring in AI & Robotics?



The AIRLab

AI and Robotics Lab was founded in 1971

- 11 researchers & professors, 11 PhD Students, 2 research assistants
- We offer one of the broader sets of courses in AI & Robotics in IT
- 40+ master theses per year,
 60+ students in the lab
- Active at international level in international research projects
- Innovation & technology transfer with national companies







AIRLab Activities

Autonomous robots:

 Sensor interpretation (e.g., computer vision), control architectures, cognitive & bio-inspired robots benchmarking, entertainment / edutainment robots

Artificial Intelligence:

 Knowledge representation & management, expert systems, uncertainty management, intelligent agents, game theory, ...

Machine Learning:

- Reinforcement Learning, Neural Networks, Bayesian Networks, Genetic Algorithms
- Videogames, Control Systems, Affective Computing, Signal Interpretation, Trading, Betting Systems, ...









Autonomous Robots

Unmanned Vehicles & Robots

Tools, techniques & devices to allow unmanned vehicles & autonomous robots operate safely indoor & outdoor

- Autonomous service robots
- Autonomous all terrain vehicles
- Unmanned aerial vehicles

Techniques from Robotics and AI

- Perception & state estimation
- Task and Motion planning
- On-line calibration/adaptation

- Automation & Mechatronics
- Mathematics & Statistics





Robot/Machine Perception

Providing to machines the mean to perceive & make sense of the surrounding environment

- (Rich) 3D reconstruction
- Object and place recognition
- Tracking & video surveillance

Techniques from data analysis

- Simultaneous Localization & Mapping
- Multi sensor/camera fusion
- Image Retrieval and data mining

- State estimation & optimization
- Embedded devices & smart sensors





RoboGames & Edutainment Robots

Develop autonomous robots able to **play** with people and

interact with them naturally

- Human-robot interaction
- Low-cost robots
- Entertainment and therapy

Techniques from AI and Robotics

- Artificial vision
- Adaptation and learning
- Playful interaction

- Hoc Lab (DEIB)
- PhyCo Lab (Design)





Navigation Strategies for Robots

Allow robots to autonomously **decide where to go** next according to perceived **state** and their overall **goal**

- map building
- search & rescue
- patrolling

Techniques from AI & Robotics

- decision theory
- game theory
- planning
- semantic mapping

Synergies with other fields

Architecture and Design



Bio-inspired Robots















Biological inspiration for the body and for the control system

Developmental robots



Artificial Intelligence

Multi Agent Interactions

Design communication tools, norms, and strategies for multi agent interaction

- Strategy design
- Norm compliance
- Artificial institutions

Techniques from AI

- Artificial institutions
- Semantic networks

- Microeconomics
- Robotics



Applications of Multiagent Systems

Design, development and deployment of multiagent systems in contexts requiring distributed decision-making

- Control of space systems
- Watershed management
- Optimization of energy consumption
- Management of financial guarantees
- Techniques from AI & Robotics
 - Distributed (constrained) optimization
 - Coordination
 - Distributed planning and scheduling

- Environmental engineering
- Aerospace engineering
- Energy engineering



Intelligent Data Access and Usage Control

Design and implementation of infrastructures for the specification, monitoring and enforcement of complex data access and usage policies

- Intelligent data access
- Agents usage control
- Technologies from AI
 - Semantic Web
 - OWL ontologies
 - Reasoning

- Security
- e-Government



Economics and Computation (EC)

Design and implement intelligent autonomous agents acting in **strategic** interaction settings

- Finding optimal strategies
- Designing economic mechanisms to induce a desirable strategy

Techniques from AI:

- Game theory
- Artificial intelligence
- Machine learning

Synergies with other fields

- Theory of algorithms
- Economy and finance



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What's on your mind?

Photo

A Music

Machine Learning

Reinforcement Learning

Develop **learning** techniques to let agents autonomously solve **sequential decision-making** problems

- Learning decision systems
- Data driven real-world control
- Techniques from AI & science
 - Machine learning
 - Statistics
 - Optimization

- Robotics
- Automatic control
- Resource management
- Finance









Computational Intelligence in Games

Improve the design and the development of **computer**

games by using AI techniques

- procedural content generation,
- players behavior analysis
- innovation in games

Techniques from AI

- evolutionary computation
- machine learning
- data-mining

- Computer graphics
- Mobile app economy
- Interaction design





User Interface with Body Signals

Design novel **prostheses** and **assistive technologies** to directly **interface** the **human body**

- Robot Tele-control
- Novel Prosthetic devices
- Rehabilitation (with robots)

Techniques from AI & Robotics

- Machine learning
- Advanced simulation
- Robot design

- Bioengineering
- Electronics
- Mechanics





Assistive Technology Group

Within the Assistive Technology Group we use artificial intelligence & robotics to **help people** with special needs

- Assistive Robots
- Ambient Assisted Living
- Brain-Computer Interfaces
- Behavioral drift analysis

Techniques from AI & Robotics

- Brain-Computer Interaction
- Evolutionary signal processing
- Alternative & Augmentative
 Communication

Synergies with other groups

• Embedded devices & wireless sensor networks





Quality of the Research in AIRLab

- Several awards from AlxIA (Associazione Italiana per l'Intelligenza Artificiale)
 - 2 Best Junior Researcher awards
 - 2 Best PhD Thesis awards (+2 Special Mentions)
 - 3 Best Master Thesis awards (+2 Special Mentions)
- Most of these prizes were taken in the last 5 years
- The AIRLab group is the most awarded in Italy

Studying AI and Robotics @ POLIMI

Studying Artificial Intelligence

A "horizontal" track characterized by:

- <u>Artificial Intelligence</u>: basics of search and reasoning
- <u>Knowledge Engineering</u>: knowledge representation & inference
- <u>Machine Learning</u>: understanding automated learning
- <u>Soft Computing</u>: Neural networks, Deep Learning, Genetic algorithms and uncertainty models (Bayesian Networks, Fuzzy systems)
- Data Mining and Text Mining: finding information in big data
- <u>Autonomous Agents and Multi-Agent Systems</u>: models of agents and of their interactions
- <u>Robotics, Robotics and Design</u>
- Philosophical issues of Computer Science
- <u>Videogame design and programming</u>

Studying Robotics

A "horizontal" track characterized by:

- <u>Robotics</u>: the basics of robotics, manipulation and perception
- Image Analysis: Computer vision and image understanding
- <u>Robotics and Design</u>: interdisciplinary lab course between computer engineering and design
- <u>Artificial Intelligence</u>: basics of search and reasoning
- <u>Soft Computing</u>
- Machine Learning
- Advanced algorithms, Simulation techniques and tools
- "Al courses"
- Unmanned Autonomous Vehicles in Air, Land and Sea: DOT

Studying AI and Robotics ...

- ... gives you, in any case, all the basics of computer engineering, so it does not prevent your future work in the "traditional" computer engineering areas
- ... makes you a **specialist** in techniques pervading all kind of applications, and are (and will be more and more) present in all aspects of our everyday life: few of these specialists are available on the **job market**
- ... gives access to **fascinating jobs**, involving the most upto-date technologies

Who's Who @ AIRLab

- BONARINI Andrea: Robotics, Soft Computing
- COLOMBETTI Marco: Artificial Intelligence, Knowledge Eng.
- AMIGONI Francesco: Artificial Intelligence, Multi Agent Systems
- CAGLIOTI Vincenzo: Computer Vision
- GINI Giuseppina: Robotics (*)
- LANZI Pier Luca: Evolutionary Computation, AI & Games
- GATTI Nicola: Artificial Intelligence, Game Theory
- LOIACONO Daniele: Evolutionary Computation, AI & Games
- MATTEUCCI Matteo: Robotics ^(*), Machine Learning
- RESTELLI Marcello: Robotics, Machine Learning
- SCHIAFFONATI Viola: Philosophy and Artificial Intelligence

^(*) Check the demos this afternoon!

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Contact

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