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Intelligent Systems

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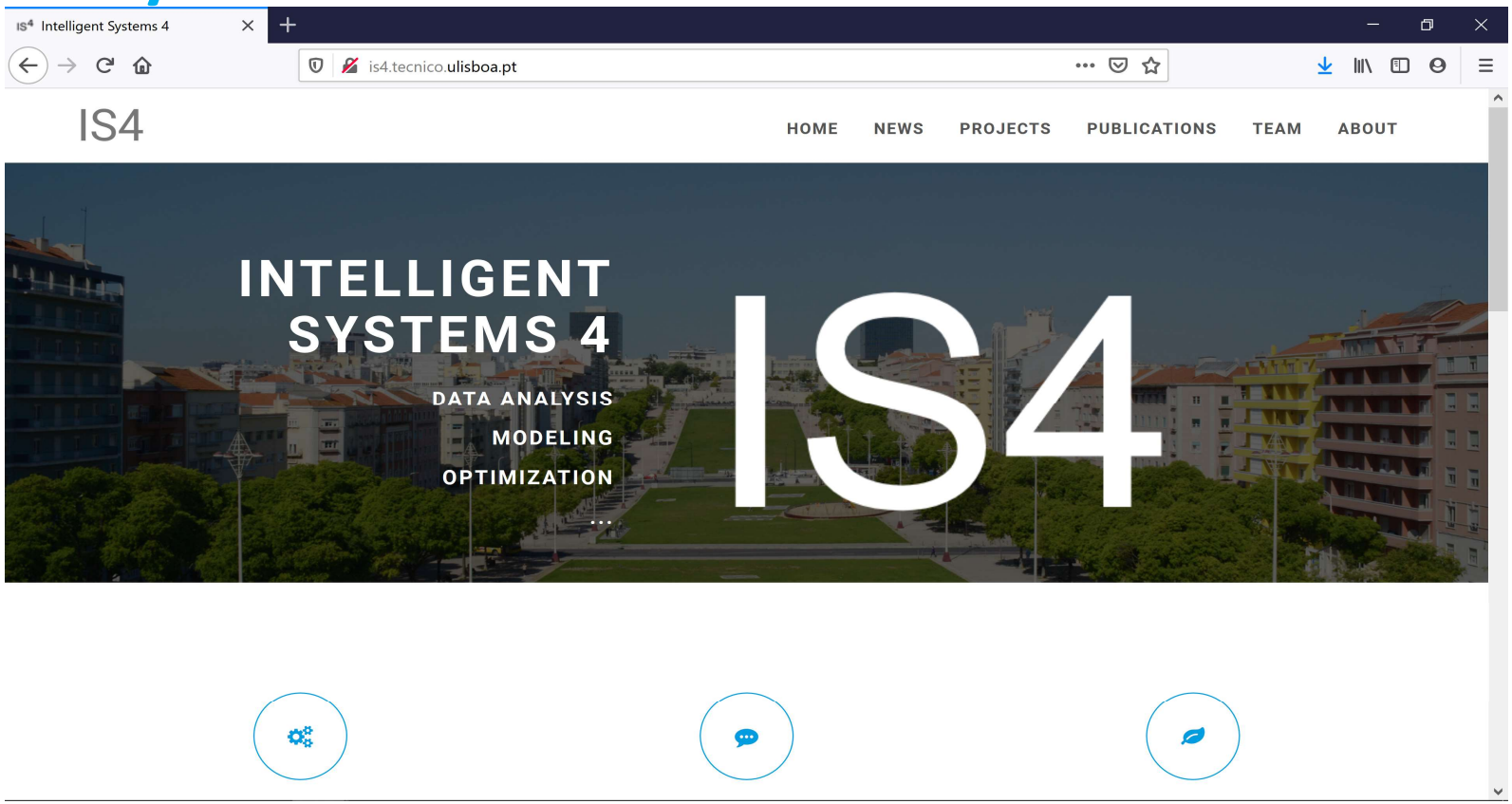

http://is4.tecnico.ulisboa.pt/

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Program

1. **Introduction to Intelligent Systems**

   Intelligent Systems and Artificial Intelligence. Characteristics of Intelligent Systems.

2. **Fuzzy Systems: Basic Concepts**

   Fuzzy operators. Fuzzy relations. Fuzzy inference. Types of fuzzy systems.

3. **Neural Networks**

   (Revisit) Shallow neural networks. (Revisit) Supervised learning in neural networks. Neuro-fuzzy systems. Deep Learning.

Program

4. **Intelligent Modeling, Decision and Control**

   Neural modeling. Fuzzy modeling. Decision theory. Intelligent decision. Fuzzy decision theory. Fuzzy control. Model-based fuzzy control. Model predictive control.

6. **Applications**

   Classification. Nonlinear Modeling. Fuzzy Control. Model Predictive Control. Energy applications. Biological and medical applications.

Main Bibliography

- J.-S. Jang, C.-T. Sun and E. Mizutani. ***Neuro-Fuzzy and Soft Computing: A Computational Approach to Learning and Machine Intelligence***. Prentice Hall, New Jersey, 1997.
- Rudolf Kruse , Sanaz Mostaghim , Christian Borgelt , Christian Braune , Matthias Steinbrecher. ***Computational Intelligence: A Methodological Introduction***. Springer, 2022.
- François Chollet. ***Deep Learning with Python***. Manning Publications Co. 2018
- Ian Goodfellow and Yoshua Bengio and Aaron Courville. ***Deep Learning***. MIT Press, http://www.deeplearningbook.org, 2016.

Other Bibliography

- G. Klir and B. Yuan. Fuzzy Sets and Fuzzy Logic, Theory and Applications. Prentice Hall Inc., Upper Saddle River, 1995.
- J.M.C. Sousa and U. Kaymak. Fuzzy Decision Making in Modeling and Control. World Scientific Series in Robotics and Intelligent Systems, vol. 27, Dec. 2002.
- James M. Keller, Derong Liu, David B. Fogel. Fundamentals of Computational Intelligence: Neural Networks, Fuzzy Systems, and Evolutionary Computation. Wiley-IEEE Press, August 2016.
- S. Haykin. Neural Networks and Learning Machines. 3rd edition, Prentice Hall, 2009.
- T. A. Runkler. Data Analytics: Models and Algorithms for Intelligent Data Analysis. Springer, 2012.
- Fakhreddine O. Karray and Clarence De Silva. Soft Computing and Intelligent Systems Design. Addison Wesley, 2004.
- Michael Negnevitsky. Artificial Intelligence: A Guide to Intelligent Systems. Addison-Wesley, Pearson Education, 2002.
- Andries P. Engelbrecht. Computational Intelligence: An Introduction. John Wiley, Chichester, 2002.
- R. Babuska. Fuzzy Modeling for Control. Kluwer Academic Publishers, 1998.
- J. Kennedy, R. C. Eberhart and Y. Shi. Swarm Intelligence. Morgan Kaufmann Publishers, 2002.
- M. Berthold, C. Borgelt, F. Höppner and F. Klawonn. Guide to Intelligent Data Analysis: How to Intelligently Make Sense of Real Data. Series: Texts in Computer Science. Springer, 2010.

Evaluation method

- **Final grade: Project** (50%) and **Exam** (50%)*
- **Project**: 3 parts
  1. Two assignments (**CA**): 5% + 5%
  2. Final Project (**FP**): 40%
- **Dates:**
  - **Exam** – 1st Exam 08/11/2023 at 10:30; 2nd Exam, 29/01/2024 at 10:30
  - **CA1: Sep. 29th**, **CA2: Oct. 06th**; **FP: Oct. 23rd**. (project proposal **02/10/2023**)
- Matlab/Python to be used in class assignments and project, when appropriate.

**Any student can be asked for an oral exam.*

What will be Evaluated

- **Exam** (minimum grade: 8/20)
  - Theory
  - Reasoning
- **Project** (minimum grade: 8/20)
  - Application to real world problems
  - Coding
  - Reporting
  - Critical thinking

Tools

- **Exam** (minimum grade: 8/20)
  - Your brain
- **Project** (minimum grade: 8/20)
  - Whatever it will help you solve the problem
  - Yes **books**!
  - Yes ChatGPT! But use it as a **learning tool**!! And do not believe in everything it “says”…

Shifts

Shifts

Shift	Capacity	No. of students	
SIntT01 (Mon. 11:00 - 13:00 - V1.16 ; Wed. 11:00 - 13:00 - VA4)	30	13	Edit
SIntPB02 (Tue. 10:30 - 12:00 - V1.33 ; Fri. 09:30 - 11:00 - V1.07)	30	13	Edit

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Goals

- To recognize computational approaches to intelligence.
- To understand the motivation for using computational intelligence systems.
- To master the basic design methodology for computational intelligence systems.
- To use intelligent systems for solving problems in engineering (scientific) problems.
- To understand the motivation for using artificial intelligence systems.

Goals…

Your goals? . . .

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INTRODUCTION

J.-S. Jang, C.-T. Sun and E. Mizutani. Neuro-Fuzzy and Soft Computing: A Computational Approach to Learning and Machine Intelligence. Prentice Hall, New Jersey, 1997.

Intelligent System?

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I THINK MY NEST SMOKE ALARM IS GOING OFF. GOOGLE ADWORDS JUST PITCHED ME A FIRE EXTINGUISHER AND AN OFFER FOR TEMPORARY HOUSING.
TOM FISH BURNE
© marketoonist.com

Automation levels in driverless cars

The U.S. National Highway Traffic Safety Administration lays out six levels of automation, beginning with humans doing the driving through driver assistance technologies up to fully autonomous cars.

LEVEL 0
The human driver does all the driving.

LEVEL 1
An advanced driver assistance system (ADAS) on the vehicle assists the human driver.

LEVEL 2
The vehicle's ADAS can control both steering and braking/ accelerating simultaneously under some circumstances. The human driver must continue to pay full attention and perform all other driving tasks.

LEVEL 3
An automated driving system (ADS) on the vehicle can perform all driving tasks under some circumstances. In those circumstances, the human driver must be ready to take the wheel and drive outside of those set circumstances.

LEVEL 4
An ADS on the vehicle can perform all driving tasks and monitor the road in certain circumstances. The human doesn't have to pay attention in those circumstances.

LEVEL 5
An ADS on the vehicle does all the driving in all circumstances. The human occupants are just passengers and are never involved in driving.

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Intelligent System?

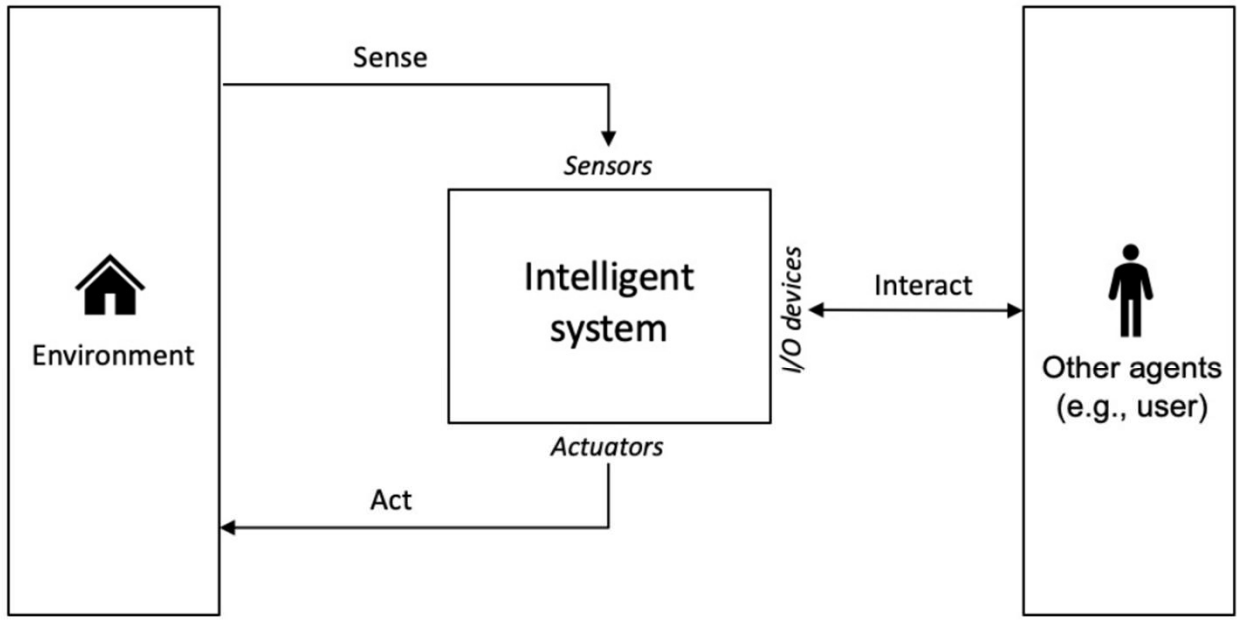

Figure 2: An intelligent system observes features of the environment, executes actions in the environment and interacts with others agents (e.g., with the human user).

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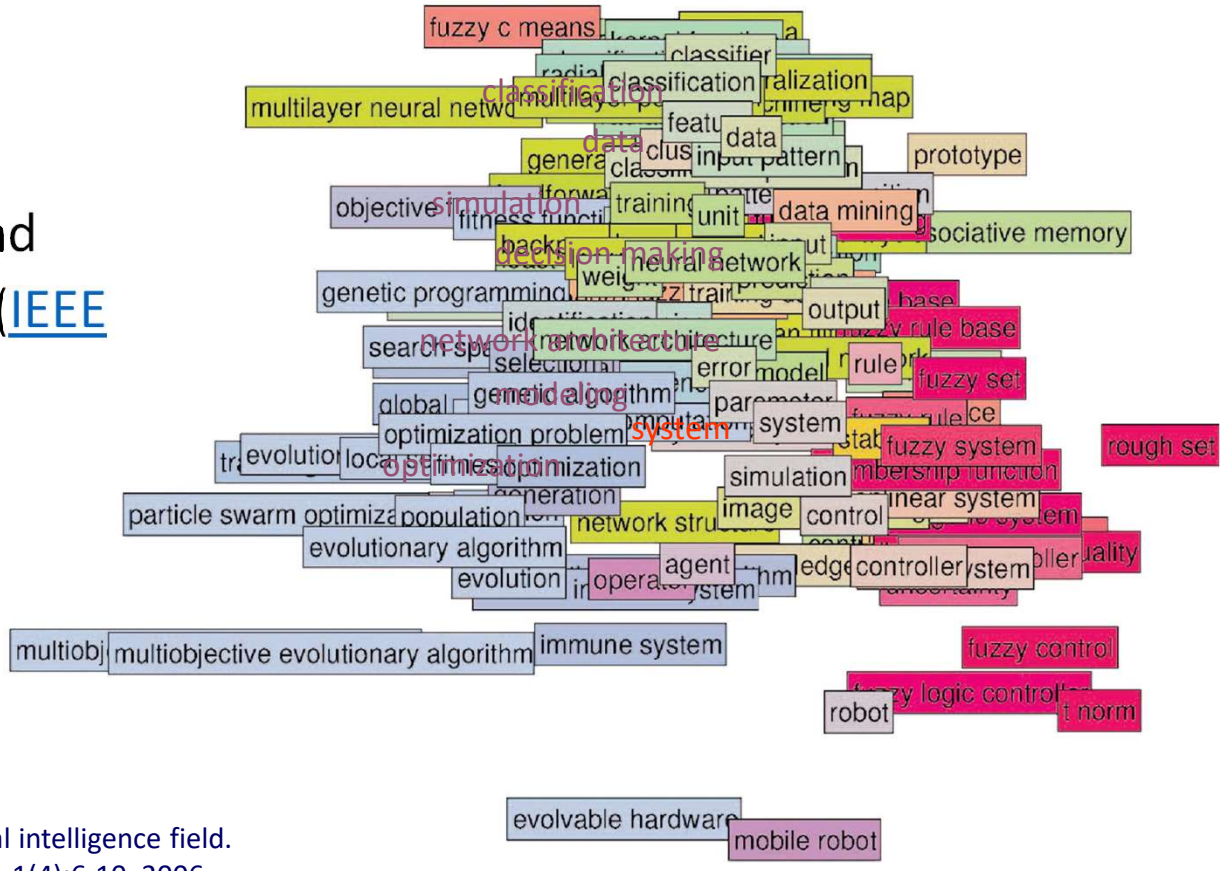
Computational Intelligence

- **Neural**, **fuzzy**, **evolutionary** and hybrid systems (IEEE CIS)



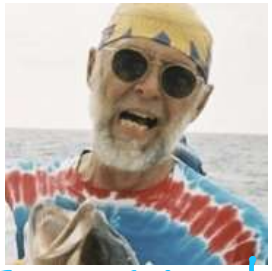
van Eck et al. Visualizing the computational intelligence field. IEEE Computational Intelligence Magazine, 1(4):6-10, 2006.

Computational Intelligence

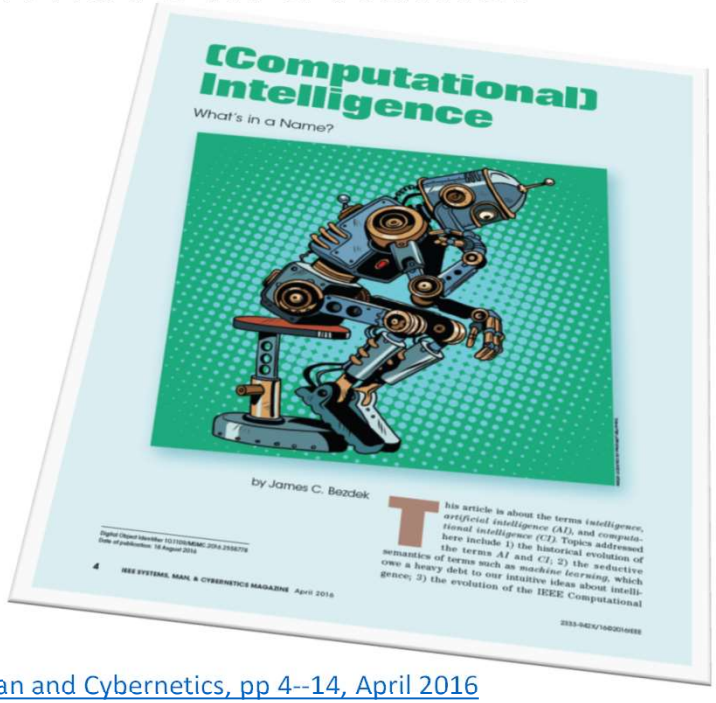
- **IEEE Computational Intelligence Society** (https://cis.ieee.org/about/what-is-ci)
- **Scope**
  - Computational Intelligence (CI) is the theory, design, application and development of biologically and linguistically motivated computational paradigms. Traditionally the three main pillars of CI have been Neural Networks, Fuzzy Systems and Evolutionary Computation. However, in time many nature inspired computing paradigms have evolved. (…) Over the last few years there has been an explosion of research on Deep Learning, in particular deep convolutional neural networks. Nowadays, deep learning has become the core method for artificial intelligence. In fact, some of the most successful AI systems are based on CI.

Computational Intelligence

- (Computational) Intelligence: What's in a Name?



James C. Bezdek



James Bezdek, (Computational) Intelligence: What's in a Name?. IEEE Systems, Man and Cybernetics, pp 4--14, April 2016 (https://ieeexplore.ieee.org/document/7549228)

(Computational) Intelligence: What's in a Name?

Publisher: IEEE Cite This PDF

James C. Bezdek **All Authors**

James C. Bezdek

11	541
Paper Citations	Full Text Views

Abstract

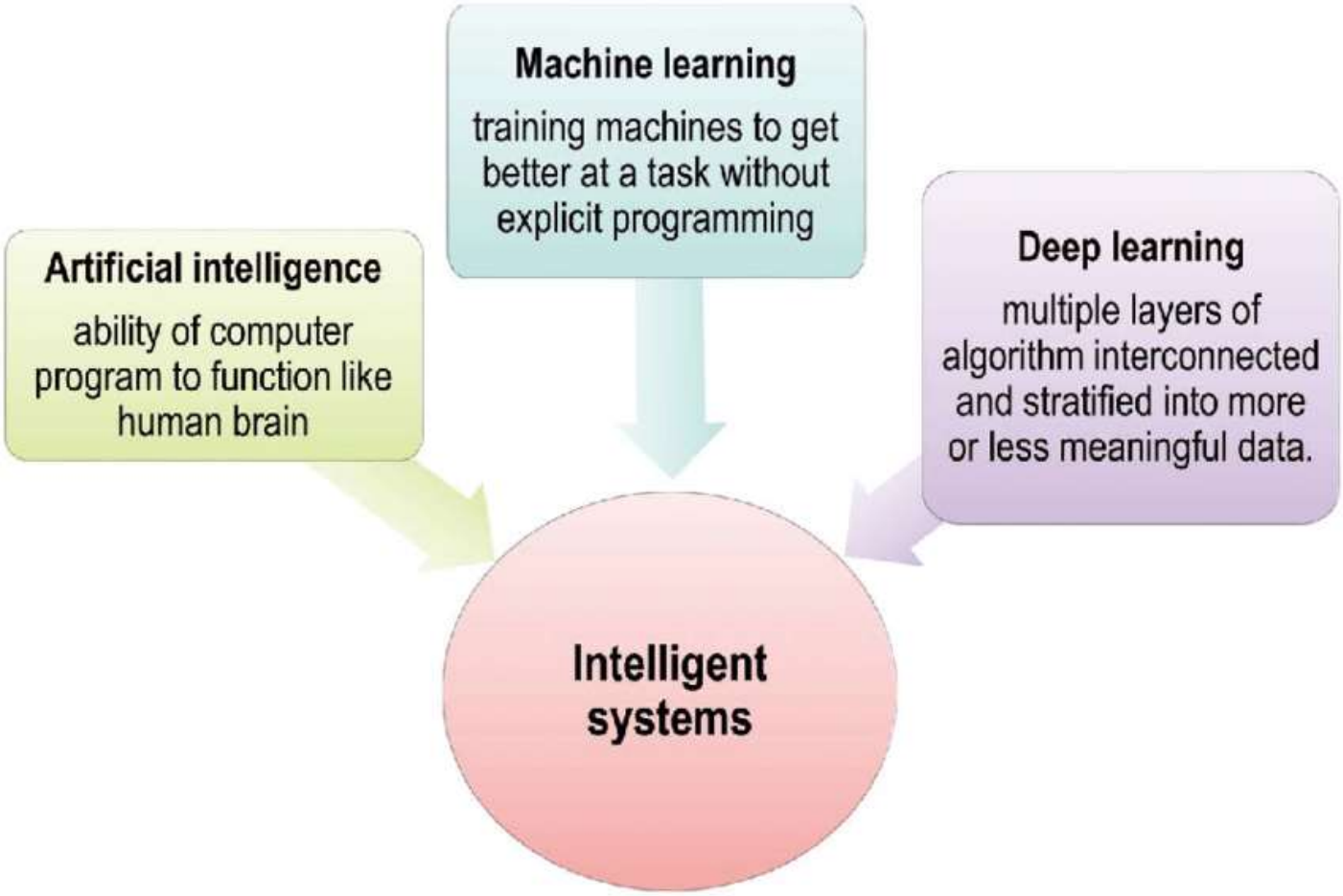
Document Sections

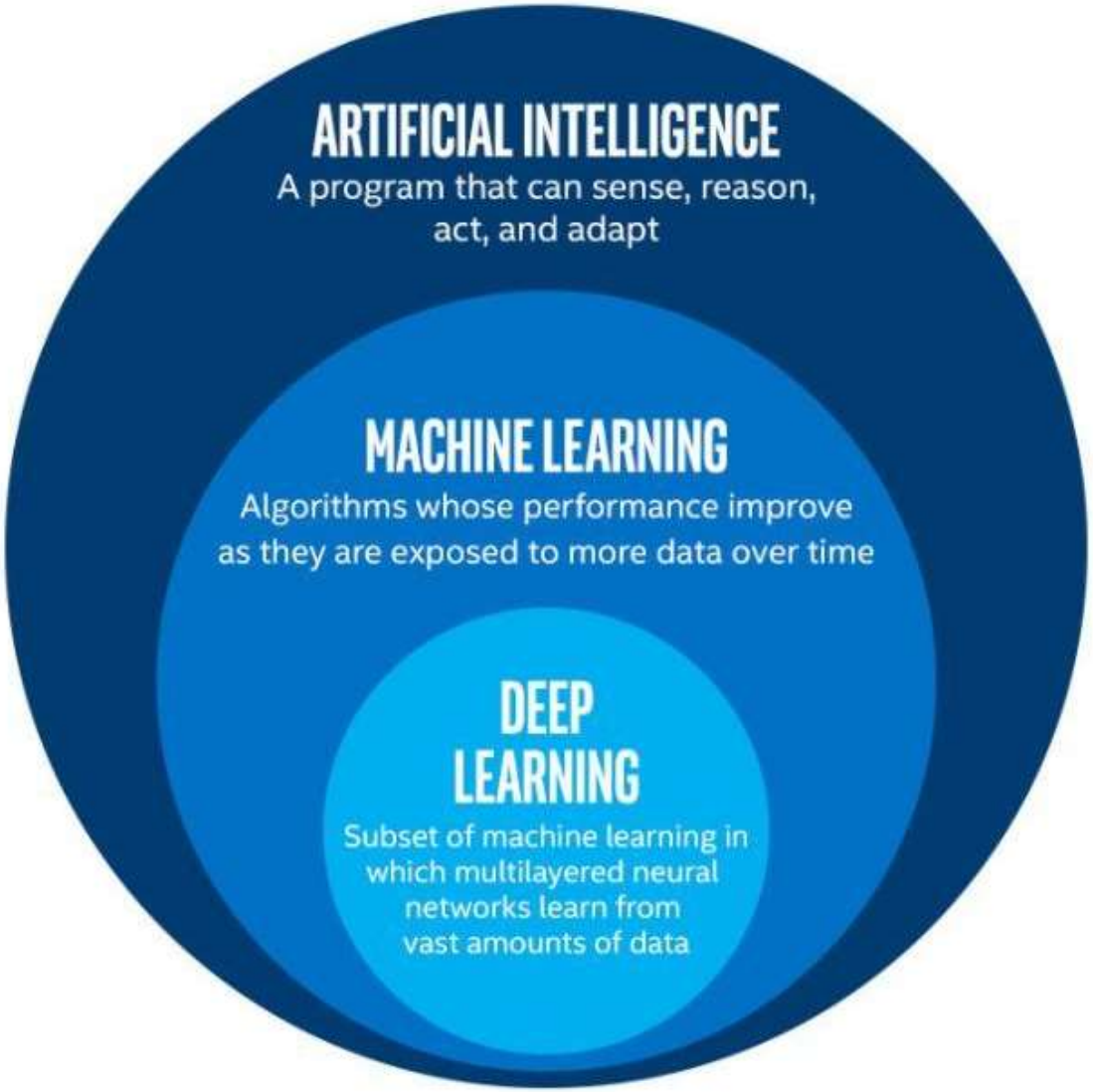
» The Songwriters and the Stars

» Folk Songs and Smash Hits

Abstract:
This article is about the terms intelligence, artificial intelligence (AI), and computational intelligence (CI). Topics addressed here include 1) the historical evolution of the terms AI and CI; 2) the seductive semantics of terms such as machine learning, which owe a heavy debt to our intuitive ideas about intelligence; 3) the evolution of the IEEE Computational Intelligence Society; and 4) the role that buzzwords play in the lives of all researchers.

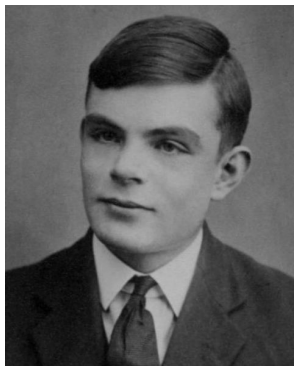
Published in: IEEE Systems, Man, and Cybernetics Magazine (Volume: 2 .

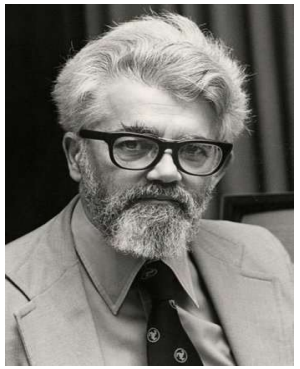

Machine learning
training machines to get better at a task without explicit programming
Artificial intelligence
ability of computer program to function like human brain
Deep learning
multiple layers of algorithm interconnected and stratified into more or less meaningful data.
Intelligent systems


ARTIFICIAL INTELLIGENCE
A program that can sense, reason, act, and adapt
MACHINE LEARNING
Algorithms whose performance improve as they are exposed to more data over time
DEEP LEARNING
Subset of machine learning in which multilayered neural networks learn from vast amounts of data

History of AI

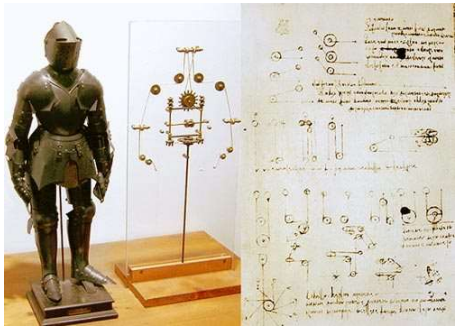
- **Important individuals in AI development**
  - **Alan Turing**
    - Father of modern computer science
    - Turing test in the 1950's
      - "Must be able to carry on a conversation over teletype that is indistinguishable from a conversation with a human"
    - Algorithm concept
  - **John McCarthy**
    - Coined the term "artificial intelligence" in 1955
    - Developed LISP language (1958)
    - Significantly influenced ALGOL language



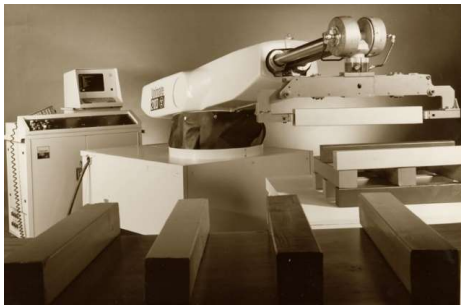


History of AI

- **Robotics**
  - **Leonardo da Vinci's mechanical knight (1495)**
    - His model lead to designs for humanoid robots



  - **George Devol's industrial robot (1961)**
    - First industrial robot to be installed in a factory



History of AI

- **Games**
  - **Pac Man**
    - Released in 1980
    - AI allowed each ghost to have distinct behaviors and movements
  - **Shogun: Total War**
    - Released in 2000
    - Thousands of AI-controlled soldiers in a battle
    - Display the emotion of groups of soldiers to simulate battles realistically

Intelligence

Definition: ability to **learn**, **understand**, **apply** knowledge, or **think** abstractly, especially in relation to new or trying situations (Longman Dictionary)

Properties:

- understanding (awareness)
- acting (conclusions)
- reasoning
- thinking

What is Artificial Intelligence?

- Artificial Intelligence (AI) is the study of agents that exist in an environment and perceive and act
- AI is the art of making computers do smart things
- AI is a programming style, where programs operate on data according to rules to accomplish goals
- AI is the activity of providing such machines as computers with behavior that would be regarded as intelligent if it were observed by humans
- Branch of computer science that is concerned with the automation of intelligent behavior

Microsoft AI chat bot

- **Microsoft has created a new artificial intelligence chat bot that it claims will become smarter the more you talk to it**

http://www.wired.co.uk/article/tay-tweet-microsoft-artificial-intelligence-answers

https://news.vice.com/article/microsoft-artificial-intelligence-tay-twitter-trolling

AI in NYork Times 26 June 2016

- **Kate Crawford. *Artificial Intelligence's White Guy Problem. The New York Times,* June 25, 2016**

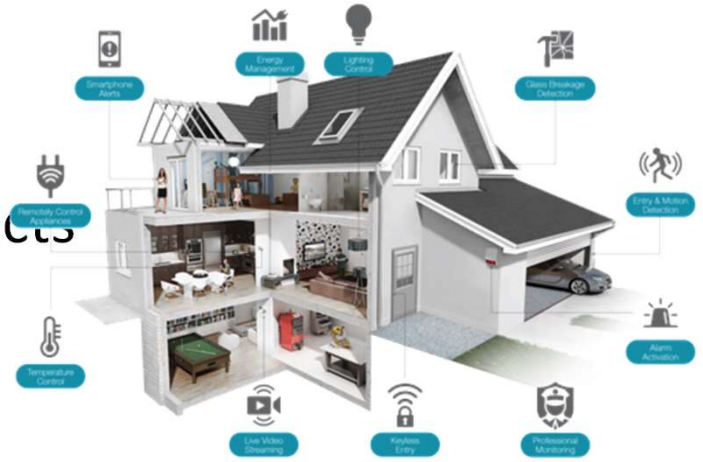
http://www.nytimes.com/2016/06/26/opinion/sunday/artificial-intelligences-white-guy-problem.html?_r=0

AI in everyday life

- **Cars**
  - Self-parking
  - Cruise control
  - Speech recognition
- **Banks**
  - Monitoring for fraud
- **Cell Phones**
  - Voice recognition
- **Internet**
  - Search Engines

AI in everyday life (cont'd)

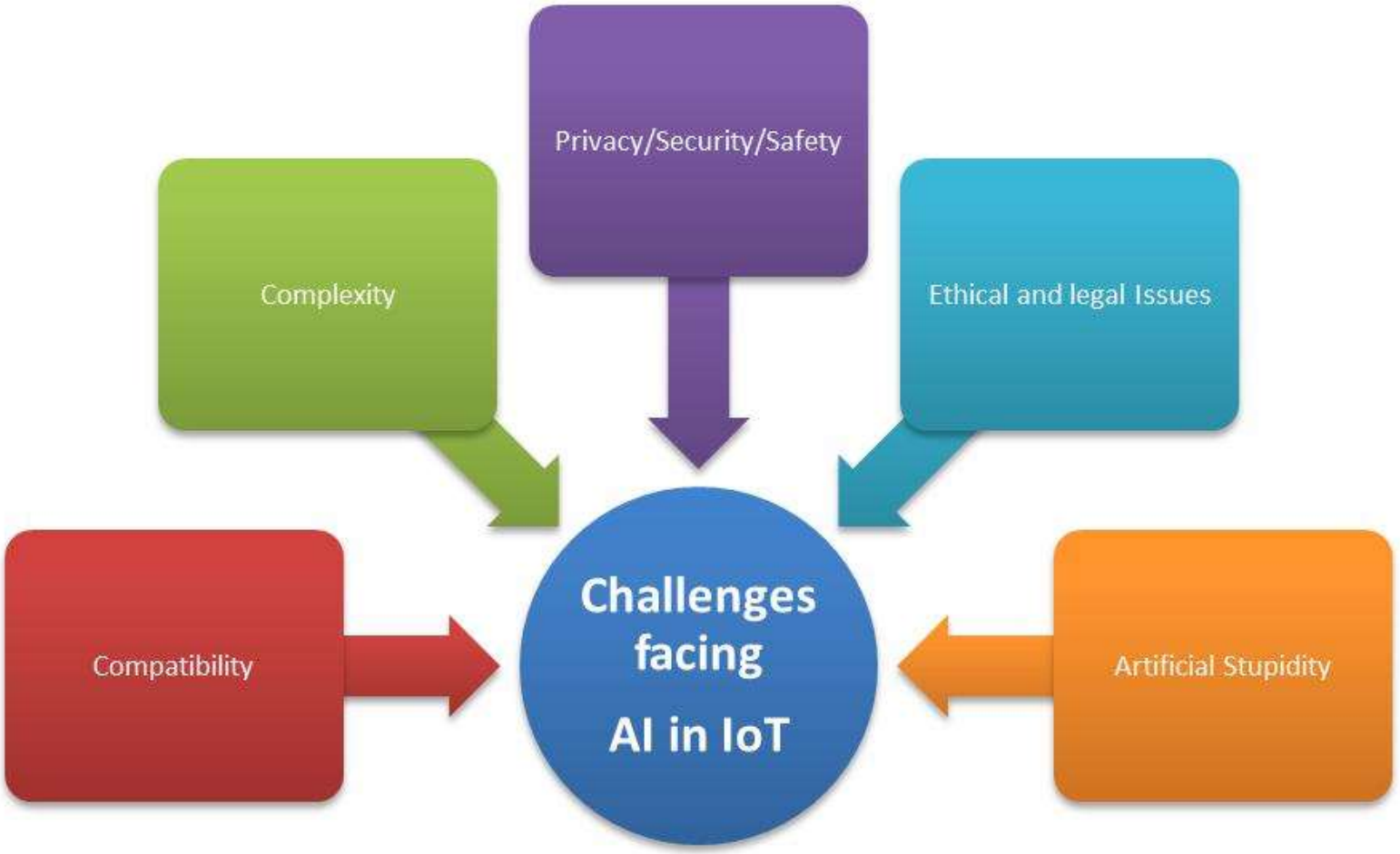
- **Intelligent Homes**
  - Passive infrarred sensors
  - Temperature sensors
  - Water heating control
  - Central heating control
  - Magnetic door and window contacts
  - Electricity and light sensors



Why use intelligent systems?

- Automation of repetitive tasks
- Augmenting limited information processing capability of humans
- Easy interaction with machines
- Understanding human brain and intelligence
- Find out limits of (human) intelligence

AI Challenges



Soft Computing in AI

- Soft Computing maybe viewed as a foundation of the emerging field of conceptual intelligence
  - Machine learning
  - Fuzzy Systems
  - Evolutionary Computation
  - Probabilistic Reasoning

- Soft Computing is the CORE component of many Machine Learning systems

Soft Computing (SC)

- Main premise is to deal with uncertainty and imprecision in the environment
  "Soft computing is an emerging approach to computing which parallels the remarkable ability of the human mind to reason and to learn in an environment of uncertainty and imprecision" (Lotfi A. Zadeh, 1992)
- Extensive numeric computation as opposed to symbolic manipulation only

Soft Computing

- Collection of methodologies, to exploit tolerance for ***imprecision***, ***uncertainty*** and ***partial truth*** to achieve ***tractability***, ***robustness*** and ***low cost solution***
- The methodologies in SC are complementary rather than competitive
- In many cases a problem can be solved most effectively by using combinations of SC techniques
- Link: *World Federation on Soft Computing*
  - http://www.softcomputing.org/

Soft computing constituents

- A consortium of several paradigms
- Closely related to machine learning

Methodology	**Strength**
Neural networks	Learning and adaptation
Fuzzy set theory	Knowledge representation using fuzzy if-then rules
Evolutionay algorithms and bio-inspired agents	Systematic randomized search (optimization)
Conventional AI	Symbolic manipulation

Historical developments

Symbolic AI

- Cybernetics (1947)
- Artificial intelligence (1956)
- LISP programming language (1960)
- Knowledge engineering and expert systems (mid 1970's)

Neural networks

- McCulloch-Pitts neuron model (1943)
- Perceptron (1957)
- Adaline and Madaline (1960's)
- Backpropagation algorithm (1974)
- Cognitron and neocognitron (1975)
- Self organizing map (1980)
- Hopfield net (1982)
- Boltzmann machine (1983)
- Backpropagation boom (1986)

Historical developments

Fuzzy systems

- Fuzzy sets (1965)
- Fuzzy controller (1974)
- Fuzzy c-means clustering (1974)
- Fuzzy modelling - TSK model (1985)
- ANFIS (1991)
- CANFIS (1994)

Other methodologies

- Genetic algorithm (1970's)
- Artificial life (1980's)
- Immune modelling (1980's)
- Genetic programming (1990's)
- Bio-inspired algorithms: ACO, PSO, etc. (1990's)

Characteristics of Soft Computing

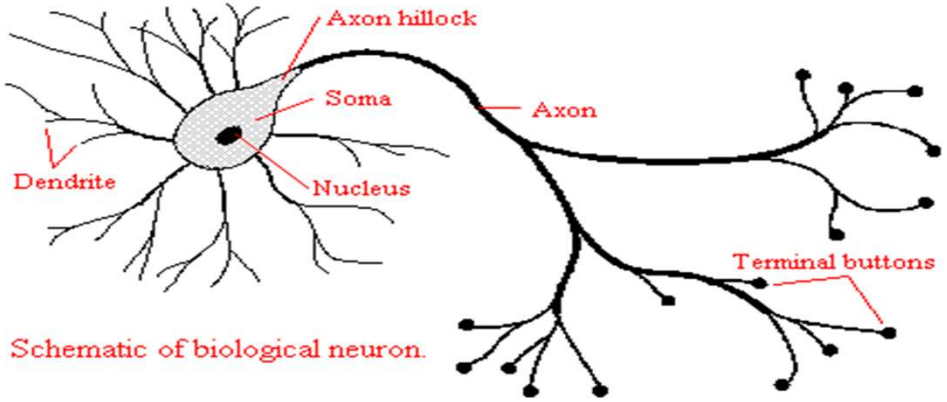
- Human expertise, e.g. fuzzy if-then rules
- Biologically inspired computing models
- New optimization techniques
  - e.g. evolutionary search or artificial colonies of insects for non-gradient based optimization
- Numerical computation
- New application domains, extends the range of fields within which AI is applied: e.g. non-linear regression

Characteristics of Soft Computing

- Model-free learning: explicit model structure not always given
- Intensive computation
- Fault tolerance: deleting neurons or rules degrades performance gracefully
- Goal driven characteristics
- Real world applications: handling of uncertainty and imprecision, adaptability

Neural networks

- Inspired by the biological nervous systems
- A lot of active research in brain modeling
- Intelligence arises out of co-ordinated actions of many computational elements (neurons)



Schematic of biological neuron.

Fuzzy sets theory

- In between connectionist systems and symbolic AI
- Systematic calculus to deal with imprecise, incomplete and vague information
- Natural interface to deal with fuzziness in natural language
- Numerical computations performed by using membership functions that represent linguistic labels
- http://www.youtube.com/watch?v=J_Q5X0nTmrA

Fuzzy sets theory

- Essentially a rule based system
- Conclusions are drawn by the inference system, given the knowledge in the rule base
- Some types of fuzzy systems are equivalent to radial basis function networks
- Sets a link between numeric computations and symbolic representation
- http://www.youtube.com/watch?v=P8wY6mi1vV8

Evolutionary computation

- Inspired by evolution of biological systems
- Evolution of “better” individuals in a society with competition
- Competition can be for limited resources or through “survival of the fittest”
- Related to heuristically informed search techniques within symbolic AI
- Requires a mechanism for selecting successful individuals

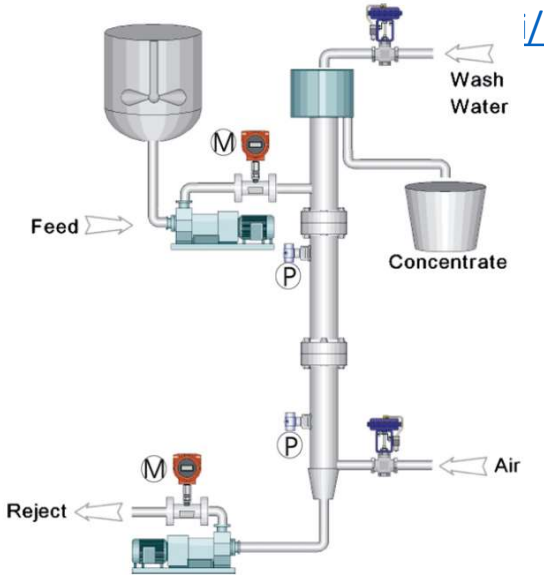
Evolutionary computation

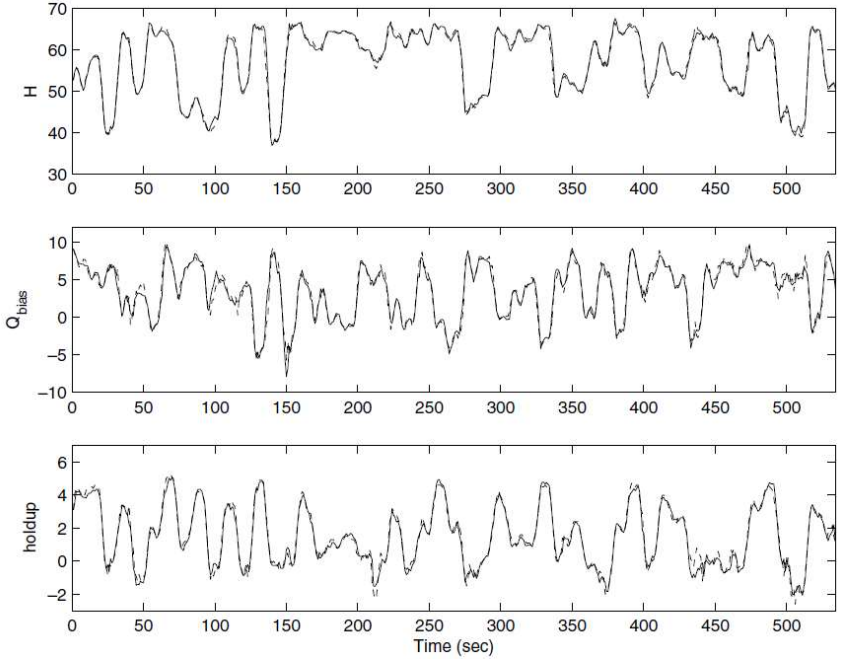
Several forms of evolutionary computation:

- Genetic algorithms and genetic programming
  - http://www.youtube.com/watch?v=ejxfTy4lI6I
- Evolutionary strategies
  - http://www.youtube.com/watch?v=mARt-xPablE
- **Artificial Life** algorithms: swarm, ants, wasps, bees
  - http://www.youtube.com/watch?v=PEfxb0wLEZg
- **Applications:** Vehicle routing, logistic scheduling, clustering and data mining problems, etc.

Applications

- Word indexing of ancient documents using fuzzy classification
  http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=4343120
- Decision tree search methods in fuzzy modeling and classification
  http://www.sci[illegible]/

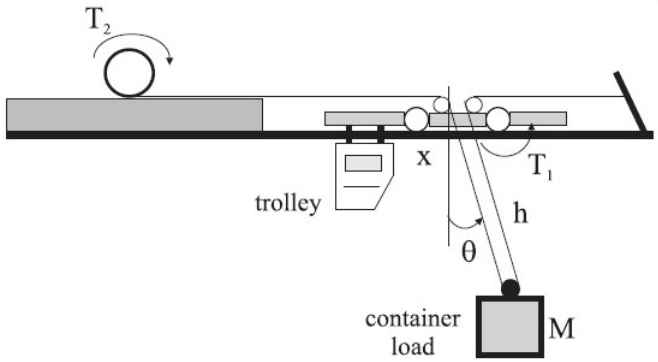


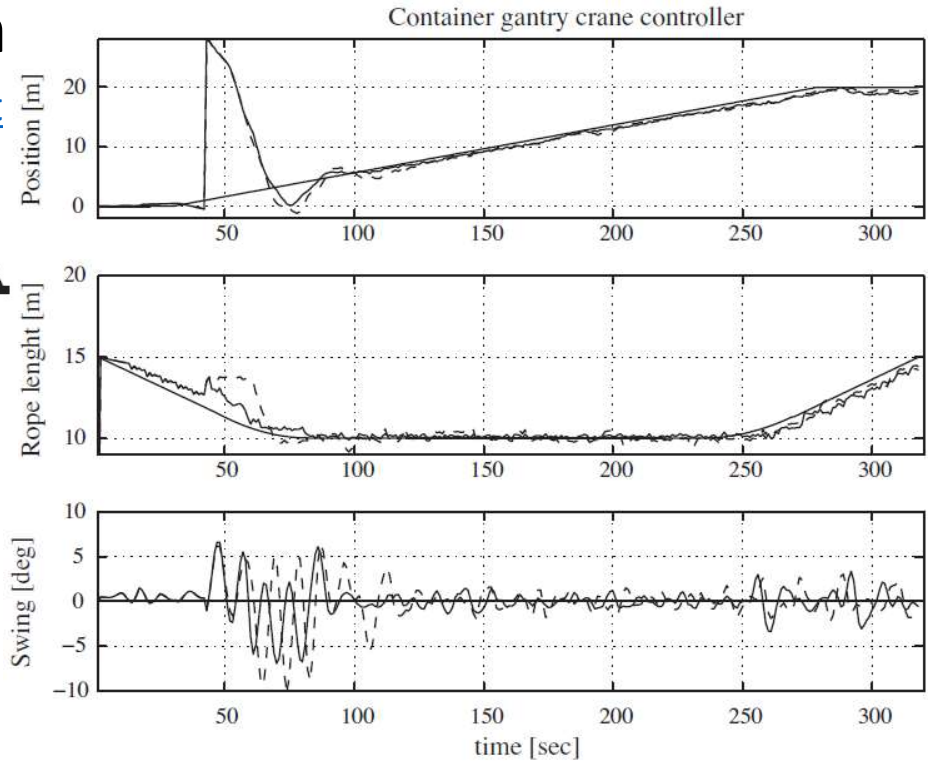


Applications in control

- Fault tolerant control usin

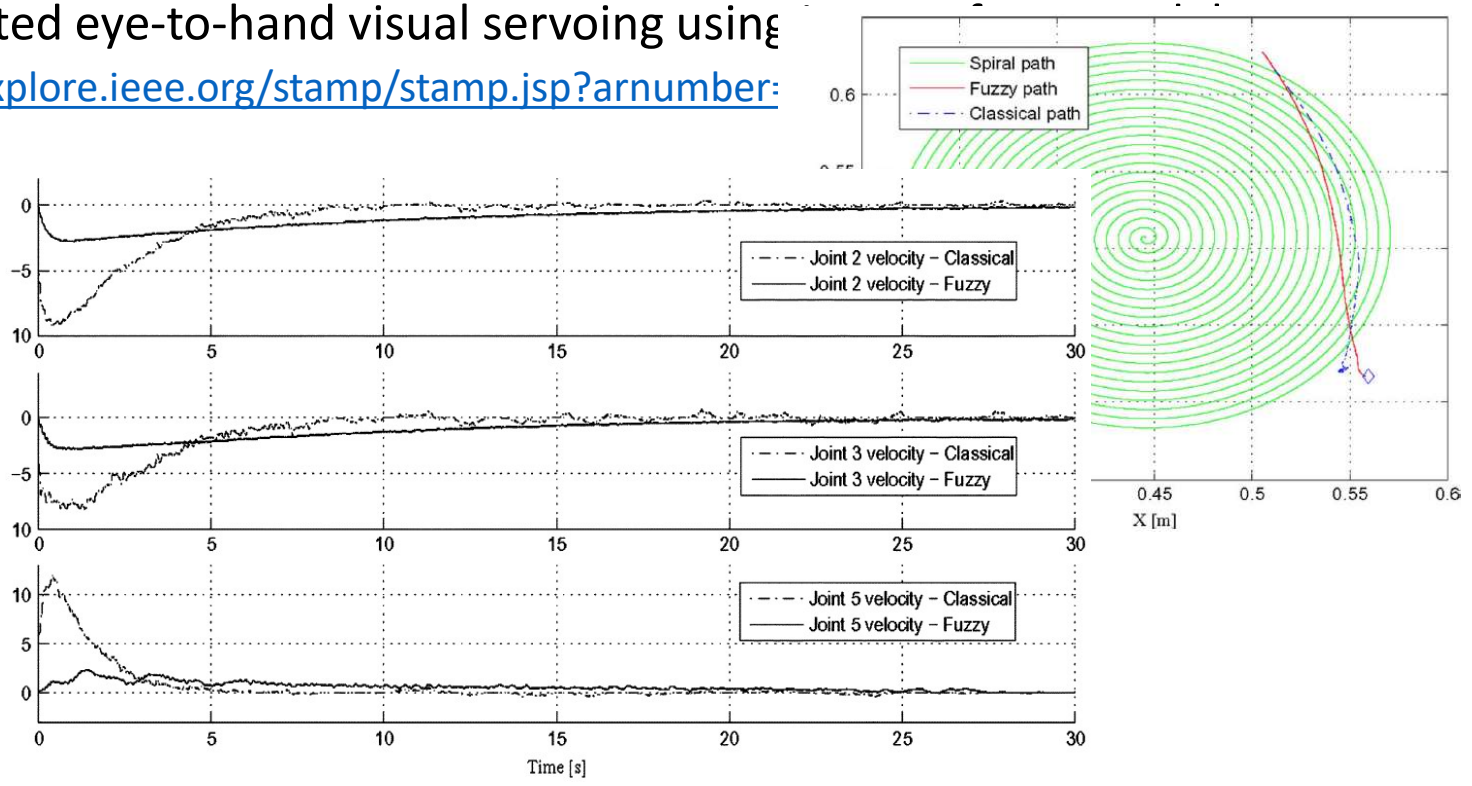
  http://www.sciencedirect.com/science/art





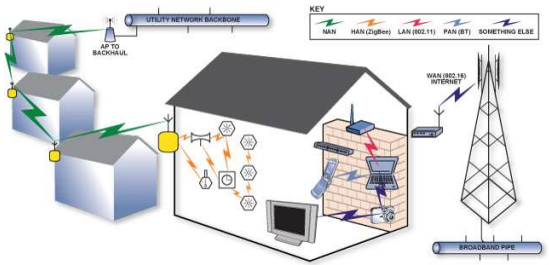
Applications in control

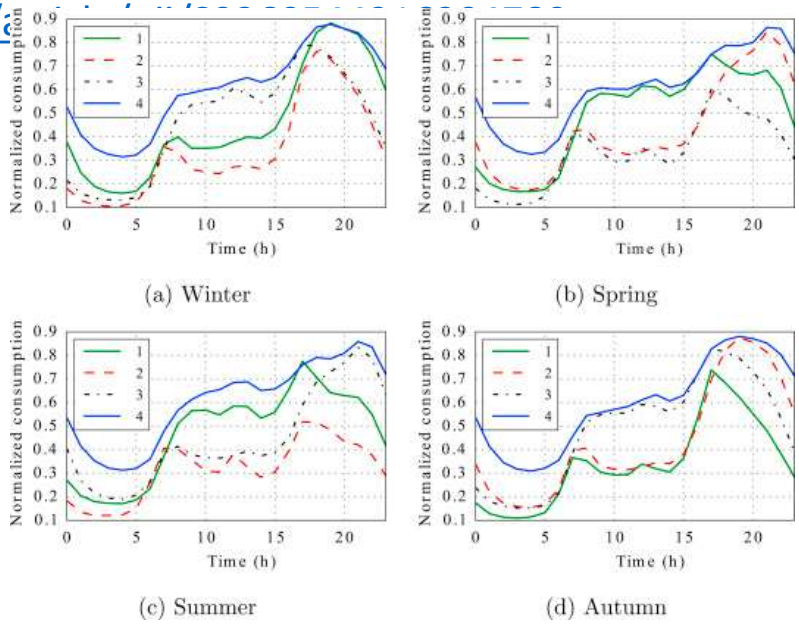
- Uncalibrated eye-to-hand visual servoing using
  http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=



Applications in energy

- Classification of new electricity customers based on surveys and smart metering data http://www.sciencedirect.com/science/a



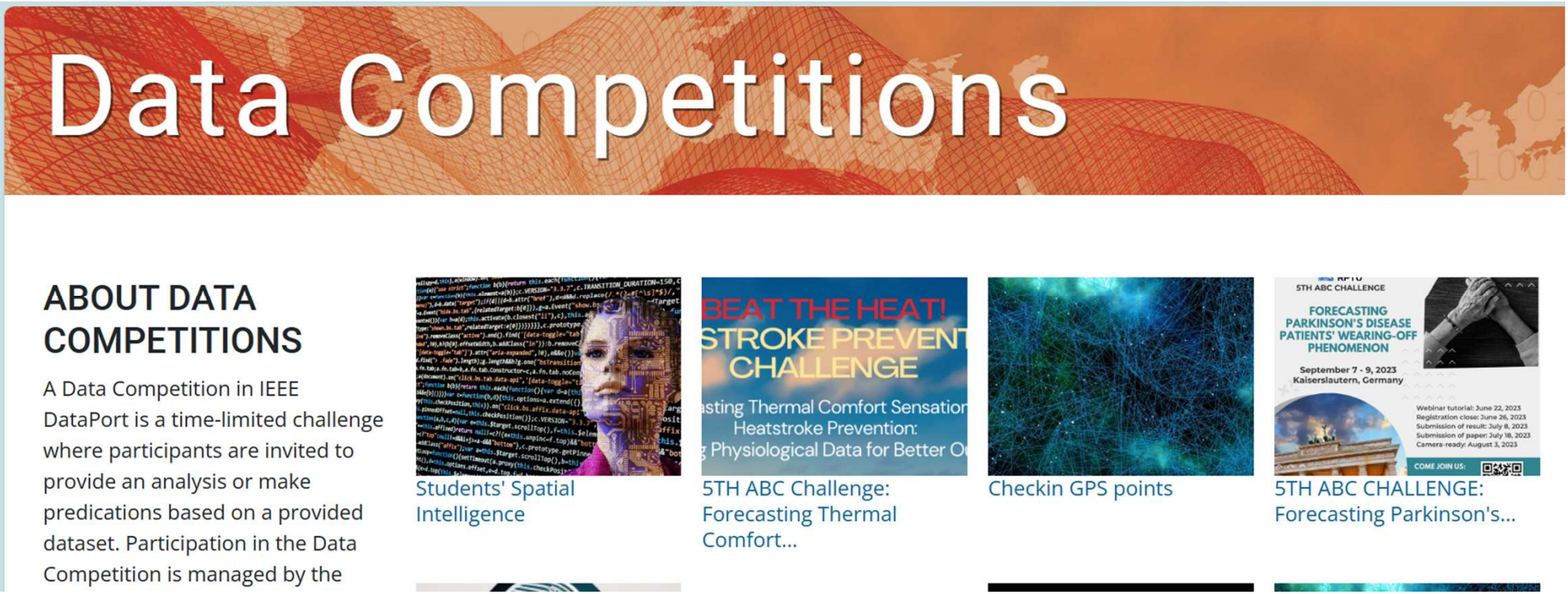


Applications in health care

- Problems in **Intensive Care Units**
  - Missing data in medical databases: Impute, delete or classify?
  - Reducing unnecessary lab testing in the ICU with artificial intelligence
  - Data mining using clinical physiology at discharge to predict ICU readmissions
  - Multi-stage modeling using fuzzy multi-criteria feature selection to improve survival prediction of ICU septic shock patients
  - Modified binary PSO for feature selection using SVM applied to mortality prediction of septic patients
  - …

IEEE-CIS Competition

- Data Competitions | IEEE DataPort (ieee-dataport.org)



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