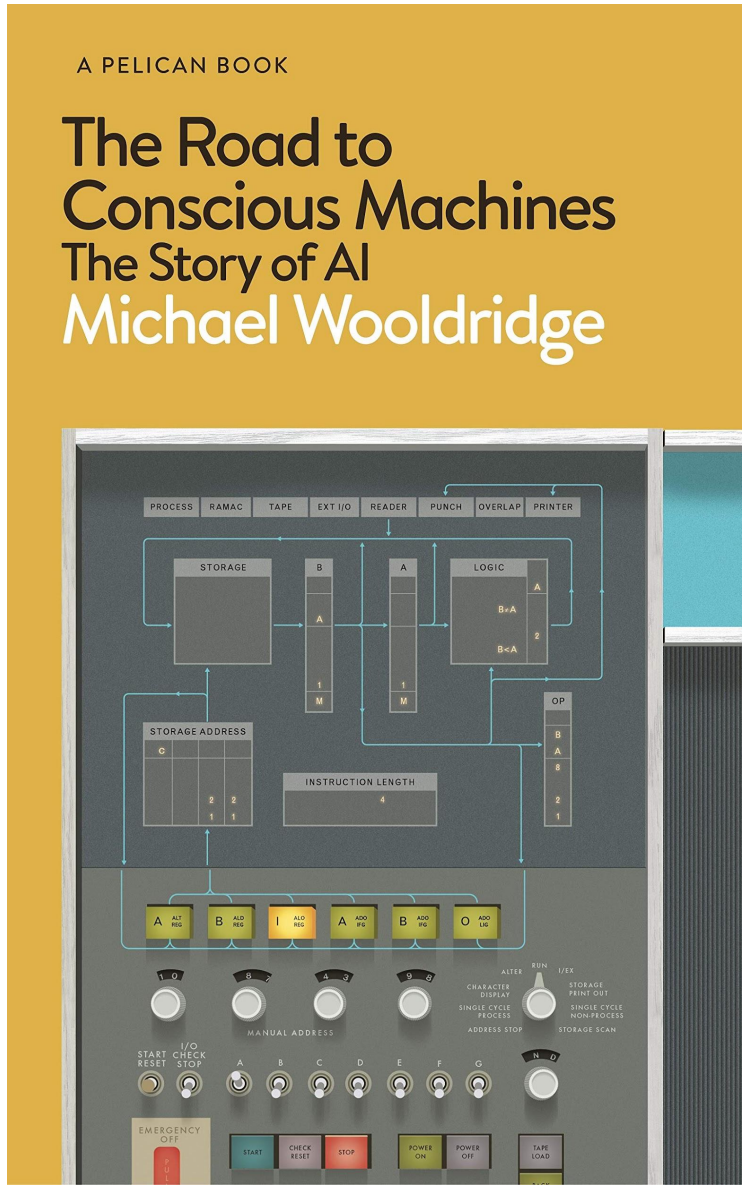
Introduction to Multi Agent Systems

Madalina Croitoru

University of Montpellier



Based on The Road to Conscious Machines (The Story of AI) by Michael Woolridge

Why AI is hard?

- Computers can reliably follow simple instructions VERY quickly and can make decisions if the protocol is clearly and precisely specified.
- Problems a computer can solve:
  - Sorting a list of numbers (1959)
  - Playing chess (1997)
  - Recognizing faces in pictures (2008)
  - Playing Go (2016)
- Problems far from being solved by a computer:
  - Human-level automated translation
  - Writing interesting stories

Brain or mind?

- How can we produce human-level intelligent behavior in a computer?
  - Model the **mind**: processes of conscious reasoning, problem solving, etc . This is called SYMBOLIC AI (makes use of symbols that stands for the things that the system is reasoning about). For example TD16 for the name of the room we use for teaching, HMIN321, HMIN108 for the name of the courses, takes_place to name that a certain course takes place in a certain room etc. We make use of these symbols for the reasoning: takes_place(HMIN321, TD16).

    Mainstream AI approach from mid 1950's until late 1980's.

  - Model the **brain**: take inspiration from certain structures that occur in the brain and model these as components in intelligent systems. These are called NEURAL NETWORKS.

    This has evolved alongside mainstream AI and since 2000 has shown impressive progress leading to the current AI boom.

The Golden Age of AI: 1956 - 1974

- John McCarthy invents LISP in the mid ‘50s (still regularly used today)
- 1955: the Dartmouth summer school (funded by the Rockerfeller Institute) with an impressive list of attendees such John Nash Jr (PhD on non-cooperative games – cornerstone of economic theories to come).
  - The title to the event, given by McCarthy was ”Artificial Intelligence”
- Funding followed and soon AI labs were founded at Stanford (by McCarthy), at MIT (by Minsky), etc.
- General Strategy: divide and conquer. In order to build an intelligent system one should **identify the capabilities required** and build systems that demonstrate each of these capabilities to be later assembled into a whole.

The Golden Age of AI: key capabilities of intelligent systems

- Perception: how to get information about its environment?
  - Building sensors
  - Interpret the raw numbers provided by sensors into “understanding” what it means
- Ability to learn from experience
  - Led to a strand of AI called Machine Learning
- Problem solving and planning
  - Achieve a goal using a given repertoire of actions (for example game playing)
  - Major problem: the space of search
- Reasoning (i.e deriving new implicit knowledge from existing facts)
- Natural Language Understanding

Golden Age of AI: systems

- SHRDLU (Stanford): problem solving and natural language understanding
  - Scenario (famous now): Blocks World (a simulated environment containing colored objects. Problem solving consisted of how to arrange objects according to user instruction using a simulated robot arm via a set of predefined actions: pick-up object from object / table, place object on object / table).
  - Very appealing, intuitive, easy to explain and “looks real”.
  - Major limitations for real world deployment: closed world (nothing else affects the blocks than SHRDLU), simulated environment and simulated robot arm.
- SHAKEY (Stanford): first attempt to build a mobile robot for the real world
  - Introduced STRIPS – THE language for planning in AI still used today
  - Major limitation: search space explosion. The A* search algorithm was developed as part of SHAKEY!

The end of the Golden Age

- 1972: the Sir James Lighthill (Cambridge) report specifically identifies combinatorial explosion as the key problem that AI failed to address
  - Major funding cuts in UK and US followed this report
- Between 1970-1980 the first AI winter occurred. The stereotype of AI researchers making overoptimistic predictions and failing to deliver was born
- Slowly, as a response, a new class of knowledge based systems emerged: “expert systems” that used the expert human knowledge in order to solve specific, narrowly defined problems
  - For the first time expert systems showed that AI can be used for problems of commercial interest in order to make money (typically in domains where a human expert acquired expertise for a long time and where the human experience was scarce)

Expert systems: late 70s to late 80s

- Most common scheme for expert systems was rules (if …. then ….).
- If Antecedent then Consequent
- Rules are triggered when the Antecedent matches the information we currently have allowing us to add the Consequent to the pool of information
- MYCIN (Stanford, 1970) intended to be a doctor's assistant providing expert advice about blood diseases in humans.
  - Benefitted from the presence of many experts
  - Reasoning (i.e the rule triggers) **can be explained** – to become crucially important for applications of AI
  - Integrated **uncertainty in the reasoning process** – another major topic of research in AI to the present day!

Expert Systems Boom

- Many other systems followed:
  - Dendral (Stanford, used by the mid 80s by hundreds of people daily to determine the chemical compound of a spectrometer read component),
  - R1/XCON (Digital Equipment Corporation, processing by mid 80s more than 80000 orders of computer configuration saving the company 40 million dollars) etc.
- The programming language of choice : LISP but many representation languages proposed: scripts (Roger Schank; Robert Abelson), semantic nets etc. Logic emerged as an unifying scheme for knowledge representation.
  - One of the earliest advocates of logic AI was John Mc Carthy
- A new job title appeared (knowledge engineer) making AI accessible

Programs as logic

- By early 80s the paradigm of logic based AI was the mainstream of AI
- PROLOG was introduced (Bob Kowalski, Alain Colmerauer, Philippe Roussel) and it even challenged LISP as the language of choice for AI!
  - Benefitted from 400 million dollar funding from Japan via the Fifth Generation project intended at commercializing technology
- The Cyc project (Doug Lenat, 1984) proposed – the key to General AI was knowledge:
  - Build a knowledge base of a complete description of consensus reality (basically the "precursor" of Google's Knowledge Graph …)
  - Lenat estimated the project required 200 person years of effort
- By the end of the 80s Cyc (of course) did not work, Prolog failed to deliver the very high hopes put in it, non monotonic features in logic were hard to capture, contradictions were not handled, knowledge was difficult to extract from experts … and … **the reality of what AI produced *again* did not live up to the hype** ….

The Brooksian Revolution

- Three key principles of Rodney Brooks (1991):
  - Meaningful AI can only be achieved with systems situated in the real world (i.e perceiving it and acting upon it)
  - Intelligent behavior can be generated WITHOUT explicit knowledge
  - Intelligence is an emergent property arising from entity interaction
- Do not follow a divide and conquer approach to AI but advocated for systems functioning in perceive-reason-act loops (a close-coupled relationship between the situation and the behavior)
- New paradigm for AI emerged: **behavioral AI**
  - Brooks founded the IRobot manufacturer of the Roomba robots (functioning based on behavioral AI)

And finally … Agent-based AI (early ‘90)

- Behavioral AI was limited at simple robotics-like applications: understanding how behaviors interact in large / complex systems was too complicated
  - Reasoning is needed in certain situations
- The focus of AI changed away from disembodied AI (like expert systems, logical reasoners) towards building agents combining behavioral with logic:
  - An agent is a self-contained, autonomous entity, situated in an environment and carrying out a specific task goal
  - Agents need to be reactive to their environment, proactive towards their goal and social in working with other agents
  - **The social aspect was a major breakthrough**

Agent based systems

- HOMER (descendant of SHRDLU): a simulated robot submarine
- AI Assistants (agents working with you and cooperating with you to do whatever you want to do): email management, meeting scheduling, music recommendation
- The Internet and the World Wide Web boom provided the perfect platform for agent based assistants leading, in part, to the dot-com bubble (1995-2000)
- Many more features of agent based systems to be subsequently explored after the 2000:
  - Rationality and decision making
  - Cooperation and communication
  - Uncertainty

And then … 2014 happened

- In January 2014 Google bought Deep Mind (a UK start-up of 25 people presenting themselves as doing AI) for 400 million pounds!
- In 2015 Uber acquired 40 researchers from Carnegie Mellon University in one single deal
- WHAT HAPPENED?
  - Machine learning : programs can compute the output WITHOUT being given an explicit recipe. The program is trained with many many many examples (“supervised learning”).
    - Machine learning needs data (and we should be careful at what kind of data we feed it)
    - Machine learning needs feature extraction
    - As old and as large field as AI (actually some researchers in machine learning were present at the 1956 summer school of McCarthy)

Neural Nets

- One of the oldest techniques in AI
- 1940: Warren McCulloch and Walter Pitts model neurons as electrical circuits
- 1950: Frank Rosenblatt introduces the perceptron model. The advocates of symbolic AI subsequently heavily criticize the model. With the death of Rosenblatt in a sailing accident in 1971 the field becomes dormant.
- 1980: revival of the field by the arrival of Parallel Distributed Processing and invention of backpropagation. The model was criticized because of the lack of computer power needed for these techniques.
- 2006: deep learning introduced by Geoff Hinton (one of the inventors of backpropagation). Now data and computer power were available to make it into a success story.
  - Last drop: Graphics Processing Units proved perfect for training neural nets.

Criticism of Deep Learning

- The intelligence they embody is opaque
- Not robust (it is possible to make imperceptible changes to images that result in misclassification)
- Biased (as good as the data it provides)

- Important to understand what these programs DO and what they DO NOT
  - Deep Mind trained a program to play ATARI video games from scratch: nobody told the program ANYTHING about the games it was playing except the console screen grid and the current score.
    - It learned to play 29 out of the 49 games at above human level (and even learned by itself human like strategies in Breakout)
  - DeepMind built AlphaGo beating Lee Sedol 4 games to 1. It then released AlphaGo Zero that learned by playing against itself to play at super human level.