# III. Artificial Intelligence

Artificial Intelligence (AI) is one of the newest fields in science and engineering and currently covers a huge variety of subfields, from the more general, as learning and perception, to the specific, such as playing chess, proving mathematical theorems, driving a car and diagnosing disease. AI is truly a universal field that aims not just to understand but also to build intelligent entities [9].

1. Brief history

The beginnings of AI can be traced to philosophy and fiction, while early inventions in electronics, engineering and many other disciplines have greatly influenced the path of AI. Some early milestones include work in problem solving, including basic work in learning, knowledge representation and inference as well as programs in language understanding, translation, theorem proving, associative memory and knowledge-based systems [10].

AI sits at the intersection of a number of important disciplines, listed in Table III.1 below, each of them contributing in some way to the development of this field. In its formative years, AI was influenced by ideas from many fields of study. These came from people working in engineering(such as Wiener’s work in cybernetics), biology(Ashby, McCulloch and Pitt’s work on neural networks in simple organisms), experimental psychology, communication theory, game theory(notably by von Neumann and Morgenstern), mathematics and statistics, logic and philosophy(for example, Church and Hempel) and linguistics(such as Chomsky’s work in grammar) [10].

These areas made their mark and continue to influence this field of study, but after having assimilated much, AI has grown beyond them and has, in turn, occasionally influenced them back [10]. Only in the last half century computational devices and programming languages have become sufficiently powerful to build experimental tests of ideas about what intelligence is.

The first work that is now seen as belonging to AI was done by McCulloch and Pitt in 1943 and proposed a model of artificial neurons, drawing knowledge from three different sources: the basic function and physiology of neurons in the brain, a formal analysis of propositional logic and Turing‘s theory of computation. Their network of connected neurons was able to compute any computable function and could also implement all the logical connectives [9].

But the birth of AI is considered to have taken place in **1956** at the Dartmouth College in Hanover, where a two-month workshop gathered 10 scientists interested in the automata theory, neural nets and the study of intelligence from all over the US, in an attempt “to find how to make machines use language, form abstractions and concepts, solve kinds of problems now reserved for humans and improve themselves” [9].

**Table III.1.** The disciplines and the personalities that lead to the development of AI

by finding answers to important questions [9]

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| Discipline | Questions | Personalities |
| Philosophy | * Can formal rules be used to draw valid conclusions? * How does the mind arise from a physical brain? * Where does knowledge come from? | Aristotle  Leonardo da Vinci  Wilhelm Leibniz  René Descartes  Rudolf Carnap |
| Mathematics | * What are the formal rules to draw valid conclusions? * What can be computed? * How do we reason with uncertain information? | George Boole  Kurt Gödel  Alan Turing  Steven Cook  Thomas Bayes |
| Economics | * How should we make decisions so as to maximize payoff? * How should we do this when the payoff may be far in the future? | Adam Smith  John von Neumann  Richard Bellman  Herbert Simon |
| Neuroscience | * How do brains process information? | Hans Berger, Camillo Golgi, Santiago Ramon y Cajal |
| Psychology | * How do humans and animals think and act? | H. Helmholtz, F. Bartlett, K. Craik, N. Chomsky |
| Computer Engineering | * How can we build an efficient computer? | J. Eckert, C. Babbage, J.M. Jacquard |
| Control theory and cybernetics | * How can artifacts operate under their own control? | N. Wiener, W.R. Ashby |
| Linguistics | * How does language relate the thought? | B.F. Skinner, N. Chomsky |

Although the workshop itself did not lead to any new breakthroughs, it succeeded in introducing all the major figures involved in the discipline to each other. For the next 20 years, the field would be dominated by these people and their students and colleagues at major universities and study groups in the US [9].

The early years (**1952-1969**) of AI were full of successes, even though in a limited way. Taking into account the primitive computers and programming tools of the time, whenever a computer did something even remotely clever it was considered astonishing. Some accomplishments from this period are:

* the General Problem Solver (GPS) of Newell and Simon, probably the first program to incorporate the “thinking humanly” approach and could handle a limited class of puzzles
* the Geometry Theorem Prover of Gelernter, which was able to prove theorems that were considered tricky by many mathematics students
* the definition of the high-level language Lisp by McCarthy, which would become the dominant AI programming language for the next 30 years
* perceptrons and flourishing work on neural networks

Although these years where full of successes and enthusiasm was high, the period between **1966 and 1973** [9] was marked by a dose of reality. The predictions stated by many scientists did come true, but it took 40 years for this to happen, rather than 10. This overconfidence came from the fact that the early AI systems showed promising performance, but failed to take into account three major difficulties:

* The programs succeeded only by means of simple syntactic manipulations and knew nothing of their subject matter. An example of a failed project because of this aspect would be the efforts of early machine translation, when it was thought that simple syntactic transformations and word replacements would suffice to preserve the meaning of a sentence.
* The combinatorial explosion. It was thought at the time, before the theory of computational complexity was developed, that scaling up to more difficult tasks would be a matter of faster hardware and larger memories, but this assumption was soon proven wrong, when researchers failed to prove theorems involving more than a few dozen facts.
* The basic structures used to generate intelligent behavior had some fundamental limitations. For example, the perceptrons, although they were shown to be capable to learn anything that they could represent, they in fact could represent very little.

Until 1969, the problem solving techniques employed were using a general-purpose search mechanism attempting to put together elementary reasoning steps to find complete solutions, and they weren’t able to scale up to larger or more difficult problems. The alternative was to build more powerful, domain-specific knowledge that would allow larger reasoning steps and could easily handle typically occurring cases in narrow areas of expertise. The **decade after 1969** [9] was marked by the emergence of projects that did just that, such as:

* DENDRAL – it was the first successful knowledge-intensive system and was used to solve the problem of inferring molecular structure from the information provided by a mass spectrometer. The first naïve version generated all possible structures for the given formula, predicted the spectrum that would be observed for each one and then compared these results with the actual spectrum of the molecule, but couldn’t manage even moderate-sized molecules. So the researchers consulted analytical chemists and all the relevant theoretical knowledge gathered from them was mapped into rules that helped in restricting the search space.
* HPP – the Heuristic Programming Project was developed to investigate the extent to which the new methodology of expert systems could be applied to other areas of human expertise.
* MYCIN – was developed to aid in the diagnosis of blood infections. It had 450 rules acquired from extensive interviewing of medical experts, took into account the uncertainty associated with medical knowledge and was able to perform as well as some specialists.
* SHRDLU – a system for understanding natural language which was able to overcome ambiguity and understand pronoun references.
* Prolog – logic based reasoning language widely used in Europe at the time.

Since **1980** [9], AI has become an industry, with the first successful commercial expert system, R1, being employed at the Digital Equipment Corporation to help configure orders for new computer systems and saved the company an estimated $40 million a year. Also, in the mid 1980s, the back-propagation learning algorithm gained the spotlight and was applied to many learning problems in computer science and psychology. The content and methodology of work in AI has seen a revolution in recent years and is more common to build on existing theories than to propose new ones, to base claims on rigorous theorems or experimental evidence rather than on intuition and to show relevance to real-world applications.

Up until the years **2000s** [9], the emphasis in computer science has been on the algorithm, but recent work in AI suggests that for many problems, it is better to focus in the data and be less meticulous about what algorithm to apply, also taking into consideration the increasing availability of very large data sources. This suggests that the problem of how to express all the knowledge that a system needs may be solved by learning methods, rather than hard coded rules, provided that the learning algorithms have sufficient data to work with.

1. Domains of application

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| Domains | Examples |
| Automotive |  |
| Games |  |
| Military |  |
| Healthcare |  |
| Finance and economics |  |
| Robotics |  |
| Speech and image recognition |  |
| Aviation |  |
| Education |  |
| Marketing |  |
| Music |  |

1. Applications and research in bioinformatics

[9] Russel, S.J., Norvig, P.: Artificial Intelligence, A Modern Approach, Third Edition, Prentice Hall, New Jersey, 2010.

[10] Buchanan, B.G.: A (very) brief history of Artificial Intelligence, AI Magazine, 4(2006), 53-60.