

Some Elements for a Prehistory of Artificial Intelligence in the Last Four Centuries

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Abstract. Artificial intelligence (AI) was not born ex nihilo in the mid-fifties of the XXth century. Beyond its immediate roots in cybernetics and in computer science that started about two decades before, its emergence is the result of a long and slow process in the history of humanity. This can be articulated around two main questions: the formalization of reasoning and the design of machines having autonomous capabilities in terms of computation and action. The aim of this paper is to gather some insufficiently known elements about the prehistory of AI in the last 350 years that precede the official birth of AI, a time period where only a few very well-known names, such as Thomas Bayes and Georges Boole, are usually mentioned in relation with AI.

1 INTRODUCTION

As it is well-known, the birthday act of artificial intelligence (AI) corresponds to a research program⁴ for a series of meetings during the summer of 1956, with 10 participants,⁵ organized at Dartmouth College (Hanover, New Hampshire, USA).

AI has immediate roots in cybernetics [98] and in computer science, but its emergence is the result of a long and slow process in the history of humanity, which can be articulated around two main questions: the formalization of reasoning and the design of machines having autonomous capabilities in terms of computation and action. There exists a number of valuable books focusing on different aspects of the modern history of AI [1, 68, 83, 80, 53, 23, 72]. But what is said about what may be called the “prehistory” of AI (corresponding roughly speaking to the time period before the advent of the first computers), is usually very sketchy and sparse, with the mention of a few names: Aristotle and his *Organon* [2] for the (Western) Antiquity, maybe Ramon Llull and his *Ars Magna* (1305) [39] for the Middle-Age, Thomas Bayes [6] and Georges Boole [10] for the modern times before the last century.

This article focuses on the time period that goes from the beginning of the XVIIth century to the beginning of the XXth century. The

reader interested in a broader panorama from the Antiquity to the 1980's, and reading French, is referred to the first chapter [62] of a handbook of AI research just published [63]. The ambition of this article is only to provide some (often forgotten or ignored) elements that may be considered as parts of the slow emergence of AI concerns during the last centuries. It should be clear that the works mentioned, which may be a posteriori related to AI, were often only small parts of the production of their authors, involved in very different scientific fields. Even if quite a number of names are cited in the following, it is very likely that names are missing. This is unavoidable with such an attempt. Moreover, we only indicate the general concerns of the authors cited and the references to their work, without discussing their contribution in detail (which would require a much longer article).

The rest of the paper is organized as follows. Section 2 covers the XVIIth century whose general concerns in logic are still largely inherited from the past. It is also the time of the first developments in probabilities. Section 3 is devoted to the XVIIIth century which pursues along the line initiated in the previous century. Section 4 deals with the XIXth century and the beginning of the XXth century. Among other issues, it points out some forgotten works which, before Boole, announce the transition towards modern logic. We try to indicate names (and facts) having a significant relation with some concerns of AI. As already said, some authors mentioned are better known however for other works not related to AI, while some others are rarely cited.

2 THE XVIIth CENTURY: PRELIMINARY STEPS TOWARDS MODERNITY

The time period that starts with the beginning of the XVIIth century exhibits a slow transition towards the birth of modern logic 250 years later with the funding works of Georges Boole, as well as it shows the first developments of probabilities. This is also the time of the emergence of the first machines.

In philosophy of knowledge, Francis Bacon (1561-1626) promotes the inductive method based on observation for scientific discovery [4], at the beginning of the XVIIth century. Besides, in 1603 the first French treatise of logic is published [36]. It is written by Scipion Dupleix (1569-1661), a preceptor of a son of the king Henri IV. His course of philosophy also includes a *Physique*, a *Métaphysique*, and an *Ethique*. His *Logique* is a vast compilation of previous knowledge, and deals, among other issues, with the square of oppositions, modalities, syllogisms, incomplete syllogisms (patterns of default reasoning called enthymemes), sorites, and argumentation, all topics inherited from Aristotle and from his followers during the Antiquity and the Middle-Age [62]. In the middle of the XVIIth century, *Le Philosophe François* [16] written by René de Ceriziers (1603-1662),

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⁴ The application for getting a financial support, written in the summer of 1955, and entitled “A proposal for the Dartmouth summer research project on artificial intelligence” (where the name of the new research area was already coined!), was signed by John McCarthy, Marvin Minsky, Nathaniel Rochester and Claude Shannon [67].

⁵ Apart from the 4 signees of the project appearing in the above footnote, they were Trenchard More, Allen Newell, Arthur Samuel, Oliver Selfridge, Herbert A. Simon, and Ray Solomonoff. Interestingly enough, it is worth noticing that these 10 participants were already carriers of the large variety of research directions that can still be observed in AI.

includes a large section devoted to logic where argumentation is developed in great detail. This is also the time where the modern history of legal reasoning [52] starts. Let us also mention the *Essai de Logique* [61] by the physicist Edme Mariotte (c.1620-1684), which discusses issues about proofs in geometry, reasoning about the physical world, and deontic reasoning.⁶

Thomas Hobbes (1588-1679) seems to be the first to explicitly link the symbolic manipulation of terms in logic to the idea of mathematical calculation. Indeed, he wrote “*Per Ratiocinationem autem intelligo computationem.*” (or in English one year later “*By ratiocination I mean computation.*”)⁷ in his *De Corpore* [48], whose reputation was unfortunately somewhat damaged by the inclusion of a tentative proof of the squaring of the circle, even if Hobbes will acknowledge its falsity later.

It is also interesting to mention here an excerpt of the fifth part of the “*Discours de la Méthode*” [31], where René Descartes (1596-1650) who advocates a conception of animals as beings with a complete lack of reason, similar in that respect to machines, shows a remarkable prescience with respect to the discussion about how to distinguish humans from machines and the Turing test.⁸

⁶ Some other authors would be also worth mentioning, such as the Flemish philosopher Arnold Geulincx (1624-1669), author of treatises of logic entitled “*Logica fundamentis suis restituta*” (1662) and “*Methodus inveniendi argumenta*” (1663).

⁷ The text continues with “*Now to compute, is either to collect the sum of many things that are added together, or to know what remains when one thing is taken out of another. Ratiocination, therefore, is the same with addition and subtraction;*” (or in Latin : “*Computare vero est plurium rerum simul additarum summam colligere, vel unâ re ab aliâ detractâ cognoscere residuum. Ratiocinari igitur idem est quod addere and subtrahere*”). One page after one reads: “*We must not therefore think that computation, that is, ratiocination, has place only in numbers, as if men were distinguished from other living creatures (which is said to have been the opinion of Pythagoras) by nothing but the faculty of numbering; for magnitude, body, motion, time, degrees of quality, action, conception, proportion, speech and names (in which all the kinds of philosophy consist) are capable of addition and subtraction.*” (or in Latin: “*Non ergo putandum est computationi, id est, ratiocinationi in numeris tantum locum esse, tanquam homo a caeteris animantibus (quod censuisse narratur Pythagoras) sola numerandi facultate distinctus esset, nam and magnitudo magnitudini, corpus corpori, motus motui, tempus tempori, gradus gradui, actio actioni, conceptus conceptui, proportio proportioni, oratio orationi, nomen, nomini (in quibus omne Philosophiae genus continetur) adjici adimique potest.*”). In fact, the anecdote reported does not concern Pythagore, but Platon, see [48] note p. 13. Moreover, as early as 1651 [47] in chapter V (“Of Reason and Science”) of “Of Man”, the first part of his “*Léviathan*”, Hobbes had given a preliminary version whose beginning was “When a man ‘reasoneth’ he does nothing else but conceives a sum total, from ‘addition’ of parcels, or conceives a remainder, from ‘subtraction’ of one sum from another; which, if it be done by words, is conceiving of the consequence of the names of all the parts, to the name of the whole; or from the names of the whole and one part, to the name of the other part.”

⁸ “I worked especially hard to show that if any such machines had the organs and outward shape of a monkey or of some other animal that doesn’t have reason, we couldn’t tell that they didn’t possess entirely the same nature as these animals; whereas if any such machines bore a resemblance to our bodies and imitated as many of our actions as was practically possible, we would still have two very sure signs that they were nevertheless not real men. The first is that they could never use words or other constructed signs, as we do to declare our thoughts to others. We can easily conceive of a machine so constructed that it utters words, and even utters words that correspond to bodily actions that will cause a change in its organs (touch it in one spot and it asks ‘What do you mean?’, touch it in another and it cries out ‘That hurts!’, and so on); but not that such a machine should produce different sequences of words so as to give an appropriately meaningful answer to whatever is said in its presence - which is something that the dullest of men can do. Secondly, even though such machines might do some things as well as we do them, or perhaps even better, they would be bound to fail in others; and that would show us that they weren’t acting through understanding but only from the disposition of their organs. For whereas reason is a universal instrument that can be used in all kinds of situations, these

The *Logique* of Port-Royal [3] by Antoine Arnauld (1612-1694) and Pierre Nicole (1625-1695) published in 1662, initiates a theory of sign and representation for about two centuries, and is a landmark in the history of philosophy of language and in logic, which however still remains here somewhat connected to issues in theology. The book is organized in four main parts corresponding respectively to the faculties of conceiving, of judging, of reasoning (deductively through syllogisms), the last part discussing methodological questions. The mathematics are here the reference that should be transposed to the study of language statements, and reasoning. Lastly, the idea of probability is here, apparently for the first time, associated not to the combinatorics of games of chance, but to the evaluation of the confidence that can be attached to testimonies. Jacques Bernoulli (1654-1705), in his *Ars Conjectandi* published only in 1713, proposes distinct calculi for these two types of uncertain situations [86]. Close to Port-Royal people, let us recall that Blaise Pascal (1623-1662) is, among many contributions, both a pioneer of probabilities (in communication through letters on this topic with Pierre de Fermat (v.1605-1665)), and the inventor (in 1642) of a mechanical computation machine called *Machine arithmétique* able to perform additions and subtractions.

This is the Dutch mathematician and physicist Christian Huyghens (1629-1695) who publishes the first treatise on the probability calculus [7] and introduces the notion of expectation in an uncertain situation, among multiple scientific contributions including the improvement of clocks. Then this will be followed by the works of Abraham de Moivre (1667-1754) who will propose the first definition of statistical independence [28]. However, it seems that it is now clear that before the beginning of the XVIIth century, people had started to be interested in questions of uncertainty and risk [69].

3 THE XVIIIth CENTURY: THE AGE OF ENLIGHTENMENT

At the transition between the two centuries, Gottfried Wilhelm Leibniz (1646-1716) has not only been the philosopher that everybody heard about, and one of the father of the infinitesimal calculus (without mentioning many other works in mathematics, in physics, and in history). Indeed he also has an important role in the evolution of logic (see for example [46]), which has been rediscovered lately [19, 20], due in particular to his search for a universal language (*lingua characteristica universalis*) that enables the formalization of the thought and an algorithmic logical calculus (*calculus ratiocinator*), thus anticipating the project of Frege. He is also at the origin of the idea of “possible worlds”, and was interested in issues in legal and deontic reasoning. Another slightly later attempt at developing a logical formalism is the one by Gottfried Ploucquet (1716-1790) [79]. Leibniz is also the first to imagine the binary numeration [58]. Moreover he proposed a machine able to perform the four arithmetic operations in 1673 (finally recognized as imperfect). Let us also add that Leibniz was a good chess player who was interested in the scientific understanding of the game.

Let us particularly mention another philosopher as a forerunner of different AI concerns: David Hume (1711-1776), for whom the origin of our knowledge comes from experience [49], and ideas are not innate (as already for John Locke (1632-1704) [59] or George Berkeley (1685-1753)). He establishes a distinction between first “impress-

organs need some particular disposition for each particular action; hence it is practically impossible for a machine to have enough different organs to make it act in all the contingencies of life in the way our reason makes us act.” (Transl. J. Bennett)

sions”, and “ideas” which are weakened images, synthesized from impressions; for him, ideas are associated by different relations such as resemblance, (temporal or spatial) contiguity, or causality (a relation that he has especially analyzed). He also makes a distinction between logical truths and empirical truths which cannot be certain, but only probable, and points out that induction cannot lead to any certainty. He has also discussed analogical arguments.

The name of the Swiss mathematician Gabriel Cramer (1704-1752) is especially attached to the resolution of linear equation systems. But if his presence is relevant in this overview of the prehistory of AI, it is because of his course of logic [22, 64], remained unpublished until now, that he wrote in 1745 as a preceptor in a rich family. In his introduction, he makes a distinction between the *logique naturelle* (the one used spontaneously in reasoning) and the *logique artificielle* (the one that is founded on principles and rules). The presentation of this latter is developed along two main parts of approximately equal importance, one dedicated to the search for truth and to “comment l’esprit humain se forme des idées, les compare pour en porter des jugements et enchaîner ces jugements pour déduire les uns des autres”, and the other devoted to the study of probabilities as measures of the likelihood of the propositions or judgements about events. Thus, in a certain way, this *Cours* could be compared in its intention to the *Laws of Thought* by George Boole who, a little more than a century later, devotes parts of equal length to what will be called later Boolean logic, and to probabilistic reasoning under uncertainty. It seems by the way that Cramer’s *Cours* would be the anonymous source of the article *Probabilité* (attributed to Benjamin de Langes de Lubières (1714-1790) [13]) in the *Encyclopédie* by Denis Diderot (1713-1784) and Jean le Rond D’Alembert (1717-1783) (edited from 1751 to 1772). Let us also indicate that the article (also anonymous) *Logique* in the *Encyclopédie* also contrasts natural logic and artificial logic and refers for this latter to the article *Syllogisme* also anonymous.

Let us also mention the Alsatian mathematician Johann-Heinrich Lambert (1728-1777) who in his *Neues Organon* [56] develops a probabilistic theory of syllogisms, with application to the handling of the probability of testimonies [86, 65, 66]. Lambert, as the article *Probabilité* in the *Encyclopédie*, proposes a reinforcement rule of the confidence in corroborating testimonies, which may retrospectively appear as a particular case of the combination rule in Dempster-Shafer belief function theory. Besides, a landmark work in probabilities is the posthumous article by Reverend Thomas Bayes (1702-1761), communicated by his friend Richard Price (1723-1791), about the famous theorem of the computation of the a posteriori probability from priors and conditional probabilities [6], a result found again by Pierre-Simon Laplace (1749-1827) in his works on probabilities and induction [57].

Some other names are also worth mentioning, on different issues. The grammarian César Chesneau Du Marsais (1676-1756), also a contributor to the *Encyclopédie*, studies the patterns in rhetorics in his *Traité des Tropes* [35], and has concerns that might still have some relevance in automated treatment of languages and in argumentation in natural language. Besides, the philosopher and mathematician Nicolas de Condorcet (1743-1794), probabilist, pioneer in statistics, studied the representativity of voting systems (as also his contemporary Jean-Charles de Borda (1733-1799), mathematician, physicist, and sailor [25]), and stated the famous paradox on the possible intransitivity of majoritarian relative preferences [18].

The Age of Enlightenment, a century of progress towards reason and rationality, is also marked by literary works that contribute to feed our collective psyche. Jonathan Swift (1667-1745), in his novel

Gulliver’s travels [89], develops an ironical criticism of the society of his time and intends to show the inadequation of humans with reason. More particularly, during the fourth travel, Gulliver stays with the *Houyhnhnms*, which are “reasonable” animals ignoring contradiction and argumentation (chap. VIII) and whose language does not include any word for expressing lies, since saying something false would be betraying the functions of language (chap. III and IV). During the precedent travel, to *Laputa*, Gulliver visits the *Academy of Lagado* (chap. V) where he sees a machine that generates sentences for helping to write books.

The XVIIIth century is also marked by the automata built by Jacques Vaucanson (1709-1782), such as his Tambourine Player [92], or his Digesting Duck (1744). These automata are in some way echoing the mechanical view of man [54] supported by the philosopher Julien Offray de La Mettrie (1709-1751). These automata impress the minds. For instance, Mme de Genlis, born Stéphanie-Félicité Du Crest (1746-1830), in one her educative and moral tale [34] stages two child automata, one making drawings and the other playing music. The idea of an animated toy may fuel all the fantasies, as in the novel *Pigmalion* [11] d’André-François Boureau-Deslandes (1690-1757), or in the novel [41] by Jean Galli de Bibiena (1709-v.1779), where the narrator is fascinated by a doll found in a store and discovers later that it is a sylph! A bit later, in 1769, the Hungarian Johann Wolfgang van Kempelem (1734-1804), born in Slovakia, built an automaton, causing people to speak a lot of it, the Mechanical Turk or Automaton Chess Player, able to answer questions. This “Turk” has opponents as famous as Catherine II from Russia, Napoléon Bonaparte, or Benjamin Franklin. Resold at the death of van Kempelem, it had a long career, and it took time before discovering how a man could be hidden in the “machine”, but van Kempelem was in spite of that the author of a genuine vocal synthesizer (in 1791)! The chess player from van Kempelem has fascinated and inspired several novels in the next centuries.

Another famous opponent to this false automaton (against whom he lost two times) is Charles Babbage (1791-1891), who later in 1837, designed the first programmable computer (with punched cards) having a memory, the *Analytical Engine*, and for which Ada Lovelace (1815-1852) (the daughter of the poet George Byron) wrote the first programmed algorithm.

4 THE XIXth CENTURY: THE RISE OF MODERN LOGIC

The beginning of XIXth century is marked by the publication of some isolated works which may retrospectively appear as important milestones between the theory of syllogisms inherited from Aristotle and modern logic. Thus, Frédéric de Castillon (1747-1814) proposed a formal calculus for solving syllogisms [26, 27]. Independently in 1817, Joseph D. Gergonne (1771-1859), a French mathematician, mainly known as a geometer, starting from the idea of set diagrams introduced by Leonhard Euler (1707-1783) for visualizing syllogistic reasoning [37] ⁹ published an article [43, 45] where he identified the five possible relations between two sets, and characterized the valid

⁹ In fact these diagrams were already known by Leibniz, who saw them in the *Universalia Euclidea* (1661) by Johann Christoph Sturm (1635-1703) who was using circles for representing propositions (just as, later in 1712, Johann Joachim Lange (1670-1744)) [60]. Such diagrams were also, apparently, known from Juan Luis Vives (1493-1540) (in a treatise entitled *De Censura Veri*, part of his encyclopedic compendium *De Disciplinis Libri*, where he uses triangles for illustrating the syllogism in Barbara “Any B is a C, but any A is a B, therefore any A is a C”), and by Ramon Llull himself! [5].

sylogisms for the first time. A modern counterpart of this work can be found in [38]. Besides, Gergonne has also proposed polynomial regression, and was interested in the rule of three [42, 44]. Quite ironically, although he was a geometer, Gergonne emphasized, as early as 1813, the interest of algebraic methods in mathematics (algebra was at that time mainly restricted to operations on the reals) [24], but this is George Boole (1815-1864) who will be the first to apply this idea to logic.

The middle of the XIXth century is marked by the publication of the founding works of Boole and Augustus De Morgan (1806-1871) on the mathematisation of reasoning [9, 29]. Boole develops a symbolic view of logic, and an equational theory of deduction, based on the binary algebra named from him. It is quite noticeable that both Boole and De Morgan were interested both in logic and probabilities in their works, which enables them to have a renewed approach of syllogisms [10, 30]. Indeed logic and probabilities have a pretty much equal place in the celebrated book by Boole [10] *The Laws of Thought*. It should be also emphasized that studies on logic and the laws of thought had become a topic relatively popular at that time with the books of the archbishops Richard Whately (1787-1863) and William Thomson (1819-1890), and of the philosopher John Stuart Mill (1806-1873)¹⁰ [97, 90, 70], published before the first works of Boole and De Morgan on this topic. The final version, substantially expanded (which even includes an appendix on the logic in India) of the *Outline of The Laws of Thought* [91] by Thomson pays an homage to De Morgan in turn. Let us also note that Stuart Mill presents new views on induction in his book among other things, and proposes five qualitative inference rules for causal reasoning. In a more amusing style, Lewis Carroll (1832-1898), the author of *Alice's Adventures in Wonderland*, under his nom de plume, actually wrote a treatise of symbolic logic [14, 15, 12] (where he is using an original diagrammatic representation), with many exercises and problems presented in a funny way. The subtitle of his book was indeed “*A fascinating mental recreation for the young*”! Besides, under his patronymic name Charles L. Dodgson, Lewis Carroll had also refined a voting method due to Condorcet [33, 82] some twenty years before.

As a following of Boole's and De Morgan's works, the algebra of logic was developed by Ernst Schröder in Germany [84], Charles Sanders Peirce (1839-1914) [73, 74, 75, 76, 77] and his followers Oscar Howard Mitchell (1851-1889) [71] and Christine Ladd-Franklin (1847-1930) [55] in the United States, and in France [21] by Louis Couturat (1868-1914), who was also a great specialist of the logic of Leibniz. The Euler set diagrams were improved by John Venn (1834-1923) who shaded the empty parts of his diagrams rather than representing the sets in the exact configuration where they are supposed to be [94, 95], and by Peirce for taking into account existential statements and disjunctive information [87]. Besides, Venn in the multiple editions of his book *The Logic of Chance* also developed probabilistic aspects of reasoning, privileging the frequentist interpretation [93].

William Stanley Jevons (1835-1882), who wrote one of the most popular introductory text to Boolean logic in his time [51], also built a logic machine in 1869, called “*Logic Piano*”, based on a substitution principle [50], which was able to draw conclusions mechanically from premisses. In a quite different perspective, automata are built during the XIXth century. Let us mention the speaking head made by Joseph Faber (1800-1850) named “*Euphonia*”, able to articulate

words, the speaking doll of Thomas Edison (1847-1931) commercialized in 1889, the “*Steam-Men*” of the American Zadock Dederick in 1868 and of the canadian George Moore, which walked in 1893 at the speed of 8 km/h, and closer to us, the automaton by Leonardo Torres y Quevedo (1852-1936) which in 1914 was able to automatically play a king and rook endgame against king from any position; see [96] for a detailed description.

The beginning of the XXth century, regarding logic, is principally marked by the development of predicate logic, after the seminal works by Gottlob Frege (1848-1925), with the introduction of quantifiers (also (re)discovered independently by O. H. Mitchell, already cited [32]). A logical system is then thought both as a representation language, and a formal system for deduction [40, 46]. This has led to a series of very important developments which have primarily concerned the foundations of mathematics. Besides, multiple-valued logics also appear at the end of the XIXth century with the pioneering works of the Scottish logician, become French, Hugh MacColl (1837-1909) [81].

Lastly, let us also mention Gregorius Itelson (1852-1926), André Lalande (1867-1963) and Louis Couturat who discovered at the “IInd Congrès International de Philosophie” at Genève in 1904 [17] that they had independently coined the term “*logistique*” for designating the symbolic logic in its new algebraic and algorithmic developments, and decided to adopt this new name. The word “*logistique*” (logistics) in this sense is now completely forgotten and out-of-date, but it is not uninteresting to see that it has been in use until the 1960's by authors who place themselves in the perspective of *The Laws of Thought* of George Boole, and proposed treatises of operative logistics as the psychologist Jean Piaget (1896-1980), or the physicist Augustin Sesmat (1885-1957), or the philosopher and logician Robert Blanché (1898-1975) [78, 85, 8].

We stop here this overview of elements for a prehistory of AI. Then the development of mathematical logic, probability and decision theory, cybernetics, and the beginning of computer science in the first half of the XXth century will influence the future development of AI. But this last part of the “*prehistory*” of AI is rather well documented. The reader is referred to the references given in the introduction.

5 CONCLUSION

We have tried here to provide an image of AI rooted in a long tradition of research, and also to suggest the synergies that have been always at work along centuries between sciences, technology, and also the world of the imagination.

AI researchers should become more aware of the existence of their remote scientific and cultural roots. It is interesting to see how logic and probabilities were seen as complementary in attempts at modeling reasoning, at least until George Boole and Augustus De Morgan. More generally, it is also instructive to see the slow progression of ideas aiming towards the formalization of reasoning, starting from Thomas Hobbes.

Finally, it is interesting to note the significant roles of many “*forgotten*” names in the slow emergence of ideas and the development of tools that are at the heart of AI.

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¹⁰ Stuart Mill is perhaps better known as an economist, and a strong advocate of utilitarianism [88], following Jeremy Bentham (1748-1832), i.e. a consequentialist approach to decision making.

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