From the First Chess-Automaton to the Mars Pathfinder

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Abstract: This paper aims to highlight the relationship of Artificial Intelligence, the first Chessautomaton (The Turk), Computer Chess (Deep Blue), Mars Mission (Pathfinder Sojourner), Intelligent Robotics and Industrial Robots Biographical and technical data is presented in order to evaluate and laudate the extraordinary achievements of extreme talents, starting with two Hungarian world class innovators: Farkas Kempelen and Antal Bejczy. This paper gives an overview of their lives and contributions, pointing out some interesting connections. A novel evaluation and classification method of robots is suggested.

Keywords: Mars Rover; Pathfinder; Chess automaton

1 Introduction

There are many Hungarians, who had a major contribution in the most important inventions and scientific milestones of mankind. John von Neumann, József Galamb, Ányos Jedlik, Tódor Kármán, Leó Szilárd, Miksa Déri are only a few of the many famous Hungarian scientists and engineers, who played a major role in shaping our world's technology over the past two centuries. Robotics is a relatively narrow and young field of engineering and computer science. Still, it is inevitable to find the names of two Hungarian scientists in the fundamental work in this field: Antal Bejczy and Farkas Kempelen.

Farkas Kempelen was the first in the world, who constructed and demonstrated a chess playing machine that was human made, supposedly independent and automatic. However, while he claimed that he designed and made an intelligent robot, several decades passed until it was revealed that it was neither intelligent, nor a robot. It only acted like one and looked like one. The "robot" was called The Turk, a chess automaton, which won most of its games for about 85 years, between 1770 and 1854. It was only 16 years after the death of its creator, in 1820, when the truth about the machine: it was an illusion as there was no automaton, no thinking machine, but a small human in the box of The Turk. The human operator played chess and moved the figures and other parts of The Turk using magnets, mirrors and mechanical structures. Looking back, we can all agree that it wasn't the robot but Kempelen, who had the intelligence, and who made the world believe the unbelievable. Although today we know that cheating is forbidden, whether we discuss sports, exams, games etc., the concept of cheating may have been differently accepted 250 years ago among certain given circumstances.

Prof. Antal K. Bejczy passed away recently, after a 35-year-long career in the American space industry. He was best known for being one of the major contributors to the Sojourner, which was the first rover to land on the Mars, conducting experiments for 85 days in 1997 as part of the Pathfinder mission [1]. As a leader of the Advanced Teleoperation Laboratory at NASA Jet Propulsion Laboratory (JPL), his team provided the remote operation capabilities and control of the robot arm.

Robotics and automation have gone under a lot of development between the creation of the first chess "automaton" and the landing of the first rover on Mars. Definitions, properties and abilities of robots have developed over time. The goal of this paper is to evaluate, how these two machines fit in the concept of robotics that mankind has developed over the centuries. The steps of development will be illustrated on 5 more distinct, but corresponding robotic objects, which will be also implemented in the evaluation.

Antal (Tony) Bejczy was always interested in such discussions. During his career, he aimed to research the most modern problems, at the same time, he was always supporting new ideas. He had a good sense of humor to comprehend funny research ideas as well, such as the comparisons and evaluations we present in this paper. Honoring his memory in this issue, we believe that he would support our efforts and would await the results of this research with curiosity and sympathy.

2 Comparison Methods

In our, research, we focus on 4 mechanical, intelligent and robotic systems:

- The Turk (TAI)
- Pathfinder (PF)
- Deep Blue (DB)
- Industrial robots (IR)

In addition, three virtual robots well be investigated, derived from the first 3 cases, while an industrial welding robot will be taken as a reference. In the following listing, some of the most relevant properties of the investigated robots are listed, primary from the Artificial Intelligence (AI) point of view.

1) **TAI**: "The Turk" was considered a thinking, intelligent machine in 1770 [2]. Considering it as a machine, it had restricted communication capabilities with its environment, had knowledge of playing chess it a high level, and finally, it was equipped with tools and was capable of moving its head and hands, in order to grasp a chess figure with its fingers and to place it where it had to be placed. TAI was also capable of producing voice, even spoke words. Taking aside the fact that it was an illusion, a kind of cheating, it worked and won for about 85 years, with the help of a hidden human operator.
2) **TM**: Let us consider the mechanism of The Turk separately. It was a mechanical construction, without any intelligence, or actively actuated mechanism, thus it was not capable of moving any of its parts by itself. In its form, it can be referred to as a simple manipulator. It is important to note that as of our knowledge, it was never on the stage "as is", since the hidden person, the human operator was necessary to control its actions.
3) **PF**: The Pathfinder was a robotic spacecraft, carrying the first Mars rover, Sojourner to the Red Planet, in which Tony Bejczy's team played a major role. It was capable of moving to any direction, avoided obstacles, took pictures, exchanged information with the control room, picked up and analyzed Martian terrain, etc.
4) **PFx**: Let us consider a virtual robot, which would be similar to the Pathfinder, as it could have been extended and equipped with more sensors and actuators, capable of carrying out further tasks, such as state-of-the-art visual system, robotic arms, data analyzers, etc.
5) **DB**: Deep Blue is one of the first successful chess computers, which defeated Garry Kasparov, the chess world champion, in 1997 [3]. 20 years ago, this was an important milestone of artificial intelligence research. Its early success lie in the appropriately increased speed and memory of the computers, aided with sophisticated AI programs with multiple optimizations.

6) **DBx**: Let us consider the virtual expansion of the DB, which would resemble on a real robot, just like TAI. DB would be equipped with cameras, wheels, actuators, robotic arms, etc. It would be capable of walking, swimming, but most importantly, it would play chess without human assistance. In this case, DBx would become an intelligent autonomously moving robot. Deep Blue did not need to smile or to move its hands, but one can assume that being capable of implementing this level of knowledge in chess, all these functions could be easily implemented by today’s technologies.
7) **IR**: Let us take a welding robot in an assembly line as reference. We composed all its knowledge from 10 different robot definitions and 50 random characteristics of robots collected from the literature.

2.1 The Relationship of the Selected Robots

The Pathfinder **(**PF) was a live demonstration of human knowledge of artificial intelligence, robotics and telecommunications, measurement techniques and numerous other disciplines. It is for the sake of the game that we added a virtual extension to it to get a more advanced (virtual) robot, PFx. In this study, we use the name TAI instead of Turk to denote the intelligent illusion.

The chess-winner machine from 1770 naturally calls for a real chess-winner computer of our era, which points to the chess-computer Deep Blue, created by IBM (DB). DB could have been extended or upgraded to a more complex, more general, actuated robot from its chess machine status, technically in a relatively easy way. This virtual machine will be called DBx.

We decided to compare the above mentioned devices as robots, therefore it is a logical step to involve a real, “reference” robot (IR) as well [4]. This reference robot was chosen to be a general industrial welding robot, one of the most widely used manufacturing robotic system in today’s industry.

The list contains 7 objects. 2 of them (PFx and DBx) are virtual extensions created by our imagination, TAI is an illusion, a hoax, and TM is derived from that illusion. Let us consider the case when we remove the illusion, the derived machine (TAI and TM) and the two extended, virtual machines (DBx and PFx) from the comparison. The 3 remaining robots would be PF, DB and IR.

One can see that only the industrial robot (IR) is a “Traditional” one, if we consider the concept of robotics that is commonly used today. DB and PF are rather specific and goal-oriented, in some aspects “perfect” for their task. DB performed the highest level of AI, using many software resources to play chess, and PF was perfect in tracing, moving (at the speed of max. 40 cm/min), obstacle avoiding, collecting materials, performing measurements and taking photos on the Mars surface, processing and sending/receiving information.

It is expected that the two corresponding upgrades (DBx and PFx) would get the highest marks in any evaluation and comparison. Before we draw any conclusions, let us not forget that these robots were, at a theoretical level, removed from the competition; so to say, they could only become virtual champions. The real competitors are only IR, PF and DB, and in spite of the high performance of TAI, it should be excluded because of cheating. However, for the sake of completeness, all robots will be included in the evaluation.

It is an interesting coincidence that Deep Blue won against the active word champion, Garry Kasparov the same year, when the successful Mars Mission of the Pathfinder was completed. In the past 20 years, more powerful chess computers and better Mars rovers were developed, and this development goes on, which is not part of discussion of this work.

3 The Game of Chess

3.1 Human Versus Human

"Chess is a two-player board game played on a chessboard, a checkered game-board with 64 squares arranged in an eight-by-eight grid. Each player begins the game with 16 pieces: one king, one queen, two rooks, two knights, two bishops, and eight pawns. Each of the six piece types moves differently.

Chess is believed to have originated in India, sometime before the 7th Century; the Indian game of *chaturanga* is also the likely ancestor of *xiangqi* and *shogi*. The pieces took on their current powers in Spain in the late 15th Century and the rules were finally standardized in the 19th Century. The first generally recognized World Chess Champion, Wilhelm Steinitz, claimed his title in 1886. The current World Champion is the Norwegian Magnus Carlsen.

The game structure and nature of chess is related to several combinatorial and topological problems. In 1913, Ernst Zermelo used chess as a basis for his theory of game strategies, which is considered one of the predecessors of game theory.

The number of legal positions in chess is estimated to be between 10^{43} and 10^{47} (a provable upper bound), with a game-tree complexity of approximately 10^{123}. This was first calculated by Claude Shannon as 10^{120}, a number known as the Shannon number. An average position has thirty to forty possible moves, but there may be as few as zero (in the case of checkmate or stalemate) or as many as 218.

The most important challenge of chess is the development of algorithms that can play chess. The idea of creating a chess-playing machine dates to the 18th Century; this was the time, when the chess-playing automaton called The Turk became famous before being exposed as a hoax. Before the development of digital computing, serious trials based on automata such as El Ajedrecista of 1912, were too complex and limited to be useful for playing full games of chess.

Since the advent of the digital computer in the 1950s, chess enthusiasts, computer engineers and computer scientists have built, with increasing degrees of seriousness and success, chess-playing machines and computer programs. Since the 1990s, computer analysis has contributed significantly to chess theory, particularly in the endgame. The challenges were magnified by Shannon and others with the huge numbers, and Shannon's paper of 1950: "Programming a Computer for Playing Chess". He wrote: "the discrete structure of chess fits well into the digital nature of modern computers" [5]."[1]

3.2 Computer versus Human

"Most players agree that looking at least five moves ahead (five plies) is required to play well. Normal tournament rules give each player an average of three minutes per move. On average there are more than 30 legal moves per chess position, so a computer must examine a quadrillion (10^{15}) possibilities to look ahead ten plies (five full moves). Examining a million positions a second would require more than 30 years. After the discovering refutation screening – the application of alpha-beta pruning to optimizing move evaluation – in 1957, some experts predicted that a computer would defeat the world human champion by 1967 [6].

In the late 1970s chess programs suddenly began defeating top human players. The real breakthrough was in 1980, when Belle (Bell Lab.) began defeating masters. By 1982, two programs played at master level and three were slightly weaker. The sudden improvement without a theoretical breakthrough surprised humans, who did not expect that Belle's ability to examine 100,000 positions a second – about eight plies – would be sufficient. By 1982, microcomputer chess programs could evaluate up to 1,500 moves a second. However, in 1989, Garry Kasparov demonstrated that Deep Thought was still considerably below World Championship Level."[2]

4 The Protagonists of the Game

In our performance study, there are three types of equally important aspects: description of things of interest, robots and people around the robots. We concentrate on facts and technical data, which are interesting enough, sometimes hard to collect, but worthy of study.

1 https://en.wikipedia.org/wiki/Chess
2 https://en.wikipedia.org/wiki/Computer_chess

4.1 An Average Industrial Robot (IR)

"An industrial robot is defined by ISO 8373 as "automatically controlled, reprogrammable, multipurpose manipulator programmable in three or more axes" [7]. There are 10 other definitions listed in this paper, although it would be hard to collect all existing descriptions from the literature. As these definitions are quite similar in terms of technical details, we could use almost any of them. Typical applications of robots include welding, painting, assembly, pick and place (such as packaging, palletizing and SMT), product inspection, and testing; all accomplished with high endurance, speed, and precision.

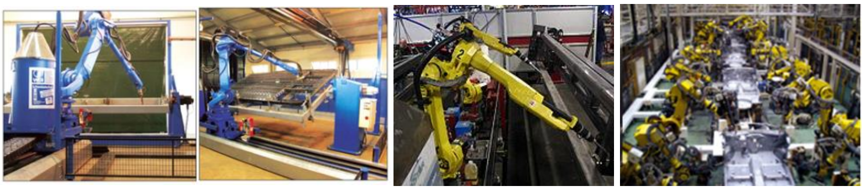

Figure 1
Different types of welding robots

Commonly used robot configurations are articulated robots, SCARA robots, delta robots and Cartesian coordinate robots, (gantry robots or x-y-z robots). In the context of general robotics, most types of robot would fall into the category of robotic arms."[3] The most important parameters or simply information and data worth to know about a given robot, or a class of given robots:

- Degree of autonomy
- Intelligence, adaptivity, flexibility
- Number of axes, Degrees of Freedom — these are usually the same
- Kinematics
- Carrying capacity or payload
- Speed — Acceleration — Accuracy — Repeatability
- Power source: electric motors and/or hydraulic actuators
- Motion control
- Drive (gears, direct drive, harmonic drive)
- Compliance
- Etc.tc.

If we did not have the 10 to 50 aspects, listed in the Appendix, we would have to match all other robots to the actual real one and in strength of the above given qualities.

[3] https://en.wikipedia.org/wiki/Industrial_robot

4.2 Short CV of Deep Blue (Chess Computer)

Figure 2
Deep blue playing Gary Kasparov in 1997

“Development for Deep Blue of IBM began in 1985 at Carnegie Mellon University. After some name changes (for example Deep Thought), in 1989 it became Deep Blue again, and in 1995 held the name “Deep Blue prototype”. It won a second place on the 8^{Th} World Computer Chess Championship with this name in 1995.

Deep Blue's evaluation function was initially written in a generalized form, with many to-be-determined parameters. The optimal values for these parameters were then determined by the system itself, by analyzing thousands of master games. The evaluation function had been split into 8,000 parts, many of them designed for special positions. In the opening book there were over 4,000 positions and 700,000 grandmaster games. The endgame database contained many six piece endgames and five or fewer piece positions.”[4]

Deep Blue was not the first “Deep” chess computer, which Kasparov met. For example, in 1989, he proved in two strong wins that Deep Thought was still far below World Championship Level. The Deep Blue era started in February 1996 and ended in May 1997, almost 20 years ago.

Deep Blue won its first game against a world champion on February 10, 1996, when it defeated Garry Kasparov in game one of a six-game match. However, Kasparov won three and drew two of the following five games, defeating Deep Blue by a score of 4–2.

4 https://en.wikipedia.org/wiki/Deep_Blue_(chess_computer)

“Deep Blue was then heavily upgraded, the chess knowledge of the program was fine-tuned (unofficially nicknamed "Deeper Blue"), and played Kasparov again in May 1997. Deep Blue won the rematch 3½–2½ by winning the deciding game six after Kasparov made a mistake in the opening. Deep Blue became the first computer system to defeat a reigning world champion in a match under standard chess tournament time controls.

The system derived its playing strength mainly out of brute force computing power. It was a massively parallel, RS/6000 SP Thin P2SC-based system with 30 nodes, with each node containing a 120 MHz P2SC microprocessor, enhanced with 480 special purpose VLSI chess chips. Its chess playing program was written in C and ran under the AIX operating system. It was capable of evaluating 200 million positions per second, twice as fast as the 1996 version. In June 1997, Deep Blue was the 259th most powerful supercomputer according to the TOP500 list, achieving 11.38 GFLOPS on the High-Performance LINPACK benchmark.

Kasparov accused IBM of cheating and demanded a rematch. IBM refused and retired Deep Blue. Writer Nate Silver suggests that a bug in Deep Blue's software led to a seemingly random move (the 44th in the first game) which Kasparov misattributed to "superior intelligence". Subsequently, Kasparov experienced a drop in performance due to anxiety in the following game.” [5]

The numbers defining computer capacities and speeds are steadily increasing as well as computation methodologies as distributed, using grid and cloud computing, etc. We have the feeling that algorithmic changes have to happen soon in computer-chess.

4.3 The Turk, the Chess-Automaton of Kempelen

The idea of creating a chess-playing machine dates back to the eighteenth century [8]. Around 1769, the chess playing automaton called The Turk became famous before being exposed as a hoax (Farkas Kempelen).

“The Turk, also known as the Mechanical Turk or Automaton Chess Player (German: *Schachtürke*, "chess Turk" Hungarian: *A Török*), was a fake chess-playing machine constructed in the late 18th Century. From 1770 until its destruction by fire in 1854 it was exhibited by various owners as an automaton, though it was exposed in the early 1820s as an elaborate hoax. Constructed and unveiled in 1770 by Wolfgang von Kempelen (Hungarian: Kempelen Farkas; 1734-1804) to impress the Empress Maria Theresa of Austria, the mechanism appeared to be able to play a strong game of chess against a human opponent.

The Turk was in fact a mechanical illusion that allowed a human chess master hiding inside to operate the machine. With a skilled operator, The Turk won most of the games played during its demonstrations around Europe and the Americas

[5] http://www.chess.com/blog/ramin18/deep-blue-chess-computer

for nearly 84 years, playing and defeating many challengers including statesmen such as Napoleon Bonaparte and Benjamin Franklin."[6]

According to certain resources, Kempelen found the first very small (dwarf) chess-genie in a dirty pub somewhere in Italy, where he was playing chess for making money. He was escaped from the jail where he was imprisoned due to the major crimes he had committed. Kempelen went to the jail and "purchased freedom" for the mini-champion. When Kempelen was travelling with The Turk, the small man had to be either in the machine or in his hotel room. Which, resulted in tension and several relationship problems between them.

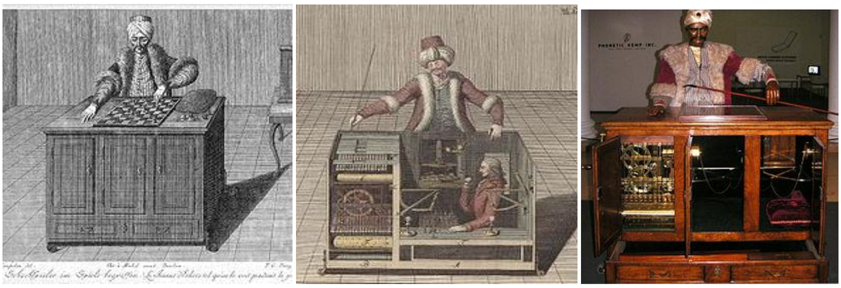

Figure 3
Left to right: Schematic representation of The Turk form the 18th Century, a fantasy image of its interior and the reconstructed machine

"The Turk made its debut in 1770 at Schönbrunn Palace. The machine consisted of a life-sized model of a human head and torso, with a black beard and grey eyes, and dressed in Turkish robes and a turban. Its left arm held a long Turkish smoking pipe while at rest, while its right lay on the top of a large cabinet that measured about three-and-a-half feet (110 cm) long, two feet (60 cm) wide, and two-and-a-half feet (75 cm) high. Placed on the top of the cabinet was a chessboard, which measured eighteen inches square (~11x11 cm). The front of the cabinet consisted of three doors, an opening, and a drawer, which could be opened to reveal a red and white ivory chess set.

The interior of the machine was very complicated and designed to mislead those who observed it. When opened on the left, the front doors of the cabinet exposed a number of gears and cogs similar to clockwork. The section was designed so that if the back doors of the cabinet were open at the same time one could see through the machine. The other side of the cabinet did not house machinery; instead it contained a red cushion and some removable parts, as well as brass structures. This area was also designed to provide a clear line of vision through the machine. Underneath the robes of The Turkish model, two other doors were hidden. These also exposed clockwork machinery and provided a similarly unobstructed view

6 https://en.wikipedia.org/wiki/The_Turk

through the machine. The design allowed the presenter of the machine to open every available door to the public, to maintain the illusion.

Neither the clockwork visible to the left side of the machine nor the drawer that housed the chess set extended fully to the rear of the cabinet; they instead went only one third of the way. A sliding seat was also installed, allowing the director inside to slide from place to place and thus evade observation as the presenter opened various doors. The sliding of the seat caused dummy machinery to slide into its place to further conceal the person inside the cabinet.

The chessboard on the top of the cabinet was thin enough to allow for a magnetic linkage. Each piece in the chess set had a small, strong magnet attached to its base, and when they were placed on the board the pieces would attract a magnet attached to a string under their specific places on the board. This allowed the director inside the machine to see which pieces moved where on the chess board. The bottom of the chessboard had corresponding numbers, 1-64, allowing the director to see which places on the board were affected by a player's move. The internal magnets were positioned in a way that outside magnetic forces did not influence them, and Kempelen would often allow a large magnet to sit at the side of the board in an attempt to show that the machine was not influenced by magnetism. The authors of this paper suppose that some mirrors were involved as well to inform the operator about the board positions and about the people around the machine.

The interior also contained a pegboard chess board connected to a pantograph-style series of levers that controlled the model's left arm. The metal pointer on the pantograph moved over the interior chessboard, and would simultaneously move the arm of The Turk over the chessboard on the cabinet. The range of motion allowed the director to move The Turk's arm up and down, and turning the lever would open and close The Turk's hand, allowing it to grasp the pieces on the board.

The pantograph was one of the secret parts of The Turk, and as long as people believed in the automatic behavior of the chess machine it could have been taken as an intelligent robot with chess playing knowledge, with arm, drives, joints, gripper and a controller. Even when it became clear that no automatic behavior is present, the pantograph-like system could still be taken at least as a manipulator from 1770. As such, it is a robot for us, worth dealing with.

All of this was made visible to the director by using a simple candle, which had a ventilation system through the model. Other parts of the machinery allowed for a clockwork-type sound to be played when The Turk made a move, further adding to the machinery illusion, and for The Turk to make various facial expressions. A voice box was added some years later, allowing the machine to say "Échec!" (French for "check") during matches.

An operator inside the machine also had tools to assist in communicating with the presenter outside. Two brass discs equipped with numbers were positioned opposite each other on the inside and outside of the cabinet. A rod could rotate the discs to the desired number, which acted as a code between the two.

The Turk could nod twice if it threatened its opponent's queen, and three times upon placing the king in check. If an opponent made an illegal move, The Turk would shake its head, move the piece back and make its own move, thus forcing a forfeit of its opponent's move. The Turk also had the ability to converse with spectators using a letter board. The director, whose identity during the period when Kempelen presented the machine at Schönbrunn Palace is unknown, was able to do this in English, French, and German."[7]

4.4 The Short Story of the Pathfinder

"Sojourner was the Mars Pathfinder robotic Mars rover that landed on July 4, 1997 and explored Mars for around three months. It had front and rear cameras and hardware to conduct several scientific experiments. Designed for a mission lasting 7 sols (7x24 hours), with possible extension to 30 sols, it was in fact active for 83 sols. The base station had its last communication session with Earth at 3: a.m. Pacific Daylight Time on September 27, 1997. The rover needed the base station to communicate with Earth, despite still functioning at the time communications ended.

Sojourner traveled a distance of just over 100 meters (330 ft.) by the time communication was lost. It was instructed to stay stationary until October 5, 1997 (sol 91) and then drive around the lander.

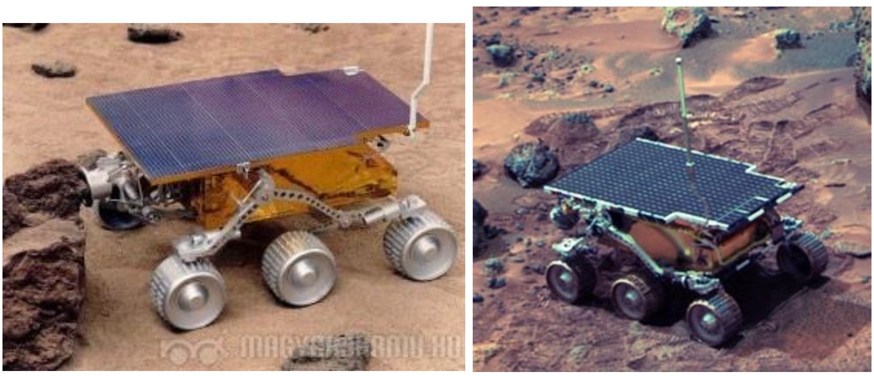

Figure 4
The Sojourner microrover

[7] https://en.wikipedia.org/wiki/The_Turk

The rover's name, *Sojourner*, means "traveler", however its name was selected after the name of a famous abolitionist and women's rights activist Sojourner Truth. The rover was also known as *Microrover Flight Experiment* abbreviated MFEX.

Sojourner has solar panels and a non-rechargeable battery, which allowed limited nocturnal operations. Once the batteries were depleted, it could only operate during the day. The batteries are lithium-thionyl chloride (LiSOCl2) and could provide 150 watt-hours. The batteries also allowed the health of the rover to be checked while enclosed in the cruise stage while en route to Mars.

0.22 square meters of solar cells could produce a maximum of about 15 watts on Mars, depending on the conditions. The cells were GaAs/Ge (Gallium Arsenide/Germanium) and capable of about 18 percent efficiency. They could survive down to about -140° Celsius (-220 °F).

Its central processing unit (CPU) is an 80C85 with a 2 MHz clock, addressing 64 Kbytes of memory. It has four memory stores; the previously mentioned 64 Kbytes of RAM (made by IBM) for the main processor, 16 Kbytes of radiation-hardened PROM (made by Harris), 176 Kbytes of non-volatile storage (made by Seeq Technology), and 512 Kbytes of temporary data storage (made by Micron). The electronics were housed inside the *Warm Electronics Box* inside the rover.

It communicated with the base station with 9,600 baud radio modems. The practical rate was closer to 2,600 baud with a theoretical range of about half a kilometer. The rover could travel out of range of the lander, but its software would need to be changed to that mode. Under normal driving, it would periodically send a "heartbeat" message to the lander. The UHF radio modems worked similar to walkie-talkies, but sent data, not voice. It could send or receive, but not both at same time, which is known as half-duplex. The data was communicated in bursts of 2 kilobytes.

The Alpha Proton X-ray Spectrometer (APXS) is nearly identical to the one on Mars 96, and was a collaboration between the Max Planck Institute for Solar System Research in Lindau, Germany (formally known as the Max Planck Institute For Aeronomy) and the University of Chicago in the United States. APXS could determine elemental composition of Mars rocks and dust, except for hydrogen. It works by exposing a sample to alpha particles, then measuring the energies of emitted protons, X-rays, and backscattered alpha particles.

The rover had three cameras: 2 monochrome cameras in front, and a color camera in the rear.[12] Each front camera had an array 484 pixels high by 768 wide. The optics consisted of a window, lens, and field flattener. The window was made of sapphire, while the lens objective and flattener were made of zinc selenide. The rover was imaged on Mars by the base station's IMP camera system, which also helped determine where the rover should go.

Sojourner operation was supported by *Rover Control Software*, which ran on a Silicon Graphics Onyx2 computer back on Earth, and allowed command sequences to be generated using a graphical interface. The rover driver would wear 3D goggles supplied with imagery from the base station and move a virtual model with the spaceball controller, a specialized joystick. The control software allowed the rover and surrounding terrain to be viewed from any angle or position, supporting the study of terrain features, placing waypoints, or doing virtual flyovers.

The rover had a mass of 11.5 kg (weighing about 25 pounds on Earth), which equates to a weight of 4.5 kg (10 pounds) on Mars."[8]

5 Evaluation and Comparison Methods

In the previous Section, all the machines/robots of concern were explained in detail. In order to compare their performance, several definitions, properties and abilities have been collected in Table III. Table III, contains important information of 7 objects, which represent real robots and virtual robots.

D stands for robot definitions (1-10), P means properties (1-30) and A denotes abilities (1-20). $W_i, i = 1\ldots 10$ are weights corresponding to the D values (1-10), while $V_j,\ j = 1\ldots 50$ are the weights corresponding to P and A values.

In order to fine-tune the evaluations, marks were attached to every line according to their importance. Definitions were marked as very important in this approach, therefore the corresponding weights were assigned the maximum value of 10. Other secondary features, such as properties and abilities were given the weight of 5. Those features, which have little importance in the evaluation, have been assigned the value of 1. The evaluation was done by adding all numbers of the weights W for D1-D10, V for P1-P30 and for A1-A20, where there is a *yes* in the object's column. These sums will define the ranking of the robots to be compared.

5.2 Numerical Results

The creation of the Table III. was done by collecting data from different sources. However, it is not a trivial task to find properties that would match with all the 7 objects due to their diversity. And after several attempts to find appropriate weight values and proper *yes* and *no* answers (y, n) in Table III., several calculations have been carried out, then the weighting factors were adjusted in order to match a real ranking.

[8] https://en.wikipedia.org/wiki/Sojourner_(rover)

5.1.1 The Question of Yes/No Answers

If all weight factors W_i would be 10 and V_j would be 5, the theoretical maximum values would be the same for each object.

$$M_{max} = 10\times10+(30+20)\times5 = 100+250 = 350 \quad (1)$$

Keeping the values of W_i and V_j according to this setting, the weighted score for competitors was collected in Table I.

Table I
Ranking of the competitors using maximum the maximum weight values

	TAI	TM	DB	DBx	IR	PF	PFx
D:W1-W10	8	0	7	8	7	5	8
F: V1-V50	25	9	22	35	20	37	40
10xD+5xF	205	45	180	250	170	235	280

If there are only *yes* answers in the boxes of a column in Table III, the object in the column cannot be beaten, as it gets the maximum evaluation value. Consequently, the number of *yes* answers in a column has decisive role. However, let us suppose that there are only *yes* answers in the D1-D10 positions and all others in P and A are *no*. Let the W_i values be (10,10,10,1,1,1,1,1,1,1), respectively. If an object gets 10 points only 3 times (e.g. D1-D3), and another one gets 1 points 7 times (e.g. D4-D10), the one with 3 *yes* values (30) will beat the other one with 7 yes values (7). If Table III would get arbitrary W_i and V_j values, other conclusions could be drawn, but normally there is technical content that defines these weights.

In order to address the question of determining the final weights, the following problem can be formulated:

Given the weight factors W_i for D1-D10, V_j for P1-P30 and A1-A20, i.e. V1-V50, it is required to find values W_i and V_j, for which the final ranking is the same as the one resulting from Table I, for the case of $W_i = 10$ and $V_j = 5$.

In order to solve this problem, there is no need to use both W_i and V_j, as it is only their relation to each other that has a direct effect on the results. Let this relation be $x = W/V$, assuming that $W_i = W$ and $V_i = V$.

Let us take the original results for $W = 10$ and $V = 5$:

$$M(PFx) \ge M(DBx) \ge M(PF) \ge M(TAI) \ge M(DB) \ge M(IR) \ge M(TM)$$

We use the following program written in Wolfram Mathematica:
wmin = 0
wmax = 10

Reduce [8 x + 40 >= 8 x + 35 >= 5 x + 37 >= 8 x + 25 >=7 x + 22 >= 7 x + 20 >= 0 x + 9 && Wmin <= x <= Wmax, x]

The result of the calculation is:

$$\frac{2}{3} \leq x \leq 4 \tag{1}$$

This means that if $2/3V \leq W \leq 4V$, then the given ranking survives. Similar calculations can be done for different weight values and for different other problems as well.

5.1.2 Ordering as Function of the Weight Parameters

The maximum points reachable in theory, if we assign 10 points to each W_i, is 350. Let us consider the following robot types:

$\mathrm{R} = \{\mathrm{PFx}, \mathrm{DBx}, \mathrm{PF}, \mathrm{TAI}, \mathrm{IR}, \mathrm{DB}, \mathrm{TM}\}$.

Let W be the weight for definitions (rows 3-13 of Table III) and V be the weight for properties and abilities (rows 17-71 of Table III). The score of each robot type is $\mathrm{M(r)} = \mathrm{n_1(r)W} + \mathrm{n_2(r)V}$, where $\mathrm{n_1(r)}$ is the number of *yes* answers for robot type r among definitions and $\mathrm{n_2(r)}$ is the number of *yes* answers among properties and abilities of robot type r. Each pair of weights (W, V) results in some descending order among robot types according to their weights $\mathrm{M(r)}$, e.g. if $\mathrm{W} = 10$ and $\mathrm{V} = 5$, the order is $\mathrm{M(PFx)} \geq \mathrm{F(DBx)} \geq \mathrm{B(PF)} \geq \mathrm{Fx(TAI)} \geq \mathrm{A(IR)} \geq \mathrm{R(DB)} \geq \mathrm{BIhe}$.

There are $7! = 5040$ possible orders of 7 elements and for each rearrangement. In the following, we study the values of W and V that result in a predefined ranking. In other words for each permutation: $\phi: \overline{1,7} \leftrightarrow \mathrm{R}$ we find the constraints on the values of W and V such as

$$\forall i \in \overline{1,6} \quad \mathrm{n_1}(\phi(i))\mathrm{W} + \mathrm{n_2}(\phi(i))\mathrm{V} \geq \mathrm{n_1}(\phi(i+1))\mathrm{W} + \mathrm{n_2}(\phi(i+1))\mathrm{V}. \tag{3}$$

It is easy to see, that if V is not zero, and then each inequality from (3) may be divided by V and reduced to one-variable inequality

$$\forall i \in \overline{1,6} \quad \mathrm{n_1}(\phi(i))x + \mathrm{n_2}(\phi(i)) \geq \mathrm{n_1}(\phi(i+1))x + \mathrm{n_2}(\phi(i+1)), \tag{4}$$

where $x = W/V$. We suppose that $x \in [0, \infty)$ and find the values of x corresponding to all possible permutations; the permutations that cannot be attained by any values of *x* (vast majority) are omitted (see Table II).

Table II

Different orders of robot types according to their weights $M(r)$ depending on "relative definitions-properties weight" $x = W/V$

Order of robot types	Corresponding interval of $x = W/V$
[PFx, PF, DBx, TAI, DB, IR, TM]	[0, 2/3]
[PFx, DBx, PF, TAI, DB, IR, TM]	[2/3, 2]
[PFx, DBx, PF, TAI, IR, DB, TM]	[2, 10/3]
[PFx, DBx, TAI, PF, IR, DB, TM]	[10/3, 17/2]
[PFx, DBx, TAI, IR, PF, DB, TM]	[17/2, 15]
[PFx, DBx, TAI, IR, DB, PF, TM]	[15, ∞)

According to Table II, it is clear that the gold medal holders from the initial ranking (PFx and DBx) are on the first positions, regardless the values of the weights, while TM is taking the last place. In the mid-field however there are some interesting positions of the others, that would be worthy of further study.

Conclusions

In this paper, we began to look for famous robot experts of Hungarian ancestry, finding a connection between Farkas Kempelen and Tony Bejczy, the two most important of them. The chess automaton of Kempelen, The Turk directly led us to Kasparov and Deep Blue. This simple path gave us the chance to introduce the game of chess, and the miraculous machines Deep Blue, The Turk and Pathfinder. Virtual machines based on these systems were introduced.

The detailed explanation of the machines started with Pathfinder (PF) and The Turk (TAI). A general industrial welding robot (IR) was added to the list, serving a as a reference for further evaluation. The two virtual extensions were made using the two most successful items: the Pathfinder (PF → PFx) and the Deep Blue (DB → DBx), which resulted in two unbeatable robots in the proposed competition.

The final score: Virtual robots were disqualified from the competition for obvious reasons, while The Turk has been dropped out for cheating, as it were in any competition. The final score reads: Deep Blue: 9.5, Pathfinder: 9 ½. It is a tie, but if there were only one gold medal, in the authors' opinion, it would go to Bejczy and the Pathfinder, since DB is too specialized, and the PF to PFx transition would be much easier to achieve than the DB to DBx transition.

It is important to note that arbitrarily chosen weight values may strongly influence the results. The method presented in this article is suitable for solving this problem. The experiments with fine-tuning, which differentiate between qualities could completely change the final scores, led us to the conclusion that according to the scoring table, ranking possibilities can be well differentiated from each other, as well.

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Appendix

A1. Robot definitions

D1. The simplest correct definition: „A re-programmable Manipulator – the same machine can be used to solve different tasks, by simply changing its control program"

D2. Wikipedia "A robot is a mechanical or virtual intelligent agent which can perform tasks on its own, or with guidance. In practice a robot is usually an electro-mechanical machine which is guided by computer and electronic programming".

D3. Encyclopaedia Britannica, a sociological definition: “any automatically operated machine that replaces human effort, though it may not resemble human beings in appearance or perform functions in a humanlike manner”.

D4. Webopedia 2: “A program that runs automatically without human intervention. Typically, a robot is endowed with some artificial intelligence so that it can react to different situations it may encounter. Two common types of robots are *agents* and *spiders*.”

D5. Oxford 1: a machine that can perform a complicated series of tasks automatically

D6.Oxford 2 (especially in stories): „a machine that is made to look like a human and that can do some things that a human can do”

D7.Merriam-Webster a) „a machine that looks like a human being and performs various complex acts of a human being (as walking or talking)”;

D8. Merriam-Webster b):”a device that automatically performs complicated often repeti*tive tasks”;*

D9.Merriam-Webster c) „ a mechanism guided by automatic controls”.

D10.ISO 8373, “an actuated mechanism programmable in two or more axes (*directions used to specify the robot motion in a linear or rotary mode*) with a degree of autonomy, moving within its environment, to perform intended tasks”

A2. List of properties for comparison

Communication with the external world, programmable manipulator, activities similar to men, independent agent in the world, completely human made, autonomous, able to move with 3-7 degrees of freedom, complex, as works in the real world, hardware and sensors really work, AI tools, teleoperator CNC based, Generation 1 -moves, Generation 2 –sensors, Generation 3 -complex signal processing, Intelligence 0, Intelligence 1, Intelligence 2, mobile, collects and evaluates sensory input, solves complex problems, has legs, has wheels, obstacle avoidance, moving instructions what to recognize, autonomous, on the ground, energy, solar cells, fixed, extra robots, nano.

A3. A list of robot abilities for comparison

See, act, localize, compute, navigate, transport, manipulate, talk learn, observe, smell, cooperate, work, dialog, play, stimulate, fly, move, create, make reasoning.

A4. The Table containing all data to compare the 7 objects

Table III

Important data of the 7 competing objects against reference values

No.	W	**D No.xx (D1-D10)**	TAI	TM	DB	DB x	IR	PF	PFx
1		D1 see above	y	n	n	y	y	n	n
2		D2 see above	n	n	y	y	n	y	y
3		D3 see above	y	n	y	y	y	y	y
4		D4 see above	n	n	y	y	n	n	y
5		D5 see above	y	n	y	y	y	y	y
6		D6 see above	y	n	y	y	n	n	y
7		D7 see above	y	n	n	n	y	n	y
8		D8 see above	y	n	y	y	y	y	y
9		D9 see above	y	n	y	y	y	y	y
10		D10 see above	y	n	n	n	y	n	n
	P	**PROPERTIES (P1-P30)**							
1		activities similar to men	y	n	y	y	y	n	n
2		independent agent in the world	**n**	n	y	y	n	y	y
3		communication with the world	y	y	y	y	y	y	y
4		programmable manipulator	y	n	n	y	y	y	y
5		completely human made	y	y	y	y	y	y	y
6		autonomous	n	n	y	y	n	y	y
7		able to move with 3-7 DoF	n	n	n	y	y	y	y
8		works in the REAL world	y	y	y	y	y	y	y
9		hardware REALLY works	y	y	n	y	n	y	y
10		AI applications	n	n	y	y	y	y	y
11		teleoperator CNC based	n	n	n	y	y	y	y
12		generation 1 -moves	n	n	n	y	n	y	y
13		generation 2 -sensors	y	n	n	y	y	y	y
14		generation 3- complex signal proc.	y	n	y	y	y	y	y
15		intelligence 0	y	n	y	y	y	y	y
16		intelligence 1	y	n	y	y	n	y	y
17		intelligence 2	y	n	y	y	n	y	y
18		mobile	n	n	n	y	n	y	y
19		collects and evaluates sensory inp.	n	n	n	n	y	y	y
20		solves complex problems	y	n	y	y	y	y	y
21		has	n	n	n	n	n	n	n
22		has wheels	n	n	n	y	n	y	y
23		obstacle avoidance	n	n	n	n	n	y	y
24		moving instructions	n	n	n	n	n	y	y
25		on the ground	y	y	y	y	y	y	y
26		autonomous	y	n	n	y	n	y	y
27		energy, solar cells	n	n	n	n	n	y	y
28		fixed	y	y	y	n	y	n	n
29		extra robots	n	n	n	n	n	n	y
30		nano	n	n	n	n	n	n	n

	A	ABILITIES (A1-A20)							
1		see	y	n	n	y	n	y	y
2		act	y	y	y	y	n	y	y
3		localize	n	n	n	n	n	n	y
4		compute	y	n	y	y	y	y	y
5		navigate	n	n	n	y	n	y	y
6		transport	n	n	n	n	n	y	y
7		manipulate	y	y	n	n	y	y	y
8		talk	y	y	n	y	n	n	n
9		learn	y	n	y	y	n	y	y
10		observe	y	n	n	y	n	y	y
11		smell	n	n	n	n	n	n	n
12		cooperate	n	n	n	n	n	n	y
13		work	n	n	n	n	y	y	y
14		dialog	y	n	y	y	y	y	y
15		play	y	n	y	y	n	n	n
16		stimulate	n	n	y	y	n	n	n
17		fly	n	n	n	n	n	n	n
18		move	n	n	n	y	n	y	y
19		create	n	n	y	y	n	n	n
20		make reasoning	y	n	y	y	y	y	y