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ARTIFICIAL INTELLIGENCE AND ROBOTICS IN DIGITAL PRODUCTION AND BEYOND

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Abstract. The paper addresses some problems of Digital Production with special emphasis on the role of Artificial Intelligence and of Robotics. Digital Production (Digital Manufacturing) is the recently applied highest level of goods' making in industry. One of the synonyms of Digital Factory is Intelligent Manufacturing. It is clear that the majority of physical works are done by networked robots and computer controlled machine tools, and the control information for the robots and other automated machines are produced by computers with appropriate software, distributed via networks. To run an automated digital, intelligent factory, or workshop we need more intelligence than before to solve problems and make correct decisions, thus artificial intelligence is used in most programming solutions. Integration means having everything at hand. This is called Product Life-Cycle Management today, as all technical and management information on products and production systems are available all the time for all phases of their design and operation. The intelligence and artificial intelligence in some non-manufacturing applications will be discussed through such examples as chess playing computers and robots and an automated vehicle designed to working on the Mars.

Key words: Intelligence; Artificial Intelligence; Robotics Mars Rover; Pathfinder; Chess Automaton; Digital Production.

INTRODUCTION

Different definitions and different ways to reach Digital Production or Digital Manufacturing (DM or DP) will be discussed, including the development of intelligence and robotics and some other components, which are necessary to build up digital factories on one hand and some advantages are detailed, which are provided by digital manufacturing. Some outstanding intelligent and robotic applications assist to understand the way to digital manufacturing, what can be called Intelligent Manufacturing today. Some people use the expression manufacturing only for part production. Production is manufacturing and assembly, and more. Assembly is the process, when parts are put together to result in products. But even knowing this the two expressions (manufacturing and production) are generally used as synonyms. Production is a set of individual and social activities, utilizing (using) tools, machines, etc. and computers, networks, etc. and programs on different levels. Some simplified examples of work organization phases of the development of production, leading to DP [1, 2] are given below.

1. Nobody works, no tools, no machines: peace.
2. One worker, no machines.
3. Some workers, no machines.

4. One worker, one or more machines.
5. Some workers, some machines.
6. Workshop: several people, several machines.
7. Factory: several workshops.
8. Holons, Smart agents (cells, systems, workshops).
9. Hierarchical Factory, several levels.
10. Eqaul factories together – Heterarchy.
11. Network of Factories.
12. Extended factories – virtual factories.

A similarly simplified view shows a possible way of development to Digital Production taking into account computers, interfaces and programs, which should be integrated parts of the above given 7. to 12. points:

1. Just do it, 1a.No Computer, 1b.No design methods 1c. No Computer, design methods.
2. Computer, no use; 2a.Computer and programs, as: CAD, CAM, CAPP, CAQ….
3. Computer & MHI human interface – Interactive use: 3a. Next generations of CAxx.
4. Computer networks – Distributed Caxx; ISO OSI IGES STEP: interfaces.
5. Standard design methodologies, as CIM, IMS, MRP, ERP, ISO-OSI, MAP/TOP.

PRODUCT/ PRODUCTION DESIGN AND OPERATION

The design and operation of all elements of a DP facility are generally very hard, as the main features of the building blocks (e.g. FMS, FMC, CNC, RC) are:

a) big size, lot of software and hardware;
b) complex, complicated structure;
c) dynamical behavior;
d) nonlinear control, etc;
e) heuristical actions, surprises, no forecast events.

The problem is NP COMPLETE, which results in the fact that there is no appropriate mathematical apparatus to solve the problems of design and operation.There are no equations, such as for example (status, output) = f (input, status, time, etc.)
or differential equations, or matrix equations
no linear or quadratic assignments
there is nothing mathematically simply manageable,
But there are tools to help, as:
0. Simplifications, approximations
Modeling, Simulation of almost everything from simple processes to enterprises, high level modeling: CIM-OSA, GRAI/GIM, PERA, GERAM.
b) Application of AI tools and means
ES, ANN, FUZZY, Genetic Algorithms, Soft Computing, etc..
c) Design methodologies: SSADM, SADT OOA, OOSE, UML, RUP, etc.
d) Hybrid systems (AI –Traditional programs, AI – OO, AI-AI, etc.). The correct application of the appropriate tools will assist to get acceptable solutions.

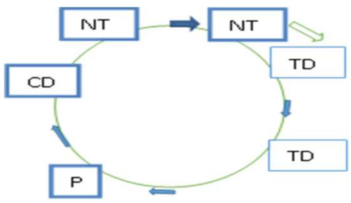
RECENT TRENDS IN PRODUCTION

The customers' demands are increasing faster than a normal programing environment could follow them. To better understand the need of having digital manufacturing the recent trends and changes in manufacturing should be taken into account, as:

– Beside mass and serial: one-of-a-kind production, mass customization of products.
– Further integration within CIM (e.g. process planning, scheduling, etc.).
– Time factor is more important (concurrent engineering, rapid and virtual prototyping, simulation).
– Quality is more emphasized (monitoring, diagnostics, ultra-precision machining, and quality management, TQM).
– Symbiosis of technical and business decisions (business process re-engineering, enterprise integration, management decision support systems are integrated.
– Globalization (world-wide distributed, networked, co-operative production).
– Sustainability and Sustainable development (green production, lean production, life-cycle engineering, assembly-disassembly, recycling).
– Instead of unmanned factory: human factors (education, organization, etc.).
– Miniaturization (submicron- nano-technologies, manufacturing, assembly).
– Application of AI techniques (intelligent manufacturing processes and systems).

DIGITAL PRODUCTION

There is a kind of a simplified ring structure (or spiral), which can be opened anywhere. The technical development (TD) increases the possibilities (P), these increase the demands of the customers (CD), and these request new production technologies, new methods, materials, organization, etc.(NT), which mean the technical development, in our recent case he DP [3, 4, 5].



TD – Technical Development
P – Possibilities
CD – Demands of the Customers
NT – New Methods, Materials, Organization
DP Digital Production

Fig. 1. Products-Production-Customer Requirements

Let us see some other expressions, which generally mean digital production:

Flexible Manufacturing Systems/Cells; Computer Integrated Manufacturing, Lean Manufacturing; Green Production; Smart Factory, Fractal Company [6], Intelligent Manufacturing Systems; Networked Manufacturing, Distributed Manufacturing; Extended Factory, Virtual Manufacturing, Cyber-Physical Production System;

The needs of a DP system – a minimal list:
the well known (and new) machine tools, robots and other equipment, machinery & Electronics and Computer Technology, hardware and software and organization: networks, interfaces, controllers, machine tools, robots, other equipment, design methods and tools, sensors, programming environments, languages, real-time manipulation, modeling, simulation, intelligence, philosophy, life-cycle management, virtual, extended enterprise, service, maintenance, ppp (private public partnership).

SOME APPROACHES TO DP

The german view**:** Germany is preparing the 4th industrial revolution (Industry 4.0) based on The Internet of Things, Cyber-Physical Production Systems, and the Internet of Services in Real Industry Industry 4.0 will be a combination of Smart-, Green- and Urban Production

The starting points are the 4 industrial revolutions:

1. End of 18th Century:	Mechanical production powered by water and steam
2. Start of 20th Century:	Mass production based on the division of labor; electrical energy
3. Start of 1970ies:	Introduction of electronics and IT; further atomization production
4. Today and near future	Cyber-physical production

EUROPEAN EFFORTS, INITIATIVES

There are several European Technology Platforms (ETP), and one of them is MANUFUTURE, which has 4 sub-programs:

1. Sustainable Manufacturing
3. Intelligent Manufacturing
2. Manufacturing processes for and with new materials
4. High Quality and high performance manufacturing

SZTAKI JOINT R&D EFFORTS WITH SEVERAL PARTNERS

In Hungary we got a chance to use the method of "to learn by experience" or "learning by doing it". Several partners were involved in the first partially government financed joint project on DF: 3 academic institutions, 3 SMEs and a real multinational firm.

Our approach leads to Digital Production (Digital Manufacturing) through Manufacturing Automation and Production Networks (PN).

We reached industrially applicable results to approach DP using multidisciplinary research and development of tools and techniques applicable for handling complex production systems working in an uncertain, changing environment, with special emphasis on artificial intelligence and machine learning approaches in the solutions. Our main topics were:

1. Telepresence and interactive multimedia
2. Monitoring of complex production structures
3. Large-scale project and production scheduling

DP SUMMARY: AN INTELLIGENT APPROACH TO PRODUCT AND PRODUCTION SYSTEMS

The recent, increased customer demands can be met only by the services of DP, and the evolution of production systems and the evolution of assisting hardware and software, which are used to build up DPs give some explanations. To support understanding 3 case studies were presented (Germany, EU, Hungary).

INTELLIGENT ROBOTICS AND MANUFACTURING

The application of intelligence in robotics and manufacturing are defined from different directions. For robotics the application of (new) sensors is involved, while for manufacturing new knowledge is requested. However the two definitions below could be explained to seem to be similar. Intelligent robotics is generally defined as the application of 3rd generation robots. These are the robots, which have external sensors (besides the traditional force and toque sensors) and feedbacks from the external sensors assist the robot in working. The most general is the application of different type of cameras and camera systems. The intelligence means more precise, better operation, if the programs, which are responsible for the intelligence are well done.

Intelligent manufacturing is defined as follows: "IMS are expected to solve within certain limits, unprecedented, unforeseen problems on the basis even of incomplete and imprecise information," Joe Hatvany and Nam SUH, 1983 Intelligent ManufacturingSystems is a worldwide co-operation to support and promote and to introduce intelligent manufacturing. It was initiated in 1992 with the with the main idea: „to unite mobile international industry, government and research resources to drive the co-operative development and spread of manufacturing technologies and systems in a global environment of change" (Hyroyuki Yoshikawa, 1992).

Several equally good simple definitions of DP can be constructed and quoted. Just one for example:

Let us have a production, which differs from most of the recently used ways, as it:

– takes into account the life-cycle of the products and the role of the workers;

– uses all up-to-date (and future) tools, means and technologies, materials;

– gets new products faster, which are more personalized:cheaper, better.

– operates without environment problems, uses less energy, materials, water.

Naturally, to design, implement and to operate such a system is rather difficult
As we use intelligence and artificial intelligence in the solution of all tasks, let us stop a little to speak about this hard to define issue. And let us take a look at non-computer intelligence as well through some achievements of the mankind, and give some hints on people, who gave definitions and explanationson intelligence.

Fig. 2. Ollantaytambo, Peru.

Fig. 3. Colossus, Rhodos

Fig. 4. Giza Pyramids, Egypt

SOME EXTREMELY INTELLIGENT CLASSICAL APPLICATIONS

Most ancient empires including Babylonians, Assyrians, the ancient Greeks and Romans, as well as the Egyptians were able to make robot-like mechanisms, for example toys, getting energy from water, and different fountain systems. Even some Indian folks, as Mayas, Incas, etc. had a kind of high level technical culture, which is partially unsolved even today. For example how the Egyptian or Maya pyramids were built, or how the huge (sometimes several tons of) blocks of granite blocks were elaborated (cut and polished) to join without a mm gap and how they were glued together without any kind of glue in the recent Peru by the Incas on a hill almost 3000 meters above see-level in without using wheels and draft animals, see Fig. 2. A completely different example is the 32 m high Colossus from 280 B.C., see Fig. 3., and see Figure 4. for the Pyramids of the ancient Egypt, built more than 4500 years ago, from left to right: Menkaure (Mykerinos) 66 m (2532–2503), Khafre (Kephren) 136 m, (2558–2562) Khufu (Kephren or Great Pyramid)143 m (2575–2566).The world is full of miracles and people always want to understand what and how happened in olden times, however there are only a few direct proofs, or written notes, or paintings or statues that help in understanding.

It is sure that to get unbelievable achievements, to build castles, cathedrals, monuments, dams, channels, mines, etc. extraordinary intelligence was necessary. And artificial intelligence was born when the appropriate computers appeared and were distributed.

INTELLIGENCE

Intelligence is something hard to define, hard to understand and hard to behave as an intelligent person. Definition: Intelligence has been defined in many different ways including one's capacity for logic, understanding, self-awareness, learning, emotional knowledge, memory, planning, creativity, adaptive behavior, problem solving and self-control. It can be more generally described as the ability to perceive information, and retain it as knowledge to be applied towards adaptive behaviors within an environment or context.

For this study: let us accept intelligence as a (human) ability or (feature, character), which is most important in understanding, learning, problem solving, finding the best ways and methods to reach the goals. The definitions of experts are often similar to our definition, sometimes are contradictory and often complement each other. Now we do not detail them. A short list of some people, who added a lot to intelligence and defined it. Some of the most recent (20th century) definitions opened the gates to AI.

Aristotele (384 BC–322 BC.); Henri Bergson (1859 – 1941); Elaine Rich (19…);

Martin A. Fischler and Oscar Firschein (SRI); F. Scott Fitzgerald (1896–1940);

Marvin Minsky (1927–); Allen Newell (1927–1992); E. L. Thorndike (1874–1949);

Robert Sternberg (1949–); D. Wechsler (1896–1981);

Alfred Binet (1857 – 1911) and Teophile Simon: Christofer F. Chabris (1966–).

MEASUREMENT OF INTELLIGENCE

To use of intelligence to define, to compare or to evaluate different achievements, it was necessary to categorize and measure intelligence. This is done mostly by using (IQ) tests. Some pioneers of measuring intelligence were:

Alfred Binet, Teophile Simon ; Sir Francis Galton (1822–1911), Lewis Terman (1877–1956); Willliam Stern (1871–1938);

James McKeehn Cattell (1860–1944) – he made the first IQ test in 1890, Louis Thurstone (1887–1955); Howard Gardner (1943–), S. Steinberg (1939–);

Aaron Sloman (1936–) defined the 3 key features of intelligence, as:

Intentionality; Flexibility and Productive Laziness. A litte past:

Al-Jazari, the great Arabic scientist of the 12th century wrote the book in 120: "Book of Knowledge of Ingenious Mechanical Devices" Abū al-'Iz Ibn Ismā'īl ibn al-Razāz al-Jazarī (1136–1206) (Arabic:) أَبُو اَلْعِزِ بْنُ إسْماعِيلِ بْنُ الرِّزاز الجزري**an Iraqi polymath: a scholar, inventor, mechanical engineer, craftsman, artist, mathematician and astronomer from Al-Jazira, Mesopotamia.)

Leonardo Da Vinci, the genius of the renaissance made the designs of several robot-like equipment in the 15th century

Farkas Kempelen of Hungary from the Austro-Hungarian Monarchy built an unbeatable chess-automaton, the secret of which was solved only 80 years after the death of the author. In the 18th century moving figures of people and of animals were common, all worked as manipulators, almost as robots, as well as the clockworks of Prague and Munich for example.

Fig. 5. Old Clockwork in Munich

Fig. 6. Old Clockwork in Pargue

We could continue with the wonders of the antique world and with the many wonders of other ages, incuding unbelieveíble constructions, machines , etc.

MODERN ROBOTICS

Now we make a great step and just mention that modern robotics started sometime in the mid-fifties of the 20th century in the USA by Joseph Engelberger and George Devon, who first used the expression robot defined as a reprogrammable manipulator. The origin of the word comes from Slavic languages and was used by the writer Karel Capek first. To make modern robots only two basic prerequisites were necessary:

– appropriate way of thinking – it is hard to define precisely;

– appropriate mechanics and electronics – it can be defined even by enumeration, here only some basic components of electronics are listed: computers, and computer networks, and sensors, cameras, etc. and finally artificial intelligence to make effective programming possible.

We shall see that Artificial Intelligence is often connected to robotics, or the statement is true that robotics is connected to AI, as they have similar goals: to copy or to substitute human in thinking (AI) and in acting (robots).

ARTIFICIAL INTELLIGENCE (AI)

The expression “Artificial Intelligence” (AI) was used first by John McCarthy (b. 1927) in 1956 at a famous Dartmouth College (USA) conference, and distribution of the expression is due to the paper of Marvin Minsky (1927 –) entitled “Steps towards artificial intelligence”.

DEFINITIONS OF AI

Some important names and some of their statements are the following:

– Cihan H. Dagli (using Barr&E. Feigenbaum) (born in 1936):

"Machine Intelligence emulates, human abilities, etc. ..”

– Aaron Sloman (1936 – ….):

"AI is a general research direction to deal with understanding/copying intelligence, etc..”

– Yoshiaki Shirai–Jun–ichi Tsujii (1949 – …):

"The goal is to use the computer to solve tasks, which need human intelligence, etc”

– Sántáné Tóth Edit:

„Development of intelligent applications, etc.”…

– Peter Jackson:

”To emulate cognitive behavior, etc. …..."

APPLICATION DOMAINS OF AI

It can be seen from several lists that AI is used in solving many different type of tasks, however we have to remind that it is not a general panacea, and that there are only a few completed solutions Most others are in experimental status.

Some application fields:

– logical games, theorem proving, automated programming;

– symbolic algebraic computation, vision, pattern recognition;
– obotics, voice recognition, natural language processing agents, multi-agents;
– constraint satisfaction, planning, design, artificial neural nets; data mining.

APPLIED METHODOLOGIES TO BUILD AI SYSTEMS

There are several tools, methods, programs, etc. to build AI systems. Some of them:
problem and knowledge representation, learning, uncertainty management, inference and search, evolutionary techniques, etc. Some names and results of ai developments, 1936 – 1977.

It is amazing to see how much happened during a relatively narrow time gap from the 1930th until 1997. Only some basic people and results' names are mentioned, as:

Turing, Neumann, ENIAC, McCarthy, Bernstein Chomsky, Feigenbaum Newell, Prolog, LISP, Mycin, PROSPECTOR, Vinograd, Deep Blue (the IBM computer wins against Garri Kaszparov, the chess world champion).

COMPARISON OF "VERY" INTELLIGENT ROBOTS

The selection of the robots to be compared. We start with Kempelen, who produced something miraculous, working like an intelligent robot in the 18th century, however it turned out to be a kind of a cheating, a hoax with recent words. It was the chess-automaton far before the computer age. And the idea was to try to find his and his robot's position (rank) among recent acheivements.

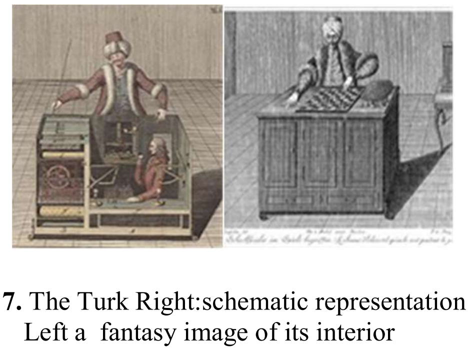


Fig. 7. The Turk Right:schematic representation
Left a fantasy image of its interior

Fig. 8. The Sojourner Micro rover

At the other end the MarsRover is a completely different machine, developed by Bejczy 20 years ago. It has the highest level of moving robotics equipped with several intelligent functions of artificial intelligence to solve extraordinary tasks.

As mentioned Artificial Intelligence cannot be avoided in modern robotics, however AI may exist without robotics as well.

The achievement of the IBM's Deep Blue computer has no specific robotic features, it played chess in a high, very, very high level. Still we claim that it could be a robot as well, similarly to Kempelen's machine.

And finally to have a normal value for comparisons we took an industrial robot, an average one with all its possibilities.

A few data on Kempelen and Bejczy

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 was published: 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 some parts of The Turk using magnets, mirrors and mechanical structures, like a pantograph among others. 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 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. 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 section is to evaluate, how these two machines fit in the concept of robotics that mankind has developed over the centuries. The reader will see how we added 5 more robots to have 7 elements in the summary table, Table II.

Comparisons, future evaluations. In our research, we focus on 4 intelligent (robotic) systems (upper 2 lines below), and in addition, 3 virtual robots are defined (lower 2 lines below) :

The Turk (TAI); Pathfinder (PF); Deep Blue (DB); Industrial robot (IR)

Turk nude (TM); Pathfinder extended (PFx); Deep Blue extended (DBx)

The 3 virtual robots were derived from the first 3, while an industrial welding robot will be taken as a reference. Next some of the most relevant properties of the investigated robots are listed, primarily from the Artificial Intelligence point of view.

1. TAI: "The Turk" was considered a thinking, intelligent machine in 1770 Considering it as a machine, it had restricted communication capabilities with its environment, had knowledge of playing chess in 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. It was an illusion, a kind of cheating, it generally won for about 85 years, having 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 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. 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. 20 years ago, this was an important milestone of AI research. Its early success lie in the appropriately increased speed and memory of the computers, and more sophisticated AI programs.

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.

7. R: Let us take a welding robot in an assembly line as reference [10]. We composed all its knowledge from 10 different robot definitions and 50 random characteristics of robots collected from the literature.

The relationship of the selected robots

The list contains 7 objects.

Fig. 9. Industrial robots – welding application

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 (TAI), the derived machine (TM) and the two extended, virtual machines (DBx and PFx) from the comparison. The 3 remaining robots to compare would be PF, DB and IR. However for being able to show our comparisons even the excluded competitors will be there in the game. At this point we should openly call this comparison experiment a game. The industrial robot (IR) is the only "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 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, processing and exchangingng information. It is expected that the two corresponding upgrades (DBx and PFx) would get the highest marks in any evaluation and comparison, but as they were removed from the competition; they could only become virtual champions. The real competitors are only IR, PF and DB.

THE GAME OF CHESS

Human versus human. "Chess is a two-player board game played on a chessboard, a with 64 squares arranged in an eight-by-eight grid. The number of legal positions in chess is estimated to be between 1043 and 1047 (a provable upper bound), with a game-tree complexity of approximately 10123. This was first calculated by Claude Shannon as 10120, 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. Computer versus human. 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 middle of the twentieth century, chess enthusiasts, computer engineers and computer scientists have built, with increasing degrees of seriousness and success, chess-playing machines and computer programs. The hallenges 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". 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 (1015) 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. 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."

And finally the IBM computer, Deep Blue won against Garri Kasparov, the chess world champion in 1977. The competing robots. 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. The real, non-virtual robots IR, TUI, DB and PF have some stories, the virtual ones (DBx, PFx and TM) have no story, they were invented by the author. 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".

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, or any set of them. The most important parameters or simply information and data worth to know about a given robot, or a class of given robots are supposed to be known by most readers. Deep Blue (DB -chess computer). "Development for Deep Blue of IBM began in 1985 and after some name changes in 1989 it became Deep Blue, and in 1995 held the name "Deep Blue prototype". It won a second place on the 8Th World Computer Chess Championship with this name in 1995. Deep Blue's evaluation function had been split into 8,000 parts, many of them designed for special positions.

Fig. 10. Deep blue playing Gary Kasparov in 1997

In the opening book there were over 4,000 positions and 700,000 grandmaster games. The end game database contained many six piece end games and five or fewer piece positions." on DeepBlue won its first game against a world champion 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 games, defeating Deep Blue by a score of 4–2. "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.

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.

THE TURK, CHESS-AUTOMATON OF KEMPELEN (TUI)

The idea of creating a chess-playing machine dates back to the eighteenth century. 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 around Europe and the Americas for nearly 84 most of the games played during its demonstrations years, playing and defeating many challengers including statesmen such as Napoleon Bonaparte and Benjamin Franklin."

THE PATHFINDER (PF)

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. *Sojourner* had solar panels and a non-rechargeable battery, which allowed limited nocturnal operations. 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 rover had three cameras: 2 monochrome cameras in front, and a color camera in the rear.[7] Each front camera had an array 484 pixels high by 768 wide. *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. 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."[1] Evaluations and comparisons. Some robot definitions (A1 - D), some selected properties (A2 - P) and some abilities (A3 - A) were taken into account for the comparisons. Below are the lists of them.

DIFFERENT ROBOT DEFINITIONS (D1-D10)

D1. The simplest 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. ncyclopaedia 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". A list of 30 properties for comparison. See Table I. lines P1 to P30 for the members of the list for a given robot, or a. class of given robots. A list of 20 robot abilities for comparison.

See Table I. lines A1 to A20 for the members of the list for a given robot, or a class of given robots.

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

Table 1. Important data of the 7 competing objects against reference values and each other
Some robot definitions (A1 - D), some selected properties (A2 - P) and some abilities (A3 - A)

No.	W	**D No.xx (D1-D10)**	TAI	TM	DB	DBx	IR	PF	PFx
1		D1 see definitions above in text	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 definitions above in text	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 definitions above in text	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 definitions above in text	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 robots	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

Table 2. Ranking of the competitors using 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

PRESENTATION OF SOME RESULTS

As a result we get Table II. with 10 & 30 & 20 (50) lines and 10 columns. The 10 columns have the following headlines: 1. serial number, 2.W for robot definition (1-10), P for Properties (1-30), A for abilities (1-20) and the 3. contains the description of the WPA columns, and finally the seven compared robots have one column each These will contain the presence or absence of the W, P and A values for the given robot. The Table contains all data to compare the 7 objects. However for the first calculations we left all W , P and A values blank (empty), then the corresponding yes or no (y, n) define whether the given robot corresponds to the definitions, has the properties and abilities or not. Generally speaking the more yes will mean a better score: If I know a lot (several y) is better than if I know a little (a few y). I this first step we had only y or n.

QUALIFICATION

In Table II.-D stands for robot definitions (1-10), P means properties (1-30) and A denotes abilities (1-20). $W_i, i = 1\ldots10$ are weights corresponding to the D values (1-10), while $V_j, j = 1\ldots50$ 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. These kind of comparisons are rather often used by engineers and economists, even if they know that due to the often arbitrary input data the results are not necessarily exact. Still good qualitative comparisons can be obtained.

NUMERICAL RESULTS

The creation of the Table I. 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 I., several calculations have been carried out, then the weighting factors were adjusted in order to match a real ranking. As the experiments are still running corresponding results will be published later on.

THE QUESTION OF YES/NO ANSWERS

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

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

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

If there are only *yes* answers in the boxes of a column in Table I, 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 point 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 I.

would get arbitrary W_i and V_j values, other conclusions could be drawn, but normally there is the technical content that defines these weights.

We stop evaluation at this point, knowing that there are tools and means in literature to make more exact comparisons. This might be the topic of a next study, where the objects to be compared will be more practical than these ones were. Here we emphasized some extreme robots and their stories.

CONCLUSION

In this paper, some approaches, and some features of the so called Digital Manufacturing (Digital Production, CIM, etc.) was discussed. DPs are the highest quality and most sophisticated manufacturing systems today. It is clear that most physical work in a DP is performed by robots, recently by intelligent robots. We concluded rather fast that in all parts and from all points of view it is the intelligence of the systems and of the designers and people around the system, what define the quality and power of a DP. Intelligence and Artificial Intelligence are equally important, thus the second part of the paper is devoted to comparison of intelligent robots of different kind, accepting robot-like machines in a a broad sense as robots. Relationships were found between the Mars rover of Prof Bejczy end 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.

Comparisons of the 4 real and 3 virtual robots were based on several features and abilities, and turned to a kind of 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 suggested 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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МЕТАДАННЫЕ

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Аннотация. В статье рассматриваются проблемы цифрового производства с акцентом на роль искусственного интеллекта и робототехники. Цифровое производство (Digital Manufacturing) – уровень производства товаров в промышленности. Один из синонимов Digital Factory - Интеллектуальное производство. Большинство физических работ выполняется подключенными к сети роботами и станками с компьютерным управлением, а управляющая информация для роботов и других автоматизированных машин производится компьютерами с соответствующим программным обеспечением, распространяемыми через сети. Чтобы управлять автоматизированным цифровым интеллектуальным заводом или мастерской, требуется интеллект, чтобы решать проблемы и принимать правильные решения, поэтому в большинстве программных решений используется искусственный интеллект. Интеграция означает «иметь все под рукой». Сегодня это называется также управлением жизненным циклом продукта, поскольку вся техническая и управленческая информация о продуктах и производственных системах доступна в любое время на всех этапах их проектирования и эксплуатации. Интеллект и искусственный интеллект в некоторых непроизводственных приложениях обсуждаются в статье на таких примерах, как шахматные компьютеры и роботы, а также автоматизированное транспортное средство, предназначенное для работы на Марсе.

Ключевые слова: интеллект, искусственный интеллект, робототехника марсохода, следопыт, шахматный автомат, цифровое производство.

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