

EVOLUTION OF ROBOTS THROUGHOUT HISTORY FROM HEPHAESTUS TO DA VINCI ROBOT

RAZVOJ ROBOTA KROZ POVIJEST DO „DA VINCIJEVOG ROBOTA“

Christos Iavazzo¹, Xanthi-Ekaterini D. Gkegke¹,
Paraskevi-Evangelia Iavazzo², Ioannis D. Gkegkes³

SUMMARY

Da Vinci robot is increasingly used for operations adding the advantages of robots to the favor of medicine. This is a historical article with the aim to present the evolution of robots in the medical area from the time of ancient myths to Renaissance and finally to the current revolutionary applications. We endeavored to collect several elegant narratives on the topic. The use of imagination could help the reader to find similarities. A trip from the Greek myths of Hephaestus through Aristotle and Leonardo Da Vinci to the robots of Karel Capek and Isaac Asimov and finally the invention of the medical robots is presented.

Key words: History; mythology; Hephaestus; Da Vinci; robot; surgery

INTRODUCTION

According to RIA (Robotic Institute of America), robot is a reprogrammable, multifunction operator designed to manipulate materials, objects,

¹ IASO, Maternity Hospital, Athens, Greece.

² Rural Practice Molos, Fthiotida, Greece.

³ Department of Surgery, Korinthos General Hospital, Corinth, Greece.

Corresponding author:

Christos Iavazzo, MD, MSc, PhD. 38, Seizani Str., Nea Ionia, Athens, Greece, 14231.

Tel: +306948054119. Electronic address: christosiavazzo@hotmail.com

tools or special devices through variable movements programmable to perform various projects [1]. The Intelligent robots can define their goals, plan their actions and correct their function according to the changes in their environment. Their applications in the areas of medicine are several. Its main objective is to save human energy and especially the continuous improvement of the accuracy of specific applications. The aim of this study is to present the evolution of robots in the medical area from the time of ancient myths to Renaissance and finally to the current revolutionary applications.

GREEK MYTHOLOGY

In the ancient history, automata – creatures similar to robots could be found in the myths mainly from Greece and Egypt. The first automaton described in the ancient literature (1300 B.C.) is the statue of Memnon – King of Ethiopia which was created by Amenhotep, son of Hapu [2]. This statue was activated by the rising sun and played music. Some of the primary displays of the robots as humanoid constructions can be found in the Greek mythology. Some myths of antiquity refer to mechanical humans, statues which talk and have a “soul”, and artificial beings that are not humans nor gods or semi-gods.

THE ROBOTS OF GOD HEPHAESTUS

Hephaestus – which is also known as Vulcanus in the Roman Mythology - was considered the god of fire, volcanoes, the god of all craftsmen who worked with metal working and especially the blacksmith, the god of stone construction and sculpture. Hephaestus according to the Pantheon of Gods is considered the legitimate son of the royal couple of Olympus, Zeus and Hera born from their premarital relations. According to another myth, Hephaestus did not have a father. Hera conceived him without sexual contact in retaliation to Zeus for the birth of goddess Athena. When Hera first saw him after his birth, she could not accept his repulsive appearance and threw him from Mount Olympus. Hephaestus fell into the ocean where he was picked up and raised for nine years by two goddesses Thetis and Eurynome. Another version of the myth describes that he was thrown from Mount Olympus by Zeus himself because he got the part of his mother in a brawl of the royal couple of Olympus.

Hephaestus was a very creative god. He was famous for the two mechanical (golden and silver) dogs which were guarding the palace of Alcinous,

two wild bulls with bronze feet with voice and fire coming out from their mouths, as well as his golden slaves and Talos. In the Iliad of Homer, the existence of some “golden slaves” is mentioned. Those “slaves” helped god Hephaestus to walk. He had set up them along with goddess Athena. So the fire (technology) and wisdom have worked together for this creation. Some of those were also used in his laboratory. More specifically, in the “Iliad” we find that “...God, stocky and tall, the anvils letting go by limping he leaves his job, his legs are weak, cannot bear him, bending down by the weight. He wears a gold robe and gets a scepter loud and goes out limping. Statues of gold help him to walk, just like the living adolescents, to whom strength and thought was given and life. The immortals taught them what they had to do and they are not removed at all from him, as he walks with difficulty...” Hephaestus goes back to his workshop, “directs his bellows over the fires and commands to liven up the fires”.



God Hephaestus

Bog Hefest

THE MYTH OF TALOS

Another mechanical being who was created by Hephaestus was Talos, a metallic giant by copper created and invulnerable. Hephaestus made Talos as a wedding gift to Europe and Jupiter, Europe’s husband, who gave him to his protégé, Minos, the king of Crete. His missions were to protect the island from the enemies, transfer the orders / commands of King Minos to his vassals and the resolution of their differences by acting as a judge of Cretan villages. For this reason, he was walking around the Cretan territory three times a year according to Plato or three times a day according to Apollodorus bearing on his shoulders the bronze tablets of the law. When the island was attacked by enemy ships, he threw huge stones against them or he burned them with his hot breath, and when it landed in ashore after burning enemies clenching them on his chest. Talos laughed sarcastically (sardonius laugh) while the stranger-enemy was burning. During the attack of the Argonauts on the island, Talos was immobilized by Medea by making magic tricks and caused confusion to him. The bronze giant was invincible-but he had a single



Talos “robot”
“Robot” iz Talosa

artery which ran from his neck and ended at the heel which was closed by a membrane. Medea penetrated the membrane and the “ιχώρ”, the divine fluid that flowed in the artery, poured like a molten metal and the giant died.

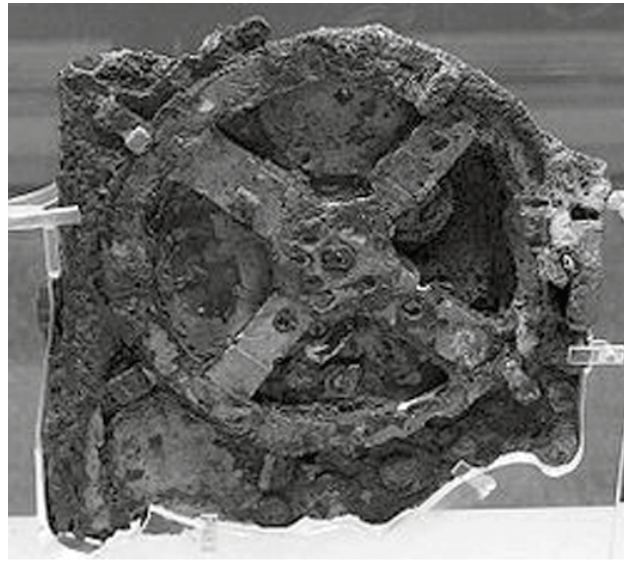
This myth gives the perception of the ancients about the humanoid machines that were in the service of people or gods. The similarity of Talos automaton and its features give feed for discussions on the holding-art of the ancient Greeks. By these two myths, the range of

services / works performed by robots in ancient history or mythology is presented, while there is a similarity with the current uses of robots (heavy manufacturing and machining processes, helping people with disabilities, transportation and management of objects, transferring orders, decision making by searching through databases of rules) [3-6].

ROBOTS IN ANCIENT GREECE

According to Apollodorus, the god Promitheus created the first man and woman with clay animated by fire which was stolen from heaven. Another relative myth is the one of Pygmalion (a Greek sculptor) and Galatea his ivory statue for which he was working for so long. He depicted a woman of perfection with which he fell in love. Aphrodite helped him to give life to the statue by kissing it. The ancient Greeks had a strong interest in technology starting with Thales of Miletus (624-546 B.C.) and reaching to Aristotle. Thales is one of the seven sages of antiquity admired both as an engineer, a philosopher and astronomer. He is the first to predict the solar eclipse in 385 B.C. Plato calls him “ευμηχανο”, translated as inventive at the field of arts. Aristotle (384-322 B.C.), a great philosopher seems to have predicted even robots among others. Although he was a physician, Aristotle himself was interested more about biology and zoology. However, he was the first who studied the anatomy of the animals. Aristotle in his book *Mechanica* admires what happens in the art with the help of science in the interest of man. In another book,

Politics, he deals with slavery which it considers necessary for the economic life of the city-states. Even the war according to Aristotle is a legitimate means of finding slaves to work for underpinning economic growth. More specifically, he writes in Politics: «ωσπερ τά Δαιδάλου φασίν η τούς του Ηφαίστου τρίποδας, ους φασίν ο ποιητής αυτομάτους θειον δέεσθαι αγώνα, ουτως οι κερκίδες εκέρκιζον αυτοί



The Antikythera mechanism

Mehanizam iz Antikythere

καί τά πληκτρα εκαθάριζεν, ουδέν αν εδει ουτε τούς αρχιτέκτοσιν υπηρετων ουτε τούς δεσπότας δούλων». This means that if every instrument could work alone when ordered, if the shuttle of loom could weave itself, if the bow could be initiated only upon the lyre, the entrepreneurs would not have the need of neither masters nor slaves. This text may be considered as a genius prediction of robot's current technology. Around 350 B.C., Archytas of Tarentum (428-347 B.C.), a Greek mathematician, created a mechanical bird called "the Pigeon" that was propelled by steam. Some years later, Ctesibus (285-222 B.C.), a Greek engineer made organs and water clocks with movable figures. Typical example of the ancient Greek technology is also the Antikythera mechanism, a calendar computer which was discovered in the ancient shipwreck of Antikythera – a small island in southern Greece. However, some would argue that Antikythera mechanism is not a robot but not relevant to a computer mechanism. Initially, archaeologists thought that this is a type of astrolabe, but researchers are now confident that this is a perfect calendar mechanism. The operation of the computer, consisting of a complex system of gears, based on the discovery of a differential gear mechanism of Archimedes. A modern model of the Antikythera Mechanism was presented by Professor Derek Pryce of Yale University after radiography of the original located in the Archaeological Museum of Athens. Professor Pryce spent twenty years of research to build the mechanism [7-10].

ANCIENT CHINA

There are several references of automata in ancient China including the wooden horse created by an engineer at the reign of King-su Tse (500 B.C.). Similar stories could be found regarding the terracotta soldiers of treasure Tihuang Hueng Chin Shih. Emperor Yang (569-618 A.D.) of the Sui Dynasty asked a man named Liu to summon him to the imperial palace to have a drink and recite poems after withdrawing from the court meeting. However, according to the tradition, it was improper for Emperor Yang to summon Liu to the imperial residence every day. For this reason, the Emperor asked his engineers to create a wooden man by imitating Liu's figure. This wooden man was mounted with a machine in its abdomen that enabled it to stand up, sit down and worship on bended knees mimicking Liu's movements [2, 11,18,19,20].

Another example is Prince Kaya (794-871 B.C.) who was a craftsman and created a doll about four feet tall which was holding a jug on its hands and it was used as a way to solve the problem of drought throughout the kingdom [21].

ANCIENT INDIA

Stories about a yantra-purusa, or a "robot-man" could be found in the ancient Indian literature. For example, in the Buddhistic Bhaisajya-vastu, a painter went to the Yavana country and visited the home of a yantracarya, or teacher of mechanical engineering. In his house, he met a "robot-girl" who washed his feet and acted as human, until he found that she could not speak [12]. Moreover, in the ancient historical book of Srimad Valkini Ramayana, a robot called Kumbakarna used in war is also described.

JEWISH FOLKLORE

In Jewish folklore, a golem is an animated anthropomorphic being, created entirely from inanimate matter. The word was first found in Psalms 139:16 [2]. It can be interpreted that Adam, created in the image and likeness of God, indicates an atavistic intention of man to create humanoids.

THE ARAB WORLD

Al-Jazari (1136-1206 A.C.), an Arab engineer, created a musical automaton, which was a boat with four automatic musicians that floated on a lake to entertain guests at royal drinking parties. The drummers could be made to play different rhythms and different drum patterns if their pegs were moved around [9].

THE ERA OF LEONARDO DA VINCI

Before the Renaissance, Saint Albertus Magnus (1206-1280 A.C.) created a bronze statue able to speak by itself. At the beginning of the Renaissance, Leonardo da Vinci (1452-1519 A.C.) was born on 1452 A.C., at Anziano, Italy. He was the illegitimate son of Piero da Vinci and a poor peasant named Caterina. His father was an attorney living in Florence. Leonardo da Vinci was characterized by artistic talent and sharp mind. He studied painting, sculpture, architecture, botany, music at the renowned workshop of Andrea del Verrocchio in Florence. Among the studies, prominent position has the study of the human body. In his famous drawing “Vitruvian man”, shows the proportions of the male human body. He was particularly interested on the human anatomy by dissection of corpse both in Florence at the hospital Santa Maria Nuova and in Rome in Santo Spirito of Chassis hospital.

At the age of 30, he moved to Milan as a cultural ambassador of Florence. The Duke of Milan assigned him tasks, ranging from scientific research to writing riddles and organizing ceremonies and celebrations. Those duties have resulted among others in designing various machines, improvement of technical projects and the expansion of scientific studies in various fields. After the fall of the Duke of Milan by the French Leonardo da Vinci army traveled to Venice and to central Italy as an engineer of the French. In Florence he continued his studies on the flying machines, reminiscent of gliders, helicopters and parachutes. In 1508, he returned to Milan after the invitation of the French governor of the city and remained there for 5 years continuing his research and his painting work when he moved to Rome, where he devoted himself to the study of the manuscripts of Archimedes.

Handyman and polymath, although it is particularly known for his artistic work, he also contributed to medical science. Da Vinci investigated everything: “asking” is the word that one could frequently encounter in his notes. He used to say: “Those who fall in love on the practical application and disregard for the science is like the captain, who travels with no wheel

and compass and never knows for sure where the boat sails.” He did not study only the sources of knowledge, but also their applications. In light of the writings of Aristotle, Celsus and Galen, Leonardo showed an interest in the anatomy of the human body and designed several sketches which were treated as teaching aids. He depicted with great accuracy the genetic system of the woman. Among other engines, Da Vinci built humanoid-robot which was used in German-Italian medieval armor, and was able to make several human-like motions including sitting up, moving its arms, neck, and had an anatomically correct jaw. This “robot” was the result of Leonardo’s anatomical research in the Canon of Proportions as described in the Vitruvian Man [2,14,15]. Leonardo displayed his automaton in 1495 at the court of Milan. It was a knight able to move. Another similar automaton created by him – the mechanical lion – was presented in 1515.

The French military surgeon Amboise Pare (1510-1590 A.C.) also published his work in 1579 regarding the artificial limbs used on his amputees and he was the first surgeon to build prostheses [20]

ENLIGHTENMENT AND ROMANTICISM

During the eighteenth and nineteenth centuries there was great activity in building robots and humanoids. Wolfgang von Kempelen (1734-1804 A.C.) created an automaton to impress the Empress Maria Theresa of Austria which is known as the Turk or the Chess Player which could play a chess game a human opponent. Jaquet-Droz family also created three doll automata (the musician, the draughtsman and the writer) which are still functional and could be found at Neuchatel in Switzerland. Jacques de Vaucanson (1709-1782 A.C.) was another French inventor of automata such as an automated loom, the Flute Player, the Tambourine Player and the Digesting Duck.

ROBOTS IN THE 20TH CENTURY

Czech writer Karel Capek (1890-1938 A.C.) was the first to use the term “robot” in his play “Rossum’s Universal Robots” which was played for the first time in Prague in 1921 and in London in 1923 [23]. Robots are presented in this play as small artificial anthropomorphic creatures which obey strictly the commands of their master, but eventually rebelled against their creators. These creatures are called “robotnik” in the Czech and Russian language from the word “robota”, which means “forced labor”.

After 20 years, in 1942, Isaac Asimov (1920-1992 A.C.) formulated the following three laws of robotics [16]:

- A robot must not injure a human being or allow the injury of a human being due to inactivity.
- A robot must obey the orders which are given by human beings except of those that conflict with the First Law.
- A robot must protect its existence unless such a protection conflicts with the First or Second Law.

In 1962, Tomovic and Boni developed a robotic limb with pressure sensors which were able to determine the size and weight of objects while Reswick and Meyler developed a device for quadriplegics, giving them the ability to manipulate objects. In 1966, McCarthy in the Artificial Intelligence Lab at Stanford developed a robotic handler with hearing, sight and touch (microphones, cameras and touch sensors) that could recognize spoken commands and to respond accordingly [2,14,16-18].

EVOLUTION OF ROBOTICS IN MEDICINE

Robots were used in the ocean or in space. Moreover, significant progress was achieved in the 1980s by the major developments in microelectronics and computer while a significant progress in medicine was also noticed by the revolution of laparoscopy. In 1804 Philip Bozzini (1773-1809 A.C.), a German physician specialized in urology and in gynaecology, discovered the first endoscope [24]. Kelling in 1902 held its first direct overview of the peritoneal cavity in a dog after inflating air while Jacobaeus was the first to apply this technique in humans in 1910. Kalk and Bruhl in 1928 analyzed the advantages of diagnostic laparoscopy, by publishing the first large series of patients submitted to this diagnostic method. Specifically an endoscope was developed and this resulted in the first laparoscopic cholecystectomy in 1987 by the French physician Dr Philippe Mouret (1938-2008 A.C.). This endoscope mimics the one used in urology from the decade of 1970s.

The application of robotics in medicine began with PUMA. In 1985, PUMA 560 was considered as the first robot was used in brain biopsy and in 1988 the robot PROBOT was used in prostate surgery. Hermes was another example as it was a software development in about 1990 used to coordinate Aesop (robotic arm). So, Hermes and Aesop are thought to be the first assistant surgeon robots. In 1992 the robot ROBODOC was used in hip replacement [25]. The FDA in the U.S. approved the first surgical robot, called

Aesop, in 1994, where a single robotic arm which controlled the camera, allowing thus the surgeon to use both hands to be operated on. Mettler in 1998 compared Aesop to the surgical assistant involved in laparoscopy during gynecological surgery and found that the time of surgery was less with Aesop, because it improves the performance by allowing to two surgeons to use both hands in the surgery. By 1999, two additional arms were added to create the surgical system Zeus (Computer Motion), and so was the model of a control platform, where the surgeon sat the dominant console and directed surgical robotic tools. The three-dimensional display was achieved with the aid of special glasses. The surgical arms were designed to mimic the movements of the human wrist. Indeed, the surgical system Zeus in 2001 held the first telesurgery operative treatment, when surgeons in New York made one successful cholecystectomy in Strasbourg, France. DaVinci robot (Intuitive Surgical Company) was first used for a robotic-assisted surgery aortocoronary bypass in October 1999 in Germany by Dr Schueler. On March 2000, Dr Francois Labore performed seven full pediatric endoscopic surgeries (ductus arteriosus), with the robotic system using the robotic system Zeus, held. In October 2002, the Zeus robotic system was approved by the FDA as suitable for laparoscopic and thoracoscopic operations. Computer Motion and Intuitive Surgical companies on March 7th, 2003 announced the merger after a legal battle that started in May 2000 and lasted three years with repeated lawsuits between them. The DaVinci assisted surgery era has started offering its advantages to the surgeon and the patient [16-18].

CONCLUSION

We tried to offer to the reader a “journey” in development of robots from ancient Greek mythology and eastern history to the era of Leonardo da Vinci and the modern applications in medicine.

REFERENCES

1. Moran ME. Rossum's universal robots: not the machines. *J Endourol* 2007;21(12):1399-402.
2. Sánchez Martín FM, Millán Rodríguez F, Salvador Bayarri J, Palou Redorta J, Rodríguez Escovar F, Esquena Fernández S, Villavicencio Mavrich H. [History of robotics: from Archytas of Tarentum until da Vinci robot. (Part I)]. *Actas Urol Esp* 2007;31(2):69-76.
3. Homer. *Iliad* (book 18), (Penguin Classics), Ed. Penguin.
4. Appolodorus. *The Library* (1,6,4,9,26), Harvard University Press.
5. Apollonius of Rhodes. *Argonautica* (4,1644), William Heinemann.
6. Heraklion-Crete org online. Website: <http://www.heraklion-crete.org/talos.html> (Accessed: 29/10/2013)
7. The Antikythera Mechanism Research Project", The Antikythera Mechanism Research Project. Retrieved 2007-07-01 Quote: "The Antikythera Mechanism is now understood to be dedicated to astronomical phenomena and operates as a complex mechanical 'computer' which tracks the cycles of the Solar System."
8. Gera DL. *Ancient Greek Ideas on Speech, Language, and Civilization*. Oxford University Press, 2003.
9. Simpson PP. *A Philosophical Commentary on the Politics of Aristotle*. The University of North Carolina Press, 1998.
10. History of robotic surgery. Website: http://biomed.brown.edu/Courses/BI108/BI108_2004.Groups/Group02/Group%2002%20Website/history_robotic.htm (Accessed: 29/10/2013)
11. Robots in Ancient China. Website: <http://history.cultural-china.com/en/183History4025.html> (Accessed: 29/10/2013)
12. Robots in Ancient and Medieval India. Website: <http://www.iskcondesiretree.net/forum/topics/robot-and-it-s-prediction-in-vedic-sastra?x=1&id=2103886%3ATopic%3A1245766&page=2> (Accessed: 29/10/2013)
13. Idel M. *Golem: Jewish magical and mystical traditions on the artificial anthropoid*. State University of New York Press, 1990.
14. Rosheim ME. *Leonardo's Lost Robots*. Springer, 2006, p.69.
15. Leonardo Da Vinci inventions. Website: <http://www.da-vinci-inventions.com/robotic-knight.aspx> (Accessed: 29/10/2013)
16. Asimov I. *The Rest of the Robots*. Doubleday. Garden City, 1964.
17. Yates DR, Vaessen C, Chartier-Kastler E, Richard F, Haertig A, Bitker MO, Rouprêt M. History of robotic surgery in surgery: a progressive evolution towards a surgical revolution. *Presse Med* 2012;41(4):427-33.

18. Yates DR, Vaessen C, Roupret M. From Leonardo to da Vinci: the history of robot-assisted surgery in urology. *BJU Int.* 2011;108(11):1708-13.
19. Sánchez-Martín FM, Jiménez Schlegl P, Millán Rodríguez F, Salvador-Bayarri J, Monllau Font V, Palou Redorta J, Villavicencio Mavrich H. History of robotics: from archytas of tarentum until Da Vinci robot. Part II. *Actas Urol Esp* 2007;31(3):185-96.
20. Moran ME. The da Vinci robot. *J Endourol* 2006;20(12):986-90.
21. Suematsu Y. Ancient China South Pointing Chariot, Department of electronic-mechanical engineering, Nagoya University, 2002.
22. Hernigou P. Ambroise Paré IV: The early history of artificial limbs (from robotic to prostheses). *Int Orthop* 2013;37(6):1195-7.
23. Sánchez-Martín FM, Villavicencio H. Comments to the article «robotic surgery: history and impact on teaching». *Actas Urol Esp* 2012;36(5):331-2.
24. Verger-Kuhnke AB, Reuter MA, Beccaria ML. Biography of Phillip Bozzini (1773-1809) an idealist of the endoscopy. *Actas Urol Esp* 2007;31(5):437-44.
25. Sugano N. Computer-assisted orthopaedic surgery and robotic surgery in total hip arthroplasty. *Clin Orthop Surg* 2013;5(1):1-9.

SAŽETAK

Da Vincijev robot se sve više koristi za operacije iskorištavajući prednosti robota u korist medicine. Ovo je povijesni članak u kojemu je cilj predstaviti evoluciju robota u medicini od vremena drevnih mitova do renesanse i konačno do sadašnjih revolucionarnih aplikacija. Nastojali smo prikupiti nekoliko elegantnih priča na tu temu. Korištenje imaginacije može pomoći čitatelju pronaći sličnosti. Predstavljeno je putovanje od grčkih mitova o Hefestu preko Aristotela i Leonarda da Vincija do robota Karela Čapeka i Isaaca Asimova te konačno izuma medicinskih robota.

Ključne riječi: povijest; mitologija; Hefest; Da Vinci; robot; kirurgija