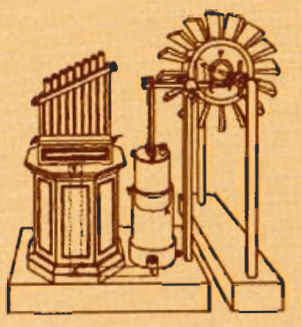
2° ΔΙΕΘΝΕΣ ΣΥΝΕΔΡΙΟ

2nd INTERNATIONAL CONFERENCE

ΑΡΧΑΙΑ ΕΛΛΗΝΙΚΗ ΤΕΧΝΟΛΟΓΙΑ

ANCIENT GREEK TECHNOLOGY



ΤΕΧΝΙΚΟ ΕΠΙΜΕΛΗΤΗΡΙΟ ΕΛΛΑΔΑΣ
Αθήνα 2006

2ο ΔΙΕΘΝΕΣ ΣΥΝΕΔΡΙΟ ΑΡΧΑΙΑΣ ΕΛΛΗΝΙΚΗΣ ΤΕΧΝΟΛΟΓΙΑΣ

2nd INTERNATIONAL CONFERENCE ON ANCIENT GREEK TECHNOLOGY

ΠΡΑΚΤΙΚΑ

PROCEEDINGS

ΤΕΧΝΙΚΟ ΕΠΙΜΕΛΗΤΗΡΙΟ ΕΛΛΑΔΑΣ
Αθήνα 2006

Τέταρτη Ενότητα

ΤΕΧΝΟΛΟΓΙΑ ΚΑΙ ΚΟΙΝΩΝΙΑ

Τεχνολογία, Οικονομία, Κοινωνία
Δουλοκτησία και Μηχανές
Περιβαλλοντικός προβληματισμός στην Αρχαία Ελλάδα
Διεθνείς επιδράσεις

Fourth Part

TECHNOLOGY AND SOCIETY

Technology, Economy, Society
Slavery versus Machines
Environmental issues in Ancient Greece
International influences

ΤΕΧΝΟΛΟΓΙΑ, ΟΙΚΟΝΟΜΙΑ, ΚΟΙΝΩΝΙΑ
TECHNOLOGY, ECONOMY, SOCIETY

ΔΟΥΛΟΚΤΗΣΙΑ ΚΑΙ ΜΗΧΑΝΕΣ
SLAVERY VERSUS MACHINES

ΠΕΡΙΒΑΛΛΟΝΤΙΚΟΣ ΠΡΟΒΛΗΜΑΤΙΣΜΟΣ ΣΤΗΝ ΑΡΧΑΙΑ ΕΛΛΑΔΑ
ENVIRONMENTAL ISSUES IN ANCIENT GREECE

ΔΙΕΘΝΕΙΣ ΕΠΙΔΡΑΣΕΙΣ
INTERNATIONAL INFLUENCES

GREEK AND MUSLIM AUTOMATA. INFLUENCE OF GREEK KNOWLEDGE IN MEDIEVAL ISLAMIC SCIENCE

M. Cigola
DART: Laboratory of Documentation, Analysis, Survey of the Architecture and the Territory, DiMSAT, University of Cassino

Περίληψη

Ο στόχος της εργασίας αυτής είναι να περιγράψει την πορεία των αυτομάτων στην ιστορία, από την αρχαιότητα ως το Μεσαίωνα μέσα από τα έργα δύο συγγραφέων, ειδικώς: του Al Jazari και του Ήρωνος του Αλεξανδρέως. Η εργασία βασίζεται στην ανάλυση σχεδίων από αρχαία κείμενα.

Abstract

Aim of this work is to delineate the history of automatas from antiquity to Middle Age, focusing the attention on two authors: al Jazari and Heron of Alexandria. The development of the work will be carried out by the analysis of drawings from ancient texts.

Construction of the first automaton, a flying dove, can be attributed to Architas of Tarantum (a pupil of Pythagoras, mathematician and musician, 5th century BC) but it can be presumed that mechanical devices were used much earlier to give an «illusion» of life to men and animals during religious ceremonies and in theatrical performances with the *deus ex machina*. We find documentary evidence of the established presence of mechanisms and automata in Greek antiquity in various authors, including Aristotle [1].

In the school of Alexandria, mechanical themes were studied and, in particular, great attention was addressed to those associated with the construction of automata. In fact Ctesibius (3rd century BC), who is considered the founder of the Alexandrine school of Mechanics, studied and applied the basic principles of pneumatics by creating automata which are operated by the force of air. He is also considered as being the first to create a water clock. His pupil Philon of Byzantium worked particularly on automata, basing their operations on pneumatics and on the principle of communicating vessels.

An important advancement for construction of automata is due to Heron of Alexandria, who probably lived in the 2nd or 1st century BC and collected and developed the works and knowledge of his predecessors. Heron was interested not so much in the practical utility of his devices as in their ability to astound and stupefy, to appear as reflections of a magical and supernatural world. Among his writings we may mention *Pneumatica*, with the most varied applications of the effect of atmospheric pressure on bodies (siphons, water organs, the so-called "Heron's fountain", statues that emitted sounds) and *De automatis* in which his mechanical inventions are presented as automata in human or animal form that execute very simple movements..

One must immediately eliminate the concept, still widespread today, of a cultural regression from the classical world in the early medieval or medieval period, morever it is incorrect that scientific activities were no longer practised.

One of the principal factors for retention of ancient knowledge in the medieval world and for formation of pre-medieval culture was the contribution of Islam. With the expansion and consolidation of the Islamic world in the Mediterranean basin, the Arabs took on a decisive role in development of the sciences. Their knowledge of Greek culture was pro-

found, and it is only thanks to their work that some Greek treatises have come down to us. Contacts with the Arab world were direct and frequent from the start of the Moslem expansion that rapidly occupied a large part of the Mediterranean basin and provided many opportunities for meeting and cohabitation between Christian and Islamic peoples; the prolonged presence of Moslem dynasties in Spain, intensified exchanges between Islamic and Christian culture. There is therefore no break between the classical world and the so-called 12th century renaissance; rather, there is a continuity between the two periods as discussed in [2].

We also have information on automata in the Middle Age, at first only from written documents and later, starting from the 13th century, also from drawings.

In 979 Liutprand of Cremona, describing the throne room of the emperor in Constantinople, wrote about a very complex automaton consisting of a bronze tree on the branches of which there were metal birds that chirruped, and wood and bronze lions that moved their tails and roared [3]; Albertus Magnus (about 1206-1280) constructed an automaton that opened the door for guests and spoke some words of greeting; there remains only the harsh verdict of his pupil, Thomas Aquinas, who believed the automata as a work of the devil and destroyed it.

Through Rome and Byzantium, the Greek mechanical culture of Heron, Philon of Byzantium and Ctesibius passed to the east, by means of the work of various translators who disseminated the oldest works and established schools on mechanical studies.

One of the first works dedicated to mechanic devices for automata is certainly that which can be attributed to the Banu Musa (Arabic word for: the son of Musa). They were three brothers who lived in Baghdad in the ninth century. They were scholars and translators of classical works, and they were certainly familiar with the mechanical culture of Heron and Ctesibius. In fact they wrote the *Book of ingenious devices*, including text and drawings, that describes over one hundred devices, most of which are trick vessels, including fountains that change form and other extremely complicated and refined devices.

Al Jazari was one of the most important authors to continue this culture, who in 1206 wrote a treatise on clocks and mechanics, titled *Kitab al-Hiyal, (Book of knowledge of ingenious mechanical devices)* [4], in which some automata are presented in a very elegant manuscript comprising texts and drawings. The treatise includes an introduction and six chapters, the first of which is devoted to water clocks and their mechanisms. The others illustrate ingenious devices, in human and animal form, for serving drinks, fountains, and clocks, with automata that sound at regular intervals. The work describes the components, functions and construction of about fifty mechanical devices [5].

The mechanisms, which make use of hydraulic energy, counterweights, levers and pulleys, are described in efficient and rigorous way; even though there is no doubt that the author indulges in description and representation in artistic forms, this can be thought an obvious choice if one bears in mind that the treatise was intended for the sultan and not for a technical reader. In spite of that, the various copies found in different parts of the world, almost all contemporary with the original manuscript, which has been lost, testify to a great interest in this work and in its subject [6].

The work by Al Jazari's can be considered of fundamental interest for the exceptional level and expertise in graphical techniques, but also morever, for the clear knowledge of mechanical and hydraulic devices. It is of relevant importance because it is a clear result of the influence of the Greek culture and particularly of Heron's work on the Arabic technical culture that finally will transfer the Greek knowledge to successive periods and cultures.

The Al Jazari's devices that we will consider are part of a chapter of *Kitab al-Hiyal* in which

the author describes fountains and musical automata, which are of interest mainly because in them the flow of water alternated from one large tank to another at hourly or half-hourly intervals; several ingenious devices for hydraulic switching were used to achieve this operation. Mechanical controls are also described in chapters dealing with a potpourri of devices [7].

The first of Al Jazari's automata shown (Fig. 1) is a clock in the form of an elephant carrying a pavilion, below which there is a human figure seated on a gilt sphere. A serpent is attached to the top of the pavilion by a chain, and the serpent's head faces a figure in human form at the top of the mechanism. When a sphere rolls from this figure in human form into the serpent's mouth, the serpent rotates to deposit the sphere in a container on the elephant's back, setting in motion a mechanism that activates another automaton, representing the animal's mahout, as if he were playing some drums.

The astonishing modernity of this miniature of seven centuries ago is found in the author's decision on how to show the movements of the serpent, by showing it in the two positions caused by the weight of the ball. The same graphics convention, though with a different type of line, is still used today for the moving parts of complex mechanisms [8].

The second device (Fig. 2) the Peacock fountain, is designed to pour washing water for the sultan; pulling a plug on its tail releases water out of the beack, as the dirty water from the basin fills the hollow base, a float rises and actuates a linkage which makes a figure offering something appear from the pedestal; when more water is used, a second float at a higher level trips and makes appear another figure. Opening the base valve, causes figure to return into the pedestal and the doors automatically close as the water level drops. In this representation, the treatment of the pedestal of the device is extremely interesting. It is represented half in section and half in view, with a sophisticated but extremely effective representational artifice, which combines undoubted skill of the draftsman and artistic sensitivity in treatment of the forms. This artistic ability of the manuscript's author is evident both in the treatment and representation of the plumes of the bird and in the choice of colours, but also in the design of the entire plate.

The Peacock fountain reminds a lot one of Heron's devices, and just that one described like a bird wich will drinck any quantity that may be presented to it (Fig. 3), even if evidently the function seems to be opposite, because the first is designed to drink, the second to pour water form the beack.

Another example (Fig. 4), is a device with human form standing in a boatm playing a long flute with his right hand and holding an oar in his left; the boat floats in a tank of water, there is a hole in the bottom of the boat by which water pours in, and when it reaches a certain level, the man begins to play his flute and the water to empty out again. This action is repeated every hour, so this is a simple clock as well as a musical automata.

This device is the same in Section 49 of Heron's Pneumatica (Fig. 5), and it testifies the passage to the muslim world of the technical and scientific acquaintances of the classic antiquity.

After the Medieval period, the technique of automata had its period of greatest development with the revival of classical Greek and Roman culture in the Renaissance which was accompanied by undoubted progress in the scientific and technical field in general. The writings of Ctesibius, Philon and Heron particularly, were preserved and transmitted to subsequent epochs through the translations of Arabs and Byzantines. They became part of the culture of wide strata of the population and exercised a considerable influence on the development of technology. The same cannot be said of the works of the medieval authors, which probably remained known to only a few initiates until their rediscovery in modern times.

Fig. 1. *al Jazari, Clock from "Kitab al-Hiyal" (N.Y. Metropolitan museum)*

Fig. 2. *al Jazari, Peacock fountain from "Kitab al-Hiyal" (fstambul, Topkapy museum)*

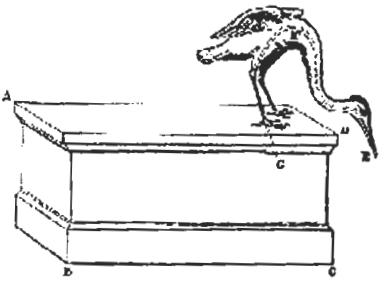


Fig. 3. The Pneumatics of Hero of Alexandria, Section 30; published London, 1851

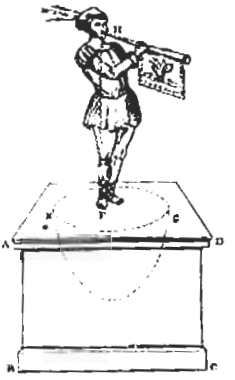


Fig. 5. The Pneumatics of Hero of Alexandria, Section 49; published London, 1851

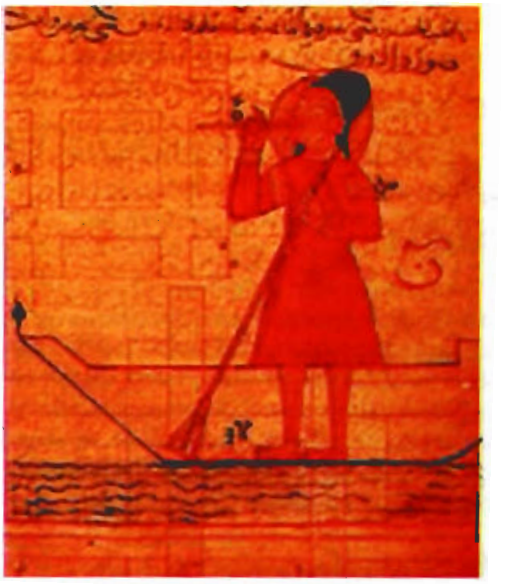


Fig. 4. al Jazari, Automata playing flute from "Kitab al-Hiyal" (Istambul, Topkapy museum)

References

1. P. Portoghesi, *Infanzia delle macchine,* Roma 1965
2. Docci, M. Cigola M., *Representación gráfica e instrumentos de medición entre la Edad Media y el Renacimiento*, in *Anales de Ingeniería Gráfica*, n. 2 Mayo-Deciembre 1995, Madrid 1997; pp. 1-20
3. *Antapodosis*, VI, 5, P. Portoghesi, *Infanzia delle macchine,* Roma 1965
4 Ebul-iz Ysmail bin ar-Razzaz el Cezeri, then called Al Jazari in the Arabic translation, wrote his treatise for the sultan of Diyarbakir, at whose court he served for 25 years. Diyarbakir was one of the sultanates of the Seljuk empire that dominated much of Anatolia in the 11th, 12th and 13th centuries, being replaced by the Ottomans in the 14th
5. A.Y. Hassan, D.R. Hill, *Islamic technology. An illustrated History*, Paris 1986
6. al Jazari, *Kitab fi Ma'rifat al-hiyal al-handasiyya (Book of knowledge of ingenious mechanical devices),* Bodleian Library, Smithsonian Museum, Istambul Topkapi Museum, New York Metropolitan Museum of Art
7 D.R. Hill, *Le Génie Mécanique dans l'Islam Médiéval*, in "Pour la Science", Janvier 1996, N°7610-01
8 Cigola M., *Drawings of automatas in middle ages*, in *Proceeding of Internation Symposium on* History of Machines and Mechanisms HMM2000, Kluwer Academic Publisher; Dordrecht Netherlands 2000; pp.335-340. ISBN - 0-7923-6372-8

ISBN: 960-8369-16-9