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AUTOMATA TECHNOLOGY IN THE MEDIEVAL ISLAMIC WORLD AND ITS INFLUENCE ON KOREA

Abbasid caliphs in the Islamic world systematically encouraged the translation of ancient Greek books on science and technology in large numbers. And in this process, knowledge related to automata also spread in the Islamic world. The leading Greek scholars who touched on the development of automata in the Islamic world were Philo of Byzantium and the Hero of Alexandria. Philo's book "Pneumatics" was translated into Arabic in Baghdad. Meanwhile, the works of the Hero, including The Mechanic, were translated into Arabic with the Greek physician Kusta ibn Luka (820–912) in the IX analysis. The Kitab al-Khiyal ("Book of Ingenious Devices") by Banu Musa bin Shakir (9th century) was one of the foundational texts for the development and systematic study of automatic devices in the Islamic world. The book was commissioned by the Abbasid Caliph Al-Ma'mun, who commissioned Ban Musa to acquire all the Hellenistic texts that were preserved by monasteries and scholars during the decline and fall of Roman civilization. The purpose of the article is to show the ways of development and subsequent influence of Islamic technologies on other cultures and civilizations. To do this, the author studied and translated a number of original sources in various languages of the East.

Key words: Islamic civilization, technology, Hellenistic texts, automatic devices, water clock.

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Ортағасырлық ислам әлеміндегі автоматтар технологиясы және оның Кореяға әсері

Ислам әлеміндегі Аббасид халифалары ежелгі грек кітаптарын ғылым мен техника туралы көп мөлшерде аударуға жүйелі түрде шақырды. Бұл процесте автоматтарға қатысты білім ислам әлемінде де таралды. Ислам әлеміндегі автоматтардың дамуына әсер еткен жетекші грек ғалымдары Византия Филоны мен Александрия Героны болды. Филонның "Пневматика" кітабы Бағдадта араб тіліне аударылған. Сонымен қатар, кейіпкердің шығармаларын, соның ішінде "Механик", IX талдауда грек дәрігері Куста Ибн Лука (820–912) араб тіліне аударған. "Китаб әл-Хиял" ("тапқыр құрылғылар кітабы") Бану Мұса бин Шакира (9 ғасыр) ислам әлеміндегі автоматты құрылғыларды әзірлеу мен жүйелі түрде зерттеудің негізгі мәтіндерінің бірі болды. Кітап Аббасид халифасы әл-Мамунның тапсырысы бойынша жазылған, ол Бану Мұсаға Рим өркениетінің құлдырауы мен құлдырауы кезінде монастырлар мен ғалымдар сақтаған барлық эллиндік мәтіндерді сатып алуды тапсырған. Мақаланың мақсаты – исламдық технологиялардың басқа мәдениеттер мен өркениеттерге даму жолдарын және одан кейінгі әсерін көрсету. Ол үшін автор бірқатар бастапқы дереккөздерді зерттеп, Шығыстың әртүрлі тілдеріне аударды.

Түйін сөздер: Ислам өркениеті, технология, эллиндік мәтіндер, автоматты құрылғылар, су сағаттары.

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Технология автоматов в средневековом исламском мире и ее влияние на Корею

Аббасидские халифы в исламском мире систематически поощряли перевод древнегреческих книг по науке и технике в больших количествах. И в этом процессе знания, связанные с автоматами, также распространялись в исламском мире. Ведущими греческими учеными, коснувшимися развития автоматов в исламском мире, были Филон Византийский и Герон Александрийский. Книга Филона «Пневматика» была переведена на арабский язык в Багдаде. Между тем сочинения

Героя, в том числе «Механик», были переведены на арабский язык греческим врачом Куста ибн Лукой (820–912) в IX анализе. «Китаб аль-Хиял» («Книга гениальных устройств») Бану Мусы бин Шакира (9 век) был одним из основополагающих текстов для разработки и систематического изучения автоматических устройств в исламском мире. Книга была написана по заказу аббасидского халифа Аль-Мамуна, который поручил Бану Муса приобрести все эллинистические тексты, которые были сохранены монастырями и учеными во время упадка и падения римской цивилизации. Цель статьи – показать пути развития и последующего влияния исламских технологий на другие культуры и цивилизации. Для этого автор изучил и перевел ряд первоисточников на различные языки Востока.

Ключевые слова: исламская цивилизация, технологии, эллинистические тексты, автоматические устройства, водяные часы.

Introduction

During the early Abbasid period (750-1258), many Greek science, technology, philosophy, and medical texts were translated into Arabic. As a result, automata technology developed in the Islamic world. An automaton (automata in plural) is a self-operating machine designed to automatically follow a sequence of operations. The Islamic world's automata-making technology peaked in the 12th century by Al-Jazari (1136-1206). And one of Al-Jazari's greatest inventions was the elephant water clock. And his elephant water clock is believed to have had a direct or indirect influence on the invention of an automatic water clock called Jagyeokru (자격루) by Jang Yeong-Sil, a Korean engineer and inventor, in 1434.

Development of Automata Technology in the Hellenistic Period

In the West, it is known that the origin of automata began in Alexandria, Egypt, which was one of the central cities of Greek learning in the Hellenistic era. The birth of automata is closely related to the history of water clocks. The first water clock with a mechanically operated puppet was clepsydra invented by Ctesibius of Alexandria (285-222 BC) around 250 BC. It was an invention that supplemented the disadvantages of existing water clocks by utilizing cogwheels and pump devices devised by Ctesibius himself. And one of the most impressive features of the water clock was that the attached puppet automatically moved and indicated the time.

Philo of Byzantium (280-220 B.C.) was the person who succeeded Ctesibius' research in the Hellenistic era and further developed it. He was a Greek engineer who was born in Byzantium and spent most of his life in Alexandria, Egypt. Philo wrote works on pneumatics and invented about 65

mechanical devices. Although less famous than Hero's works, his treatise on pneumatics was copied and studied widely during the Middle Ages and translated into Arabic.¹

The Greek-Egyptian mathematician and engineer Hero of Alexandria (c. 10 AD – c. 70 AD) contributed greatly to the development of automata, succeeding Ctesibius and Philo. Hero is known to have invented the world's first steam-powered device, called an aeolipile. The aeolipile is a bladeless radial steam turbine that spins when the central water container is heated. The aeolipile is considered to be the first recorded steam engine or reaction steam turbine.

Much of Hero's original writings and designs have been lost, but some of his works were preserved in manuscripts from the Eastern Roman Empire and to a lesser extent, in Latin or Arabic translations. Among them, his "Pneumatica" and "Automata" were collections of ancient techniques and knowledge about automata. These works passed from Alexandria to Roman culture, and later to the Byzantines and to the Arabs. During the High Middle Ages, Hero's works were read, studied, and copied throughout the Mediterranean.²

Materials and Methods

The author of the article made a fascinating virtual journey through medieval manuscripts and texts in Arabic, Greek and Korean, using in his work methods such as translation, text analysis, historical analysis, comparative method and the collection of visual data to illustrate his statements and ideas.

¹ Nadia Ambrosetti, "Wavering between the truth and the false: a short excursion through Greek and Arab automata", *Allah's Automata: Artifacts of the Arab-Islamic Renaissance (800-1200)*, Siegfried Zielinski and Peter Weibel(eds.), Hatje Cantz, 2016, p.41.

² Ibid., pp.40-41.

Literature review

This amazingly interesting and extremely useful material, revealing new facts and achievements of Muslim civilization, was described in a number of works by modern scientists from different countries, mainly Western ones. Nadia Ambrosetti, "Wavering between the truth and the false: a short excursion through Greek and Arab automata", Allah's Automata: Artifacts of the Arab-Islamic Renaissance (800-1200), Gunalan Nadarajan. "Islamic Automation: Al-Jazari's Book of Knowledge of Ingenious Mechanical Devices", Dimitri Gutas, Greek thought, Arabic culture: the Graeco-Arabic translation movement in Baghdad and early Abbasid society (2nd-4th/8th-10th centuries). The experts paid tribute to the development of theoretical and practical knowledge, which they designated as "Islamic technologies" – Donald R. Hill, Islamic Science and Engineering, Ahmad Y. Al-Hassan & Donald Hill, Islamic Technology: An Illustrated History, Salim T.S. Al-Hasani (ed.), 1001 Inventions: The Enduring Legacy of Muslim Civilization.

Results and Discussion

Translation Movement during the Abbasids and the Development of Automata Technology in the Islamic World

The Abbasid Caliphate ruled over most of the Arab world between 758-1258 CE. emphasized and encouraged the systematic development of science and technology. With its new capital in Baghdad, the Abbasid caliphate, especially during the rule of Al-Ma'mun (819-833), invested huge amounts of resources in cultural activities and scientific scholarship. Al-Ma'mun was a firm believer in the value of drawing from the intellectual traditions of Greek, Sanskrit, and Chinese knowledge that thus infused Islamic science and technology. It is noteworthy that a substantial portion of Greek texts was translated into Arabic under the Abbasid Caliphate, especially between the mid-8th century and the mid-11th century. The principal driving force behind these translation initiatives was the establishment of the library, Khizanat al-Hikma (The Treasury of Knowledge), and a research institute, Bayt al-Hikma (House of Wisdom) in the early 9th century. This quest towards developing a comprehensive knowledge resource was so ambitiously pursued that by the middle of the 10th century, the caliphate had gathered close to 400,000

volumes and by 1050, all significant works of the Hellenistic period were available in Arabic.³

In this way, in the Islamic world, ancient Greek science and technology books were translated in large quantities with systematic support from the Abbasid Caliphs. And in this process, knowledge related to automata could also be spread to the Islamic world. The leading Greek scholars who directly influenced the development of automata in the Islamic world were Philo of Byzantium and Hero of Alexandria. Philo's book, "Pneumatica", was translated into Arabic in Baghdad. And it is thanks to the Arabic translation that his work has been passed on to us today. Meanwhile, Hero's works including "Mechanics" was translated into Arabic from Greek by the physician Qusta ibn Luqa (820–912), in the 9th century.

1) The Banu Musa Brothers

The Banu Musa brothers led the translation and research projects in the science and technology sectors encouraged by the Abbasids in Baghdad around the 9th century while laying the foundation for the invention of various mechanical devices, including automata. The Banu Musa brothers, namely Abu Ja'far, Muhammad ibn Musa ibn Shakir, Abu al-Qasim, Ahmad ibn Musa ibn Shakir and Al-Hasan ibn Musa ibn Shakir, were three ninth-century Persian scholars who lived and worked in Baghdad.

Al-Ma'mun recognized the abilities of the three brothers and enrolled them in the famous House of Wisdom, a library and a translation center in Baghdad. Studying in the House of Wisdom under Yahya ibn Abi Mansur, they participated in the efforts to translate ancient Greek works into Arabic by sending Greek texts from the Byzantines, paying large sums for their translation, and learning Greek themselves. On such trips, Muhammad met and recruited the famous mathematician and translator Thabit ibn Qurra. At some point, Hunayn ibn Ishaq was also part of their team. The brothers sponsored many scientists and translators, who were paid about 500 dinars a month. Had it not been for the brothers' efforts, many of the Greek texts that they translated would have been lost and forgotten.⁴

³ Gunalan Nadarajan. "Islamic Automation: Al-Jazari's Book of Knowledge of Ingenious Mechanical Devices", Foundation for Science and Technology and Civilization, 14th November 2008, <https://muslimheritage.com/islamic-automation-al-jazaris-book-of-knowledge-of-ingenious-mechanical-devices/>

⁴ Dimitri Gutas, *Greek thought, Arabic culture : the Graeco-Arabic translation movement in Baghdad and early 'Abbasid society (2nd-4th/8th-10th centuries)*, London & New York, Routledge, 1998, p.133.

Kitab al-Hiyal (The Book of Ingenious Devices) by Banu Musa bin Shakir (9th century) is one of the foundational texts for the development and systematic exploration of automated devices in the Islamic world. The book was commissioned by the Abbasid Caliph Al-Ma'mun, who instructed the Banu Musa to acquire all of the Hellenistic texts that had been preserved by monasteries and by scholars during the decline and fall of Roman civilization. The Banu Musa brothers invented a number of automata (automatic machines) and mechanical devices, and they described a hundred such devices in their *Book of Ingenious Devices*. This book is a large illustrated

work on mechanical devices, including automata, published in 850.

About 25 of the 100 mechanical devices introduced by the Banu Musa brothers in the book were similar or identical to those invented by Hero or Philo. However, it should be noted that although the Banu Musa brothers were influenced by Hero or Philo, many of the original mechanical devices that they first invented themselves were also significant. For example, their *Book of Ingenious Devices* introduces seven sophisticated fountain systems, which were among their original inventions.



Figure 1 – Robotic flute player by the Banu Musa brothers

The fountain devices they manufactured are designed so that one or several fountain streams can be emitted at regular time intervals, changing into various shapes such as “lily”, “shield”, and “spear”.⁵

One of the most impressive devices described in *the Book of Ingenious Devices* is a robotic flute player. Known as ‘The Instrument that Plays by Itself’, it produced different sounds by using small variations in air and water pressure by means of conical valves as automatic regulators. Pins on a rotating drum open, via tiny levers, one or more of the nine holes of a flute, which is positioned parallel to the drum. The wind for the flute is generated by water that fills a reservoir and forces the air to escape, and the whole drum is driven by a waterwheel.⁶

⁵ Gunalan Nadarajan, op. cit.

⁶ Jim Al-Khalil, *The House of Wisdom*, New York, The Penguin Press, 2011, p.74.

2) Al-Jazari

The research and production of automata in the Islamic world, which began in Baghdad, culminated in the late 12th century in Anatolia by Al-Jazar(1136-1206). Today he is regarded as an outstanding scholar who laid the foundation for mechanical engineering.

Al-Jazari is best known for writing *Kitab fi ma'rifat al-hiyal al-handasiya(The Book of Knowledge of Ingenious Mechanical Devices)*. This book described 50 mechanical devices in six categories: Clocks, Trick vessels, Liquid dispensers and phlebotomy measuring instruments, Fountains and musical automata, Water-raising machines, and Miscellaneous.



Figure 2 – Al-Jazari's Elephant Clock

He composed the book with the declared intention of enabling later craftsmen to reconstruct his machines. For this reason, the manufacture, construction and assembly were scrupulously described, giving us a wealth of information about the methods of mechanical engineers in the Islamic world.⁷

What is interesting is that Al-Jazari has devoted continuous interest and enthusiasm to the development of humanoid automata that resemble human appearance and behavior. One of the simplest humanoid automata he invented is the girl automaton that could serve water, tea or drinks. The drink was stored in a tank with a reservoir from where the drink drips into a bucket and, after seven minutes, into a cup, after which the waitress

appears out of an automatic door serving the drink.⁸ Meanwhile, Al-Jazari created various types of automatic musical instrument, some of which were designed for human-shaped musicians to perform the movements of playing music.

Among the automatic mechanical devices Al-Jazari invented, the elephant water clock is considered the best work. It was the first clock in which an automaton reacted after certain intervals of time (in this case, a humanoid robot striking the cymbal and a mechanical robotic bird chirping) and the first water clock to accurately record the passage of the temporal hours to match the uneven length of days throughout the year.⁹

⁷ Donald R. Hill, *Islamic Science and Engineering*, Edinburgh: Edinburgh University Press, 1993, p.124.

⁸ "The Arabic Automata", <http://history-computer.com/Dreamers/Arabic.html>.

⁹ Ahmad Y. Al-Hassan & Donald Hill, *Islamic Technology: An Illustrated History*, Cambridge University Press, 1992, pp.57-59.



Figure 3 – Jang Yeong-sil’s Jagyeokru (Korean self-striking water clock)

The Elephant Clock used as its timer a bowl that would slowly sink into a hidden water tank. Every half hour the timer would set off a series of dramatic sounds and movements. A ball would roll from the top of the clock and turn an hour dial, while the scribe and his pen would revolve automatically to show the minutes past the hour. As it dropped down, the ball triggered the elephant driver’s mallet to strike a cymbal.¹⁰

The Influence of Al-Jazari on the Development of Technology in Korea

The advanced automata manufacturing technology in the Islamic world influenced the development of science and technology in the East and the West. In particular, Al-Jazari elephant water clock directly or indirectly affected Jagyeokru (자격루) invented by Jang Yeong-sil (1390– after 1442) in Korea, which was, at that time, ruled by the Joseon Dynasty (1392-1910).

Jang Yeong-Sil was Chief Royal Engineer in charge of the engineering and construction project for re-equipping the Royal Observatory during the reign of King Sejong (세종 1432-1438). Jang Yeong-Sil devoted himself to making five kinds of astronomical instruments and ten timekeepers. He was one of those mechanical geniuses who

contributed to the advancement of pre-modern science and technology. In particular, he is famous for inventing Korea’s first automatic water clock called the Jagyeokru (자격루) in 1434. Jagyeokru means “self-striking water clock” in Korean.

Conclusion

Prior to the invention of the Jagyeokru, various automatic water clocks were already invented in the Islamic world and in China. Upon hearing about the usage of self-striking water clocks in foreign countries, King Sejong assigned Jang and other scientists to build a clock emulating such automatic devices. After their initial attempts failed in developing an operational water clock, Jang traveled to China to study the various designs of water clocks. Many scholars presume that around this time, Jang Yeong-Sil was inspired not only by water clocks made in China’s Song Dynasty but also by the inventions of the Islamic world, including Al-Jazari’s elephant water clock.

As a result, when Jang returned in 1434, he could make Korea's first self-striking water clock, the Jagyeokru. The Korean water clock worked by having water poured into the largest bronze vessel which flowed into the smaller vessels which then flowed into the long water tanks. When the water level rose to the appropriate level, a floating rod touched a lever device which caused a ball to roll and hit another ball at the other end. The rolling ball would trigger the gong, bell, drum, and even

¹⁰ Salim T.S. Al-Hasani(ed.), *1001 Inventions: The Enduring Legacy of Muslim Civilization*, Washington D.C., National Geographic, 2012, pp. 43-44.

a wooden puppet which marked the hour with a placard.

There is no evidence yet that Jang Yeong-sil saw Al-Jazari's elephant water clock or read the book written by him. However, there are similarities between Jang's Jagyeokru and Al-Jazari's elephant water clock in that both of them use water power,

that the power is doubled with iron balls, and those puppets serve as an indicator to inform the time. In this respect, we cannot rule out the possibility that Jang Yeong-Sil was at least indirectly inspired by the automatic water clocks invented by Muslim engineers including Al-Jazari's elephant water clock.

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