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THE TECHNICAL INGENUITY OF AL-JAZARI AND ITS RELEVANCE TO CONTEMPORARY ENGINEERING AND DESIGN

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Abstract

This paper explores the technical ingenuity of Al-Jazari, a 13th-century Muslim inventor, engineer, and polymath, and his relevance to contemporary technology and design. Al-Jazari's contribution to the history of technology is significant, as he is known for his pioneering inventions in various fields, including mechanics, automata, and fluid mechanics. His works are characterized by their intricate and sophisticated design, which not only served practical purposes but also revealed an artistic and aesthetic sensibility. Through an analysis of Al-Jazari's works, this article highlights the innovation and creativity that characterized his approach to technology and design. It shows how his inventions were based on a deep understanding of the fundamental principles of mechanics and fluid dynamics, as well as the use of novel materials and techniques. The influence of Al-Jazari's inventions on later developments in technology and design is also explored. It is shown how his ideas have influenced the design of modern machines and mechanisms. The article concludes with the assertion that Al-Jazari's technical ingenuity is of great importance to contemporary engineering and design. By studying Al-Jazari's works and ideas, engineers and designers can gain a deeper understanding of the fundamental principles of mechanics, fluid dynamics and materials science, as well as an appreciation for the artistry and aesthetic qualities of well-constructed machines. In addition, his inventions can serve as a source of inspiration for contemporary design, as they demonstrate the possibilities of combining functional efficiency with beauty and elegance. Overall, this article highlights the continued relevance of Al-Jazari's technical ingenuity to contemporary engineering and design.

Keywords: *Al-Jazari; technical ingenuity; automata; history of technology*

KECERDIKAN TEKNIS AL-JAZARI DAN RELEVANSINYA DENGAN REKAYASA DAN DESAIN KONTEMPORER

Abstrak

Artikel ini mengkaji kecanggihan teknologi Al-Jazari, seorang penemu, insinyur, dan polimatik Muslim abad ke-13, dan relevansinya dengan teknologi serta desain kontemporer. Kontribusi Al-Jazari terhadap sejarah teknologi sangat signifikan, karena ia dikenal dengan penemuan perintisnya di berbagai bidang, termasuk mekanika, otomata, dan mekanika fluida. Karya-karyanya dicirikan oleh desainnya yang rumit dan canggih, yang tidak hanya memiliki tujuan praktis tetapi juga berorientasi kepada nilai artistik dan estetika. Melalui analisis terhadap karya-karya Al-Jazari, artikel ini menyoroti inovasi dan kreativitas yang mencirikan pendekatannya terhadap teknologi dan desain. Ini menunjukkan bagaimana penemuannya didasarkan pada pemahaman mendalam tentang prinsip dasar mekanika dan dinamika fluida, serta penggunaan bahan dan teknik baru. Pengaruh penemuan Al-Jazari

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pada perkembangan teknologi dan desain selanjutnya juga dieksplorasi. Terlihat bagaimana idenya telah memengaruhi desain mesin dan mekanisme modern. Artikel tersebut diakhiri dengan penegasan bahwa kecerdikan teknis Al-Jazari sangat penting bagi rekayasa dan desain kontemporer. Dengan mempelajari karya dan ide Al-Jazari, para insinyur dan desainer dapat memperoleh pemahaman yang lebih dalam tentang prinsip-prinsip dasar mekanika, dinamika fluida, dan ilmu material, serta apresiasi terhadap kualitas artistik dan estetika dari mesin yang dirancang dengan baik. Selain itu, penemuannya dapat berfungsi sebagai sumber inspirasi untuk desain kontemporer, karena menunjukkan kemungkinan menggabungkan efisiensi fungsional dengan keindahan dan keanggunan. Secara keseluruhan, artikel ini menyoroti relevansi berkelanjutan dari kecerdasan teknis Al-Jazari dengan teknik dan desain kontemporer.

Kata kunci: *Al-Jazari, kecerdasan teknis, automata, sejarah teknologi*

Introduction

The development of technology has been a common endeavor of various civilizations and nations throughout history. Progressive societies have significantly contributed to technology through philosophical analysis and rational thought, leading to faster technological advances on a large scale. The development of technology has been documented by successive civilizations through written records that have been preserved and defended over time. One such forgotten masterpiece is the hand-drawn mechanical systems of Al-Jazari, a Muslim scholar, mechanical engineer, and inventor who lived in the 12th century. Badi'al-Zaman Ab al-'Izz ibn Ism'l ibn al-Razz al-Jazar was a Muslim polymath and mechanical engineer who lived during the Golden Age of Islam. He is best known for his book, "The Book of Knowledge on Ingenious Mechanical Devices." Al-Jazari's designs and innovations influenced the development of clocks, water-lifting machines, and other mechanical devices that were used centuries after his time. His work also laid the foundation for the development of automata and robots, which are becoming increasingly sophisticated and widespread in modern times. Al-Jazari's work represents a crucial chapter in the history of engineering, and his contributions continue to influence modern technology and design today.

The book of Al-Jazari is considered the technological accumulation of the Islamic period and reflects the technological state of mankind at that time (Cultural Ministry of Turkey 1990). Compared to other civilizations, Muslims made significant contributions to

technological development and automata that served many social purposes. Al-Jazari's book has an important written source identity to understand the technological level of the time and to determine to whom today's technology owes its origin.

Al-Jazari's work has significant implications for the study of cybernetics and robotics, particularly with regard to controllable, hand-held mechanical devices that are the closest thing to the current state of the art. His book has provided visual and intellectual descriptions for the further development of the technology, making it accessible to researchers, engineers, scientists, and a younger audience. Al-Jazari's inventions, including the internal combustion engine and the piston structure, are still relevant and important to technology today (Al-Hassani 2001, Uzun 2008, Sen 2013, al-Jazaari 1973).

Al-Jazari's work was introduced to Europe in the late 19th century by Dr. Eilhard Wiedemann and his translation into English by Donald R. Hill made his influence on modern technology even more apparent (Wiedemen 2020, Hill 1996, Steurer 2021, Duangkumpha 2019). Hill argues that Al-Jazari's ideas and inventions influenced the development of modern robots, steam engines, internal combustion engines, and other automatic control systems. His inventions, such as the crank mechanism, the programmable automaton, and segmented gears, were groundbreaking and influential in their own ways (Dirik 2023).

Al-Jazari's inventions testify to a sophisticated understanding of mechanics, for he used hydraulic and gear systems to control his machines. His work even laid the foundation for the philosophy and methodology of cybernetics, with self-regulating machines and techniques for static balancing and calibration. Today, Al-Jazari's influence on the history of engineering and automation is undeniable, as he represents a crucial turning point in the field of robotics and cybernetics (Dirik 2023, Novikov 205, Wiener 1948, Johnson and Wiener 1949, Ashby 1957, Wiener 1965). He used hydraulic and gear systems to control his machines and laid the foundation for the philosophy and methodology of cybernetics. His inventions, such as the crank mechanism, the programmable automaton, and segmented gears, were groundbreaking and influential

in their own ways.

This paper has examined the contributions of Al-Jazari and his mechanical designs, which offer important insights into the history of technology in Muslim civilization. Al-Jazari's work represents a crucial turning point in the field of robotics and cybernetics. He demonstrated a sophisticated understanding of mechanics and paved the way for future technological advances. By examining his designs and their implications, we can better understand the key scientific and technological principles of Muslim civilization and appreciate the significance of Al-Jazari's work in the context of modern technology. Overall, Al-Jazari's legacy is a testament to the cooperation of civilizations and nations throughout history, and his work continues to inspire and inform technological innovation today.

Al-Jazari's machines used a variety of mechanisms, methods, and design features that were innovative for their time and had a lasting impact on the development of technology. Some of the most important mechanisms and methods he used are:

- Camshafts: Al-Jazari's machines were among the first to use camshafts to control the movement of mechanical parts. Camshafts are devices that convert rotary motion into linear motion. They are still used today in many modern machines, including engines and pumps.
- Linkages: Al-Jazari's machines also used linkages, i.e., arrangements of rigid links connected by movable joints. Linkages can be used to transmit motion and power between different parts of a machine and are still used in many modern machines, including motors, pumps, and robotic arms.
- Crankshafts: Al-Jazari's machines also used crankshafts, devices that convert rotary motion into reciprocating motion or vice versa. Crankshafts are still used in many modern machines, including engines, pumps, and generators.
- Feedback mechanisms: Al-Jazari's machines often used feedback mechanisms to control their operation. A feedback mechanism is a device that senses the output of a machine or system and uses this information to adjust the input to the machine or system. Feedback mechanisms are still used today in many modern

machines and systems, such as control systems for aircraft and industrial processes.

- Modularity: Al-Jazari's machines were often modular, with interchangeable components that could be easily replaced or upgraded. This design approach is still used today in many modern machines and systems, including computers, smartphones, and industrial machinery.

Overall, al-Jazari's machines were distinguished by their innovative use of mechanisms, methods, and design features, many of which are still in use today. His work represents an important contribution to the history of technology and is a testament to the ingenuity of the Islamic Golden Age.

Inventions/Techniques

This section is about various mechanisms and methods used by al-Jazari, a Muslim engineer and inventor from the 12th century. One of his inventions was the camshaft, which consisted of a shaft with cams attached to it and was used in his water clocks and water lifting machines. The camshaft was later adopted in European mechanisms from the 14th century onward.

Al-Jazari also developed the crankshaft and crank-slider mechanism, which converts a continuous rotary motion into a linear reciprocating motion. This mechanism was used in his two-cylinder pumps and water-lifting machines, such as the crank-driven Saqiya chain pump and the double-acting suction pump with a reciprocating piston.

In addition, al-Jazari used innovative design and construction methods such as laminating wood to minimize deformation, statically balancing wheels, using wooden templates and paper models, calibrating openings, and casting metals in closed mold boxes with sand. Al-Jazari's contributions to mechanics and engineering were significant, and his inventions and techniques influenced later European and world advances in technology.

Segmental Gear

Al-Jazari's segmental gear is a type of mechanical component used to transmit a reciprocating motion to or from a gear wheel (Hill 1996). The segmental gear consists of a sector of a circular gear or ring with gears or teeth on the periphery or face of the gear. This allows the gear to mesh with

another gear and transmit motion between them.

Al-Jazari is credited with the invention of the segmental gear, which is considered an important contribution to the development of mechanical engineering. Before his invention, gears were usually made as complete circular discs, which limited their versatility in transmitting motion over short distances. Al-Jazari's segmental gear enabled more flexible and efficient transmission of motion in machines, which in turn led to more complex and sophisticated mechanical designs (White 1940).

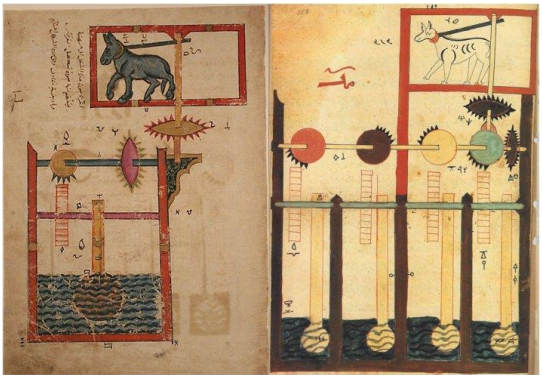

Figure 1. Al-Jazari's segmental gear mechanism (al-Jazari 1973)

The use of segmental gears in European machines did not become established until several centuries after al-Jazari's time. All in all, the segment gear represents an important milestone in the history of mechanical engineering and bears witness to al-Jazari's innovative and pioneering spirit.

Water-Raising Machines

Al-Jazari developed a series of machines for lifting water in the 13th century, many of which contained innovative and ingenious mechanisms. His machines included a saqiya chain pump, a double-acting suction pump with a reciprocating piston, and a noria, a water wheel that raised water from a lower to a higher level.

The saqiya chain pump is driven by a hand-powered wheel with a series of bowls attached to a chain. As the wheel turns, the suction cups pick up the water and move it upward, where it is discharged into a trough or irrigation channel. The double-acting piston suction pump consists of two pistons, each with a valve, that move in opposite directions to lift the water from a well or reservoir and discharge it into a trough or channel.

Al-Jazari's water-lifting machines also featured innovative mechanisms, such as the crankshaft and crank-slide mechanism he used in his two-cylinder pump. This mechanism, which is similar to the modern crankshaft, converts a continuous rotary motion into a linear reciprocating motion and is central to modern machines such as the steam

engine, the internal combustion engine, and automatic controls.

Figure 2. Al-Jazari's water-raising machines (Hill 2020)

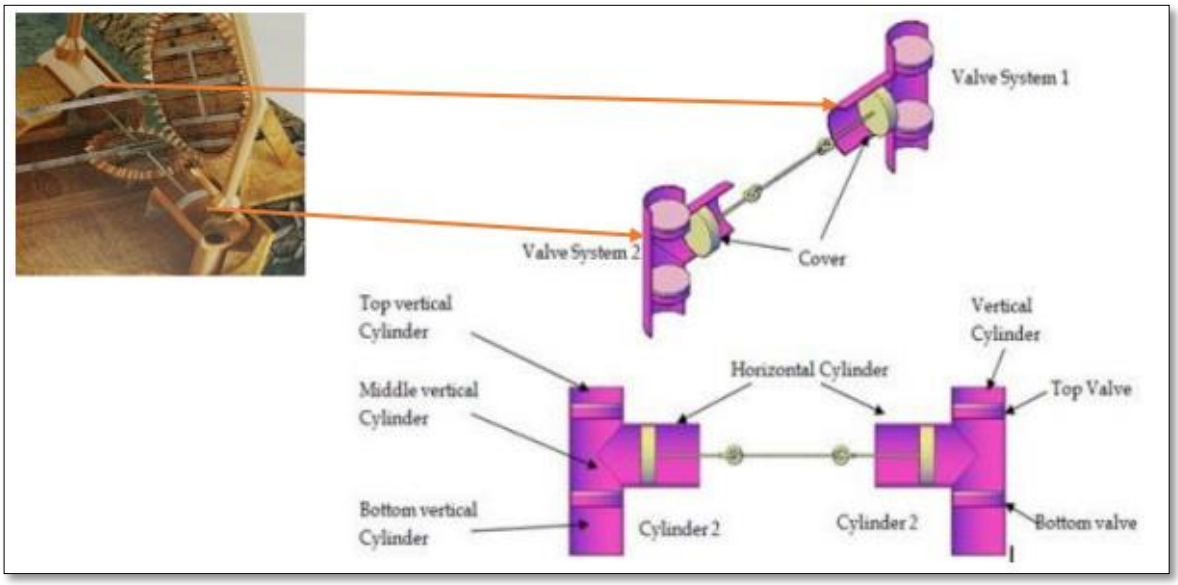

Figure 3. An illustration of hydraulic and gear system (Akmal and Salleh 2014)

Al-Jazari's invention of a water-lifting machine that used a water wheel to generate mechanical energy was a significant technical advance. This machine was driven by a gear system that transmitted the circular motion of the water wheel to a crankshaft, which mechanically converted the rotary motion into a linear thrust. The machine had suction pipes, suction pumps, double-acting pumps, and double-cylindrical piston suction pumps, all connected to the oscillating slotted rod driven by the

waterwheel. The pistons were equipped with horizontal, opposing cylinders and suction and discharge pipes, each operated by a valve. The distribution pipes were connected in the middle of the machine to create a single outlet for the irrigation system.

When the wheel turns in the water, it drives a vertical gear, which in turn drives a horizontal gear. The special slotted rod connected to the horizontal gear wheel moves back and forth in a circular motion, moving the arms attached to either side of the slotted end. The arms act on the pistons of the fixed cylinders and create a suction and pressure pump.

As each piston moves towards the opening of the cylinder, a gap is created at the bottom of the cylinder, and the flap of the intake pipe opens while the flap of the outlet pipe closes at the top. After the water from the intake pipe has been filled into the cylinder, the piston moves back and the lower flap closes, while the upper flap opens and pushes the water upwards.

The system is the first form of today's double-acting pumps, and the mechanism that moves the piston rods is the first form of the lever-rod mechanism used in today's engines.

The significance of this invention lies in several key features. First, it was the first time a true intake manifold was used. In addition, the crank-rod mechanism enabled the conversion of rotation into reciprocating motion, and the engine was also the first application of the double-acting principle. Al-Jazari's invention also included a gearbox that could drive water to power other devices. Using a unique combination of gears, he was able to change the direction of motion from vertical to horizontal. By connecting the main gear to a suction pump, he was able to create a piston-like, bidirectional motion.

Overall, Al-Jazari's invention of the water lifting device represented a significant advance in hydraulic technology, and his use of novel mechanisms and components, as well as novel mechanics, laid the foundation for today's water supply systems.

Automata

Al-Jazari is known for his contributions to robotics, particularly his invention of automated devices that run on water. Among his notable inventions are the automatically

moving peacocks, which were probably powered by a system of cams and levers. He also invented the earliest known automatic gates and created automatic doors as part of one of his elaborate water clocks. Al-Jazari's automata can be described as moving mechanical devices designed to imitate the movements of humans or animals. He created several automatic devices, such as peacocks, doors, and water wheels, which were operated by waterpower and cams. His automata focused on manipulating the environment for human comfort and practical applications, which distinguished them from the dramatic, illusion-focused designs of the Greeks (Wiedeman 2020). Al-Jazari's work in robotics was influential in advancing the field and may have influenced the work of Leonardo da Vinci during the Italian Renaissance. The practical applications of al-Jazari's work in robotics were a significant contribution to the field, although, as in other pre-industrial societies, the lack of significant impetus for the development of robotic science limited their work (Hill 1996).

Drink-Serving Waitress

Al-Jazari's drink-serving waitress is an example of an automaton created in the 13th century. It was a life-size female figure made of copper that could serve drinks to guests. The waitress would move, make gestures, and pour water or other liquids from a decanter into a cup held by the patron.

Figure 4. Al-Jazari's Drink-Serving waitress (5W Blog)

The mechanism for operating the waitress consisted of a system of gears and cams that controlled the movements of the figure's arms, hands, and head. The automaton was driven by a water wheel, and the flow of water was controlled by a series of valves and float chambers. The drink-serving waitress is a remarkable example of al-Jazari's ingenuity and

creativity in creating practical and functional automata using water-power.

Hand-Washing Automaton

Al-Jazari's hand washing machine was a sophisticated mechanical device that contained a flushing mechanism similar to that found in modern flush toilets. The device depicted a female humanoid automaton standing next to a basin filled with water. When the user pressed a lever, the water drained from the basin and the female automaton refilled it with clean water from a tank. The automaton was operated by a series of gears and levers that enabled it to perform its functions automatically.

Figure 5. Al-Jazari's Hand-washing automaton (5W Blog)

The device was an early example of an automated plumbing system and an important precursor of modern plumbing technology. It demonstrates a high degree of technical sophistication and innovation, as well as a deep understanding of the principles of fluid dynamics and mechanical engineering. Al-Jazari's invention paved the way for the development of modern plumbing systems, which are now essential for the functioning of modern cities and societies.

The Peacock Fountain

The Peacock Fountain is a remarkable invention of Al-Jazari, described in his book, The Book of Knowledge of Ingenious Mechanical Devices. The fountain is an automatic machine that mimics the movements of a peacock, which was a revered bird in the Islamic world.

The Peacock Fountain is a complicated machine consisting of a basin, a water tank, and a peacock statue mounted on a tree-like structure. The statue is equipped with numerous mechanical components, including a hydraulic pump, a float valve, and a series of camshafts and gears. The machine also contains a

music box that produces melodic tunes while the fountain is in operation.

When the machine is activated, water is pumped from the basin into the water tank. The float valve is then activated, causing the water to flow from the tank into a series of pipes that control the movement of the peacock. The camshafts and gears control the movement of the peacock's head, tail, and wings, which move in a lifelike manner. The Peacock Fountain of Al-Jazari is given in figure 2.

Figure 6. View of Peacock Fountain of Al-Jazari (National Geographic 2023)

The Peacock Fountain of Al-Jazari is a remarkable example of a hydraulic automaton designed to simulate the natural movements of a peacock. The fountain consists of a life-size peacock standing on a platform with a fountain of water issuing from its beak while the peacock's tail spreads out in colorful plumage.

Although the Peacock Fountain was designed in the 12th century, its influence on contemporary technology is remarkable. First, it is an early example of an automaton that inspired the development of modern robotics. In particular, the Peacock Fountain uses a hydraulic system to control the movement of the peacock's tail and the flow of water from its beak, which is a precursor to the use of fluid power in modern hydraulic systems. This technology has found wide application in the operation of heavy machinery, manufacturing processes, and even the movement of aircraft control surfaces.

In addition, the peacock fountain is an early example of mechatronics, a field that combines mechanical, electrical, and computer engineering. The movement of the peacock is controlled by an elaborate system of gears, levers, and pins that work in a predetermined sequence to create the illusion of natural movement. This system of pre-programmed movements is the basis of modern automation and is used in various industrial areas, e.g., assembly lines and process control systems.

Musical Robot Band

Al-Jazari's robotic band was an elaborate automaton in the form of a boat that floated on a lake and had four automatic musicians who played instruments to entertain guests at royal drinking parties. The boat was powered by a water wheel, and the flow of water was controlled by a hydraulic circuit, one of al-Jazari's innovations.

The automaton contained a programmable drum machine with pins or cams that could be moved to create different rhythms and drum patterns. This made it possible to create a variety of music and program the drummer to play different beats. The other musicians in the band were also automated and played different instruments, such as a harp, a flute, and a dulcimer.

Figure 7. Al Jazari's Musical robot band (Nadaraian 2007)

The robot belt of Al-Jazari may have been one of the first programmable automata. The mechanism could be set to play different rhythms and patterns by moving the pins of the drum machine, similar to programmable music boxes.

Clock

Al-Jazari is known for his contributions to the development of various types of clocks, including water clocks and candle clocks. Among his inventions were portable and monumental water-powered clocks. His portable water-powered scribe clock was about a meter high and half a meter wide and was successfully reconstructed. This clock used a water-driven scribe to mark the hours on a rotating paper scroll. Al-Jazari's monumental water-powered astronomical clocks were even more impressive. They displayed moving models of the sun, moon and stars and were intended to show not only the time but also the positions of the heavenly bodies in the sky. These clocks were often large, complicated machines that required a great deal of technical skill to build and operate. Al-Jazari's innovations in clockmaking were significant in their time and laid the foundation for future

developments in timekeeping technology.

Candle Clocks

Al-Jazari designed an advanced type of candle clock that was among the most sophisticated of its kind. The candle burned on the underside of a cap with a hole through which the wick passed, while the wax collected in a depression that was periodically removed. The candle rested in a shallow bowl with a ring on the side connected by rollers to a counterweight. While the candle was burning, the weight pushed it upwards at a constant speed, operating the automata in the bowl at the bottom of the candle. The clock also had a dial to show the time and a bayonet catch, a fastening mechanism still used today. This advanced design made al-Jazari's candle clock unique, and no other candle clocks of this complexity have been found.

Figure 8. Al-Jazari's Candle Clocks (Al-Hassani 2001)

Elephant Clock

The elephant clock is one of the most famous inventions of Al-Jazari, an eminent Muslim scholar, mechanical engineer, and inventor who lived in the 12th century. He lived in the 12th century. The Elephant Clock is a water-powered clock with a life-size elephant and various other mechanical figures that move and make sounds to indicate the time. The elephant clock itself is a life-size brass sculpture of an elephant mounted on top of the clock. The elephant is covered in intricate patterns and is surrounded by other smaller brass figures, including a rider, a driver, and a snake. The figures move and make sounds to indicate the time. The rider strikes a cymbal, and the driver moves his arm to beat a drum.

The elephant clock is not only a remarkable technical feat but also

reflects the social and cultural values of the time. The figures on the clock represent different regions and religions, with the rider being a symbol of the Indian subcontinent, the driver representing the Islamic Middle East, and the snake being a symbol of pre-Islamic Persian mythology. The elephant clock thus demonstrates the cultural and intellectual exchange that took place during the Middle Ages. The elephant water clock of al-Jazari is given in figure 1.

Figure 9. View of the elephant clock of Al-Jazari (Al-Jazari 2023)

The influence of al-Jazari's elephant water clock on contemporary technology can be traced through its impact on the development of mechanical and automated systems. Al-Jazari's mechanical inventions, such as the crank mechanism and segmented gears, served as basic principles for the development of modern mechanical systems.

Al-Jazari's elephant water clock was a remarkable feat of engineering. It used a complex series of hydraulics and mechanical gears to control the movement of the elephant and other components of the clock. The clock used water as its power source, with the flow of water controlled by valves and levers. The Elephant Water Clock was designed to ring a bell and spray water on the hour, with the movement of the elephant indicating the time of day.

The Elephant Water Clock was a precursor to modern automated systems and demonstrated the potential of machines to perform complex tasks with minimal human intervention. The use of water as an energy source was also a significant advance, as it provided a sustainable and renewable source of energy that could be easily controlled and manipulated.

The principles of hydraulics and mechanical gearing used in the elephant water clock are still relevant today and are used in a variety of mechanical systems such as motors, pumps, and other mechanical devices.

With the development of robots, automated manufacturing processes, and other advanced systems, the concept of automating tasks has also become prevalent in modern technology.

The clock from the time of Al-Jazari was a masterpiece of ingenuity that used a variety of mechanisms to keep time with impressive accuracy. One of the most fascinating aspects of the clock was its use of automata, which made the process of keeping time both visually and aurally interesting. The beating of the cymbal and the chirping of birds were just two examples of these charming elements. Overall, Al-Jazari's clock was a marvel of engineering and a testament to the ingenuity of mediaeval Islamic scientists. Its use of automata, closed circuits, and gravity set it apart from other timepieces of the era, and its accuracy and reliability are truly impressive.

Cybernetics

Cybernetics, a term first used by Norbert Wiener in 1948, is a general science of control and communication in animals and machines. It refers to the transmission of information and the instruments of control by which desired changes can be achieved with the help of information (Novikov 2015, Wiener 1948). Cybernetics deals with systems that behave like living beings and direct them towards the most appropriate goal. This interdisciplinary science integrates results from various fields, including control theory, communication theory, operations research, mathematics, logic, semiotics, and physiology. Over the years, cybernetics has found application in many fields, including electronics, automated machines, telecommunications, and robotics (Wiener 1965).

It is interesting that most people associate cybernetics with Wiener, although the seminal work of Al-Jazari over 800 years ago had a profound impact on this science. Al-Jazari created the cornerstones of today's mechanical and cybernetic sciences, and his machines were the world's first cybernetic systems. Al-Jazari developed automatic balance systems using water and pressure forces, inspiring today's science of automatic control. He used interactive structures with gears between buoys and pulleys, and his devices worked with hydraulic and mechanical

cybernetic systems (Carver and Scheier 2012).

The term "waterpower cybernetics" is used in reference to Al-Jazari's work because he understood the philosophy of cybernetics with "water-power" and did not use it as a concept. Other types of cybernetics include second-order cybernetics, autopoiesis, homeostasis, third- and fourth-order conceptual cybernetics, and neo cybernetics. Cybernetics has always been evaluated differently by experts. Some believe that Al-Jazari is an undeniable pioneer and scientist who initiated contemporary cybernetic and robotic studies and has no rival in any culture (Siddique, Mitchell, O'Grady and Jahankhani 2012).

From a cybernetic perspective, Al-Jazari's inventions represent a sophisticated integration of control systems, feedback mechanisms, and actuators. These elements work together to create a closed system that responds to changes in the environment and performs as desired.

In Al-Jazari's water clock, for example, a feedback mechanism uses the flow of water to maintain the water level in the tank to ensure accurate timing. This feedback system controls a series of gears and levers that move the hands and bells of the clock, producing an audible chime at regular intervals.

Similarly, in Al-Jazari's mechanical peacock, a feedback mechanism based on a series of cams and levers controls the movement of the bird's tail feathers and head, producing realistic, lifelike movement.

These feedback systems are crucial to the operation of Al-Jazari's inventions, as they allow the machines to respond to changes in the environment and maintain their intended functionality.

Without these cybernetic elements, Al-Jazari's machines would not be able to perform their intended functions with the precision and accuracy for which they are known.

Conclusions

In summary, Al-Jazari's technical ingenuity and inventions have left an indelible mark on the world of engineering and design. His contributions to automata, water clocks, and other mechanical devices were remarkable for their time, and his inventiveness is a testament to the innovative potential of human ingenuity. Al-Jazari's works are not

only a source of historical inspiration but continue to provide valuable lessons for contemporary engineers and designers. His creative approach to problem solving, which focused on combining different disciplines such as physics, mathematics, and aesthetics, can serve as a guide for today's engineers in tackling complex problems. Moreover, Al-Jazari's work highlights the importance of striking a balance between technical efficiency and practicality and aesthetic appeal and cultural significance—a balance that is a major challenge for contemporary designers.

Al-Jazari's works demonstrate a deep understanding of cybernetic principles, although he developed them centuries before cybernetics. His mechanical inventions use feedback loops, automatic control systems, and self-regulating mechanisms to achieve the desired results. Al-Jazari's water clocks, automata, and music automatons are just a few examples of how he applied these principles in his work.

Al-Jazari's works offer valuable insights into the development of cybernetics and its relevance to contemporary technology and design. His achievements were truly remarkable for their time and continue to inspire and inform modern engineers and designers. By studying Al-Jazari's inventions, engineers can better understand how to incorporate feedback loops, control systems, and self-regulating mechanisms into their designs.

Overall, Al-Jazari's technical ingenuity, interdisciplinary approach, and emphasis on aesthetics and cultural significance continue to serve as models for contemporary engineers and designers.

Al-Jazari's works represent a significant milestone in the history of engineering and cybernetics. They demonstrate the power of human ingenuity and the potential for innovative thinking that transcends time and space. The legacy of Al-Jazari's cybernetic inventions is an important reminder of the importance of looking to the past to inform the present and shape the future.

References

A. R. Amirul Akmal Bin Mohammad Yazid, Mohd Fahmi Bin Md Salleh, "The Mechanical Engineer: Abu'l –'Izz Badi'u'z – Zaman Ismail ibnu'r – Razzaz al Jazari," *Seminar on Religion and Science: Muslim Contributions*, vol. 69, no. 4, pp. 59–61, 2014, doi:

10.1246/nikkashi1948.69.59.

A. Uzun and F. Vatansever, "Ismail al Jazari machines and new technologies," *Acta Mechanica et Automatica*, vol. 2, no. 3, pp. 91–94, 2008.

C. S. Carver and M. F. Scheier, "Cybernetic Control Processes and the Self-Regulation of Behavior," in *The Oxford Handbook of Human Motivation*, 2012. doi: 10.1093/oxfordhb/9780195399820.013.0003.

Cultural Ministry of Turkey, *Olaganüstü Mekanik Araçların Bilgisi Hakkında Kitap (The Book of Knowledge of Ingenious Mechanical Devices)*. 1990.

D. A. Novikov, *CYBERNETICS: From Past to Future*. Heidelberg: Springer, 2016. – 107 p., 2015. [Online]. Available: http://www.mtas.ru/biblio/CyberneticsE.pdf.

D. Hill, *A History of Engineering in Classical and Medieval Times*. Routledge, 1996.

E. Wiedeman, *Über die Uhren im Bereich der islamischen Kultur (German Edition):* saxoniabuch, 2017. Accessed: May 30, 2020. [Online]. Available: https://www.amazon.com/Uhren-Bereich-islamischen-Kultur-German/dp/3957705053.

G. Nadarajan, "Islamic Automation : A Reading of al-Jazari ' s The Book of Knowledge of Ingenious Mechanical Devices (1206)," 2007.

H. G. Johnson and N. Wiener, "Cybernetics: Control and Communication in the Animal and the Machine.," *The Economic Journal*, 1949, doi: 10.2307/2226579.

I. al-R. al-Jazarī, *The Book of Knowledge of Ingenious Mechanical Devices*. 1973. doi: 10.1007/978-94-010-2573-7.

K. Duangkumpha *et al.*, "Urine proteomics study reveals potential biomarkers for the differential diagnosis of cholangiocarcinoma and periductal fibrosis," *PLoS One*, vol. 14, no. 8, p. e0221024, Aug. 2019, doi: 10.1371/JOURNAL.PONE.0221024.

L. White, "Technology and Invention in the Middle Ages," *Speculum*, vol. 15, no. 2, pp. 141–159, 1940, doi: 10.2307/2849046.

l-Jazari: The Mechanical Genius - Muslim Heritage Muslim Heritage. https://muslimheritage.com/al-jazari-the-mechanical-genius/ (accessed Feb. 18, 2023).

M. Dirik, "Al-Jazari: The Ingenious Inventor of Cybernetics and Robotics 1", Accessed: Feb. 17, 2023. [Online]. Available: www.dergipark.org.tr/en/pub/jscai.

M. Steurer, R. J. Hill, and N. Pfeifer, "Metrics for evaluating the performance of machine learning based automated valuation models," *Journal of*

Property Research, vol. 38, no. 2, pp. 99–129, 2021, doi: 10.1080/09599916.2020.1858937.

Medieval robots? They were just one of this Muslim inventor's creations | National Geographic. https://www.nationalgeographic.co.uk/history-and-civilisation/2020/08/medieval-robots-they-were-just-one-of-this-muslim-inventors (accessed Feb. 18, 2023).

N. H. Siddique, R. Mitchell, M. O'Grady, and H. Jahankhani, "Cybernetic Approaches to Robotics," *Paladyn*, vol. 2, no. 3, pp. 109–110, 2012, doi: 10.2478/s13230-012-0006-3.

N. Wiener, "Cybernetics, or Control and Communication in the Animal and the Machine".

N. Wiener, "Cybernetics, Second Edition: or the Control and Communication in the Animal and the Machine." p. 212, 1965.

N. Wiener, *Cybernetics; or, Control and communication in the animal and the machine.* M.I.T. Press, 1948.

S. Al-Hassani, "Al-Jazari: The Mechanical Genius," *MuslimHeritage. com*, 2001.

The 800-year-old Cutaway Graphics of Ismail Al-Jazari | 5W Blog." https://5wgraphicsblog.com/2016/11/15/the-800-year-old-cutaway-graphics-of-ismail-al-jazari/ (accessed Feb. 18, 2023).

The Book of Knowledge of Ingenious Mechanical Devices: (Kitāb fī ma 'rifat ... - P. Hill - Google Books."https://books.google.com.tr/books/about/The_Book_of_Knowledge_of_Ingenious_Mecha.html?id=EUTqCAAAQBAJ&printsec=frontcover&source=kp_read_button&redir_esc=y#v=onepage&q&f=false (accessed May 30, 2020).

W. R. Ashby, "An Introduction to cybernetics," *Psychoanal Rev*, vol. 84, no. 1, p. 156, 1957.

Z. Şen, "Ancient water robotics and Abou-l Iz Al-Jazari," *Water Sci Technol Water Supply*, vol. 13, no. 3, pp. 699–709, 2013, doi: 10.2166/ws.2013.031.