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Islamic Automation:

A Reading of al-Jazari's *The Book of Knowledge of Ingenious Mechanical Devices* (1206)

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ISLAMIC AUTOMATION: A READING OF AL-JAZARI'S *THE BOOK OF KNOWLEDGE OF INGENIOUS MECHANICAL DEVICES* (1206)[*]

Prof. Gunalan Nadarajan[**]

Introduction

The *Kitab fi ma rifat al-hiyal al-handasiyya* (The Book of Ingenious Mechanical Devices) by Ibn al-Razzaz al-Jazari was completed in 1206. It was arguably the most comprehensive and methodical compilation of the most current knowledge about automated devices and mechanics. The work systematically charted out the technological development of a variety of devices and mechanisms that both exemplified and extended existing knowledge on automata and automation.

Donald Hill, who translated and had done most to promulgate the importance of this text, claimed "it is impossible to over-emphasize the importance of Al-Jazari's work in the history of engineering. Until modern times there is no other document from any cultural area that provides a comparable wealth of instructions for the design, manufacture and assembly of machines… Al-Jazari did not only assimilate the techniques of his non-Arab and Arab predecessors, he was also creative. He added several mechanical and hydraulic devices. The impact of these inventions can be seen in the later designing of steam engines and internal combustion engines, paving the way for automatic control and other modern machinery. The impact of Al-Jazari`s inventions is still felt in modern contemporary mechanical engineering".[1]

This essay presents al-Jazari's *Book of Knowledge of Ingenious Mechanical Devices* (1206) as a significant contribution to the history of robotics and automation insofar as it enables a critical re-evaluation of classical notions and the conventional history of automation and therefore of robotics. Al-Jazari's work is presented as exemplary of what is called here "Islamic automation", where the notions of control that have informed the conventional history of automation and robotics are substituted by subordination and submission to the rhythms of the machines. Al-Jazari is in some ways the most articulate of what is a long tradition of "Islamic automation" in Arabic science and technology wherein automation is *a manner of submission* rather than the means of control that it has come to represent in our times. It is proposed here that "Islamic automation" also provides some interesting examples of what I call "untoward automation", which involves deliberate and elaborate programming for untoward behaviour in automated devices. In addition to articulating the cultural specificities of technological development, this essay positions al-Jazari's work as a catalyst for critical readings of and new directions in robotic arts.

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[1] Hill, 1998: II, p. 231-2.

Figure 1: Elephant clock of al-Jazari, from a MS copy of his treatise The Book of Knowledge of Ingenious Mechanical Device copied in Syria in 1315 by Farkh ibn 'Abd al-Latif (Ink, colors, and gold on paper; height. 30 cm – width 19.7 cm). Source: Metropolitan Museum, New York: https://www.metmuseum.org/toah/ho/07/wae/hob_57.51.23.htm

Islamic Science and Technology

Before embarking on a presentation of al-Jazari's work, it is useful to contextualize Islamic science and technology that informed and substantiated his work. It is noteworthy that the Abbasid Caliphate that 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-Mamun (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 8^{th} century till mid 11^{th} 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 9^{th} century. This quest towards developing a comprehensive knowledge resource was so ambitiously pursued that by the middle of the 10^{th}

century, the caliphate had gathered close to 400,000 volumes and by 1050, all significant works of the Hellenistic period were available in Arabic.[2]

It is noteworthy though that our current notions of science and technology are significantly different from those that mediate the quest for knowledge in Islamic societies. The word, *'ilm* that is most commonly used to denote 'knowledge' in Arabic, Hill reminds us, included a wide range of fields as astronomy, mechanics, theology, philosophy, logic and metaphysics. This practice of not differentiating between seemingly separate fields is best understood in the context of the Islamic view of the interconnectedness of all things that exist and wherein the quest for knowledge is a contemplation on and discovery of this essential unity of things. It is this essential unity and coherence of all things in the world, referred to in Islamic philosophy as *tawhid* [oneness], which makes it almost impossible to articulate and maintain the distinctions between the sciences and other areas of inquiry and experience.

According to Avicenna, a significant philosopher-scientist and an important Islamic proponent of this view, "there is a natural hierarchy of knowledge from the physics of matter to the metaphysics of cosmological speculation, yet all knowledge terminates in the Divine. All phenomena are creations of Allah, His theophanies [visible manifestations of divinity], and nature is a vast unity to be studied by believers as the *visible sign* of the Godhead [divine nature or essence]. Nature is like an oasis in the bleak solitude of the desert; the tiny blades of grass as well as the most magnificent flowers bespeak of the gardener's loving hand. All nature is such a garden, the cosmic garden of God. Its study is *a sacred act*".[3] In Islam, Avicenna's notion of "visible sign" is embodied in the term *a'yat* (sign), where the scientific study of the natural world and its manifestations does not issue from an impassioned curiosity but a passionate quest to discover these signs and thus arrive at a better understanding and appreciation of God's magnificence. The Qur'an has several instances where this invocation to Muslims to decipher the *a'yat* is made. For example, in Surah 10: "He it is who has made the sun a [source of] radiant light and the moon a light [reflected], and has determined for it phases so that you might know how to compute years and to measure [time]...in the alternative of night and day, and in all that God has created in the heavens and on earth, there are messages indeed for people who are conscious of Him".[4]

[2] See Hill, 1993: 10-14.
[3] Cited in Bakar, 1996: 114; emphasis by the author.

[4] Cited in Bakar, 1996: 70.

Figure 2: Two photos of the fascinating reproduction of the 8.5 meter high elephant clock of al-Jazari in the Ibn Battuta Mall, Dubai. This reproduction was designed by Muslim Heritage Consulting and FSTC. Al-Jazari's elephant clock was the first clock in which an automaton reacted after certain intervals of time. In the mechanism, a humanoid automata strikes the cymbal and a mechanical bird chirps after every hour. See: http://muslimheritage.com/topics/default.cfm?ArticleID=466 and http://muslimheritage.com/topics/default.cfm?ArticleID=188.

Bakar argues that in thus deciphering the peculiar ways in which each thing manifests itself and exists in this world, one is arriving at an understanding of its specific *islam* (manner of submission), i.e., of how that thing submits to the will of God.[5] This notion of *islam* as a "manner of submission" is a useful reference point to begin a discussion of the Islamic notion of technology. While, it is logical to assume that the Islamic notion of technology is related to and continuous with its notion of *'ilm*, there are practically no scholarly studies that are dedicated to the exploration of the Islamic conceptualization of technology. While there are several works that exhaustively *describe* the various technologies developed by Islamic societies and scholars, these works rarely deliberate on their specific philosophical and cultural underpinnings. This paucity might be indicative of the refusal within Islamic thought to present technology as a *material application* of scientific knowledge, a practice that is common in many conventional histories of technology. It is suggested here that in the Islamic lifeworld, technology is yet another *a'yat* but of a different sort. It is suggested that technological objects are signs that have been *made to manifest as such by human design*. And it is important here to clarify that this design itself is a sign of the submission of the person who 'makes' the technological object as much as the object's functional operations reflect its own manner of submission. In Islamic aesthetics and technology alike, the notion of the human creator is philosophically subordinated to that of God the creator. The task of human creativity in Islamic thought is thus conceived as that of *referring to* and *making manifest God's creative work* rather than 'showing off' one's own ability to create. In this sense, then technological objects are also *a' yat* that manifest the *islam* or "manners of submission" of those forces and processes that are implicated in them.[6]

'Fine Technology' as Genealogical Nexus

In this reading of al-Jazari's work I draw on Foucault's genealogical method. It is well beyond the scope of this essay, however, to engage in a full explication of the specific details and values of the genealogical method in reading histories of technology. Thus, what will be presented here is a very brief introduction to the principal elements of the genealogical method as formulated by Michel Foucault via his reading of Friedrich Nietzsche.

According to Nietzsche, who first formulated the critical possibilities of genealogy as historical method, "whatever exists, having somehow come into being, is again and again reinterpreted to new ends, taken over, transformed, and redirected by some power superior to it; all events in the organic world are a subduing, a becoming master, and all subduing and becoming master involves a fresh interpretation, an adaptation through which any previous 'meaning' and 'purpose' are necessarily obscured or even obliterated".[7] Thus, the meaning of a thing in history is not fixed and unchanging as it is sometimes conveniently assumed in conventional historical methods. The conventional historiographical practice usually seeks out the *Ursprung* (origin), wherein there is, Foucault claims, "an attempt to capture the exact essence of things, their purest possibilities and their carefully protected identities because this search assumes the existence of immobile forms that precede the external world of accident and succession".[8] The genealogical method in contrast is governed by the *Herkunfts-Hypothesen* (descent-hypothesis) that turns away from such metaphysical preconceptions and "listens to history"; leading the historian to the discovery that there is no eternal essence behind things; that things "have no essence or that their essence was fabricated in a piecemeal fashion from alien forms".[9] With his ears cocked up to detect the faintest of sounds made within the historical space, the genealogist finds "not the inviolable identity of their origin", but rather "the dissension of other things".

"Genealogy", he thus claims, "is gray, meticulous, and patiently documentary. It operates on a field of entangled and confused parchments, on documents that have been scratched over and recopied many times".[10] Foucault also argues that genealogy is able and attempts to record events in their singularity without reference to some teleological design or purpose. He recognises the usefulness of the genealogical method in subverting the totalizing histories that drew from the Hegelian teleological versions of history where usually notions of 'purpose' or 'utility' tended to predetermine the specific ways in which a thing's history was 'always-already' interpreted.

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[5] Bakar 1996: 71.
[6] It is important for me to here clarify that while I elaborate a notion of how Islamic technology was conceived within a particular historical context, it is impossible within this essay to extrapolate and extend the study into how such religiously framed notions of technology operate in contemporary Islamic societies.
[7] Nietzsche, 1967: 77.
[8] Foucault, 1980: 142.
[9] Foucault, 1980: 142.
[10] Foucault, 1980: 139.

The primary value of the genealogical method in interpreting histories of technologies, it is proposed here, is in its suspension of utility or instrumental rationale of a technological object in its readings.[11] The genealogical method forgoes the notion of 'original' utility in predetermining interpretation but instead seeks out the specific discourses and practices that constitute a particular technological object/experience. In this essay, it is proposed that there is a *genealogical nexus* between what has been variously described and discussed as machines, automation and robotics. In formulating the link between them as genealogical, the conventional practice of identifying either one of them as preceding or proceeding from the other (i.e., the habit of origin-seeking) is problematized.

It is suggested here that one develops a better appreciation of their complex historical interactions and contemporary constitution by working from this *temporary suspension of their differences* within this nexus. It is proposed here also that the notion of 'fine technology' provides a useful reference point to instantiate and analyse this nexus between machines, automation and robotics. "Fine technology", science and technology historian Donald Hill states, "is the kind of engineering that is concerned with delicate mechanisms and sophisticated controls" and that "before modern times, comprised of clocks, trick vessels, automata, fountains and a few miscellaneous devices." Hill notes that the "apparent triviality of these constructions should not…be allowed to obscure the fact that a number of the ideas, components and techniques embodied in them were to be of great significance in the development of machines technology".[12]

Some of the earliest examples of fine technology are recorded in the works of an Egyptian engineer, Ctesibius from Alexandria (ca. 300 BCE). Vitruvius, the architect and theorist claims that Ctesibius invented the organ and monumental water clock. According to Devaux, "Diodorus Siculus and Callixenes gave this description of animated statues of gods and goddesses that featured at the festivities organized in 280 BCE by Ptolemy Philadelphus in honour of Alexander and Bacchus: a four-wheeled chariot eight cubits broad, drawn by sixty men, and on which was a seated a statuette of Nysa measuring eight cubits, dressed in a yellow, gold-brocade tunic and a Spartan cloak. By means of a mechanism she would stand up unaided, pour out milk from a golden bottle, and sit down again".[13]

The works of Philo from Byzantium (230 BCE) whose text *Pneumatics* exists in a number of Arabic versions has also described a variety of automata and trick vessels that exemplify early fine technology. Another early text, that again only exists in Arabic versions, is *On the Construction of Water Clocks* by Archimedes. This work, though suspected to have been only partially written by him with later additions by Islamic scholars, was instrumental in introducing some of the principles of water-mediated control and power generation that was systematically developed by Islamic engineers. Hero from Alexandria (1st century CE) is probably one of the most well known and most widely read of the authors of fine technology. His primary texts are *Pneumatica* and *Automata* where he expounds on the fundamentals of pneumatics and plans for a variety of machines and automata that embody and are driven by such pneumatic forces.

While there are several important and interesting exponents of fine technology exemplifying Islamic automation, for the purposes of this essay, we will restrict our discussion to the work of the Banu Musa. *Kitab Al-Hiyal* (The Book of Ingenious Devices) by Banu Musa bin Shakir (9th century) is one of the

[11] A more thorough analysis of the historiographical value of the genealogical method for the history of technology, though necessary, is well beyond the scope of this essay.
[12] Hill, 1993: 122.
[13] P. Devaux cited by Ifrah, 2001: 169.

foundational texts for the development and systematic exploration of automated devices in the Islamic world. It is clear from the various references in their text that they knew of Heron's work that had already been translated by Qusta Ibn Luqa during their time (ca. 864) and possibly with their support. In fact, of the slightly more than hundred devices that they describe in their book, Hill identified twenty five devices having similar features to and in some cases almost completely resembling Hero's and Philo's automata. However, it is crucial here that despite these similarities in the physical and operational features between these automata, the culturallyspecific ways in which these machines were conceived and used by the Banu Musa are significantly different enough for one to be cautious not to perceive their work as simply derivative. It is also noteworthy that the Banu Musa were inventors in their own right and there are several machines described in this book that are uniquely theirs and perhaps even invented by them. For example, their fountains are unique in their designs and mechanical features. Hill claims that the Banu Musa "display an astonishing skill in the manipulation of small variations in aerostatic and hydrostatic pressures." This attention to and ability to harness minute variations required the use of several innovative mechanisms including the crankshaft (which Hill suggests might be the first recorded use of this historically significant technology); a variety of and differently arranged siphons; float valves that helped mediate and trigger the changes in water levels; throttling valves that helped maintain regular flow with minimal water pressure; and most importantly, the development of a sort of 'on-off' control mechanism that responded to distinct and varying limits.

The Book of Knowledge of Ingenious Mechanical Devices

Al-Jazari was in the service of Nasir Al-Din, the Artuqid King of Diyar Bakr, and he spent twenty-five years with the family, having served the father and brother of Nasir Al-Din. Al-Jazari notes in his introduction to the book, that he "never began to contruct a device of mine without his anticipating it [i.e. its purpose] by the subtlety of his (the king's) perceptions".[14] While this patronage provided him with the financial means to continue his own research into and development of such devices, he felt obligated to not just make these machines for the benefit of the functional and aesthetic pleasures of the king but also to record it for future generations and more importantly to contextualise his own work in relation to those of his predecessors whose works he was well aware of. He explicitly and/or indirectly refers to the works of Hero, Philo, Archimedes, Banu Musa, al-Muradi and Ridwan – drawing upon the technical achievements and mechanical peculiarities of their works even while noting very quickly how he has tried to further refine and more importantly, depart from their mechanisms.

The book is presented in six categories (*naw'*) – 10 chapters on water clocks including one of his most dramatic and ambitious, Elephant Clock; ten chapters on what are called "vessels and figures that are suitable for drinking sessions presenting a variety of trick automata vessels dispensing wine and water; ten chapters on water dispensers and phlebotomy (blood-letting) devices; ten chapters on fountains and musical automata, some of the devices explicitly seeking to improve on the rhythms and patterns expressed by the fountains of the Banu Musa; five chapters on water-raising machines – one version of which still survives in Damascus, in the As-Salhieh district on the slopes of Mount Qassiyoun; and five chapters on a miscellaneous list of machines including geometrical designs for a latticed door, an instrument for measuring spheres and a couple of locks. These devices are presented as *hiyal* (ingenious devices) that are driven by two forms of motive power, water and air pressures. The motive power of these pressures are

[14] Al-Jazari, 1206/1976: 15; words in parentheses added by the author.

inherently unstable and capricious and had thus to be managed in complex and meticulous ways so as to create the desired effects.

Figure 3: A creative model of a device designed by al-Jazari (chapter 6 of category III) used for measuring blood lost during phlebotomy (bloodletting) sessions, a popular therapy in the medieval world. Taken from a MS of al-Jazari's treatise copied in Egypt in 1354. Source: http://www.sciencemuseum.org.uk/images/I022/10284929.aspx

Al-Jazari's descriptions are methodical and ordered in a form that he rarely veers away from. He typically begins with a general description of the machine and follows this with a number of separate sections that provide details on the specific ways in which the machines work along with a number of accompanying drawings that illustrate the structural aspects of the machine. It is useful to note that these illustrations are relatively static with little or no dynamic elements incorporated into them to suggest their potential movement – the dynamics of the machines are only described through his exhaustive and point-to-point descriptions of how the mechanism works. In the following section, the descriptions of several automata is presented as in the original texts so as to enable a clear understanding of style, detail and specific mechanical outcomes of these machines.

Arbiter (Hakama) for a Drinking Session (Chapter 3 of Category II)

This is an elaborate three part automated *hakama* consisting of three distinct automata – a servant girl on a dais, a castle with four servant girls and a dancer and finally an upper castle with a horse and rider. The highly ritualized session begins with a servant bringing the automata in three different sections and assembling them in the middle of a drinking party seated in a circle around it. "It is then left in the middle of the assembly until a period of *about* 20 minutes has elapsed. Then it emits an audible musical sound and the horse and rider rotate slowly past the members of the assembly as if to stop opposite one of them. The dancer makes a half turn to his left and [then] a quarter turn to his right. His head moves, as do his hands, each holding a baton. At times, both his legs are on the ball. At times [only] one. The flautist plays with a sound audible to the assembly and the servant girls play their instruments with a continuous regular rhythm, with varied sounds and drumbeats. [This continues] for a while and then the rider comes to a halt, with his lance pointing to one of the party. The servant girls are silent and the dancer is still. Then the servant girl tilts the bottle until its mouth is near the rim of the goblet, and pours from the bottle clarified, blended, wine till the goblet is nearly full, whereupon the bottle returns to its previous position. The steward takes it [i.e., the goblet] and hands it to the person towards whom the lance is pointing. [After the goblet is drained] the steward puts it back in front of the servant girl. This is repeated about twenty times, at intervals of about twenty minutes. Then the door is left open in the upper castle and a man emerges from the door, his right hand indicating 'no more wine' and the left hand indicating 'two more goblets'".[15]

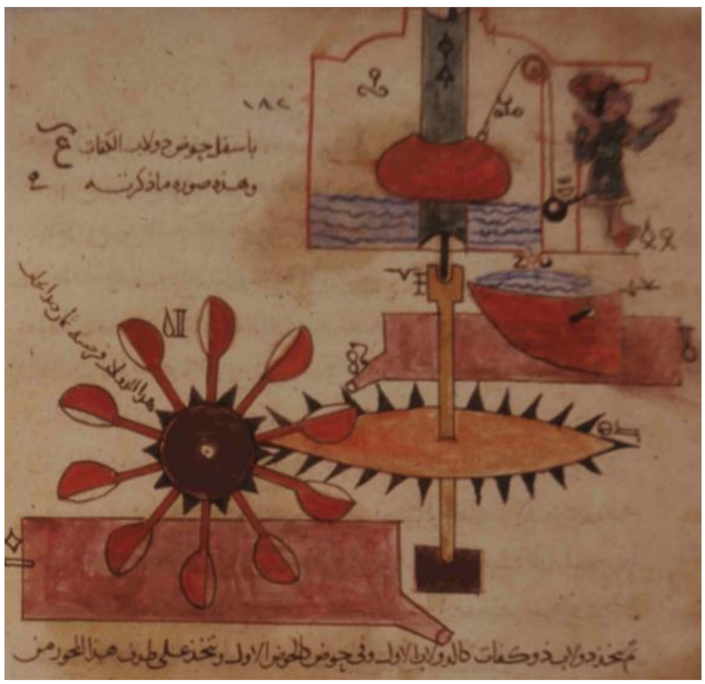

Figure 4: Automat arbiter for dispensing liquids (for drinking): al-Jazari 1974, category II, chapter 3, p. 103. Held at the Topkapi Palace Museum Library in Istanbul, al-Jazari, *Al-Jami' bayn al-ilm wa'l-amal al-nafi fi sina'at al-hiyal*, MS Ahmet III 3472.

Boat of Automata (Chapter 4 of Category II)

"The boat is placed on the surface of a large pool of water, and is seldom stationary but moves in the surface of the water. All the time it moves the sailors move, because they are on axles, and the oars move it (i.e. the boat) through the water until about half-an-hour has elapsed. Then, for a little while, the flute player blows the flute and the (other) servant girls play their instruments with that are heard by the assembly. Then they fall silent. The boat moves slowly on the surface of the water until about half-an-hour

[15] Al-Jazari, 1206/1974: 100.

has passed (again). Then the flute player blows the flute audibly and the servant girls play the instruments, as happened the first time. They do not desist until they have performed about fifteen times" (al-Jazari, 1206/1974: 107).

Figure 5: An illustration by al-Jazari of the internal mechanics of an automated boat: al-Jazari 1974, category II, chapter 4, p. 107. Held at the Topkapi Palace Museum Library in Istanbul, al-Jazari, *Al-Jami' bayn al-ilm wa'l-amal al-nafi fi sina'at al-hiyal*, MS Ahmet III 3472.

Perpetual Flute (Chapter 10 of Category IV)

"Water flows from the supply channel and falls into funnel N and flows through end H of the pipe because it is tilted towards tank K and float E. It runs through hole P into tank A, driving the air from it, which streams into pipe J. The flute plays until the water rises to the level in the siphon S – the hole P is narrower than end H (of the pipe). The water rises in the tank of float E, the float rises and lifts the extension H with its rod, pipe L tilts and discharges from end T into tank Z and float W. Water runs through hole Q into tank B, driving the air from it, which streams through pipe D into the flute's jar, which plays like a flute until tank B is filled. The water rises to the bend in siphon F, and in the tank of float W, which rises, lifting the extension of end T with its rod. The water in tank A has evacuated through siphon S. Then the water runs away from end T which comes away from tank B. And so on as long as the water flows".[16]

[16] Al-Jazari, 1206/1974: 176.

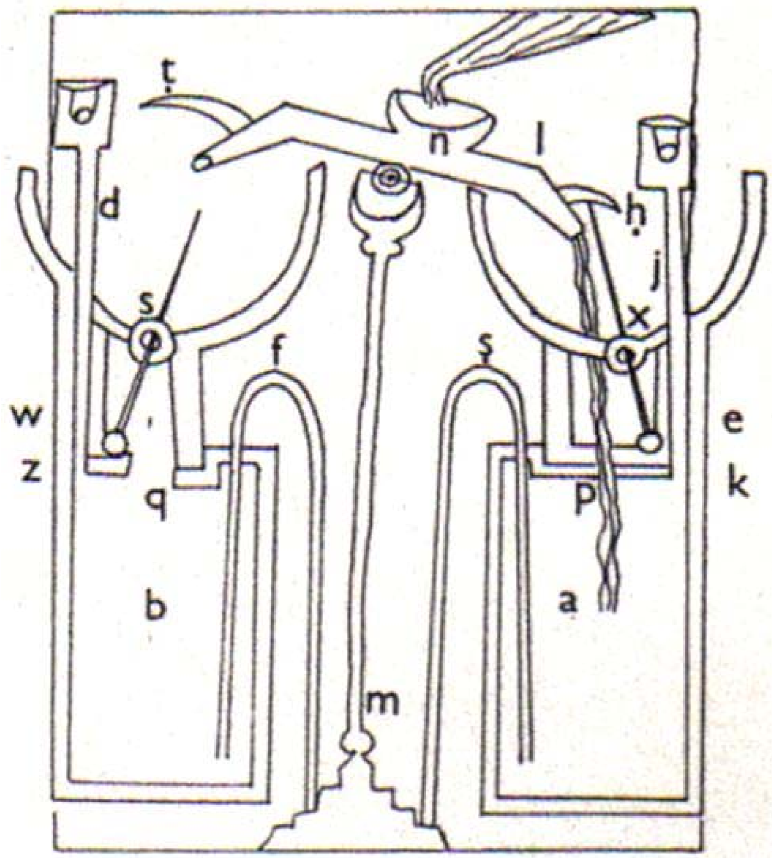

Figure 6: Diagram of the perpetual flute (al-Jazari, 1206/1974: 177)

Islamic Programming

Hill claims that one main distinguishing feature of the Arabs was a constant striving after control in order to construct machines which "would work automatically for long periods *without human intervention*" (emphasis is mine). He states, "many types of control, most of which are thought of as quite modern, were employed to achieve these results: feed-back control and closed-loop systems, various types of automatic switching to close and open valves or change of direction of flow, and precursors of fail-safe devices".[17]

In relation to al-Jazari's machines, Hill is similarly puzzled that in some cases "the techniques devised for given purposes were often more sophisticated than were strictly necessary. It is simpler, for example, to maintain a static head by fixing an overflow pipe, rather than using a valve-operated feedback control".[18] Ifrah claims that al-Jazari in his works, "gives a description of true *sequential automata*, driven notably by a camshaft, which transforms the circular motion of a sort of crankshaft into an alternating motion of a distributor: such automata thus marks a break with the Greco-Roman concept of the simple device endowed with automatic movements".[19] This, he argues, is a significant milestone in the *sequential*

[17] Hill, 1998: IV, p. 30.
[18] Hill, 1998: II, p. 233.
[19] Ifrah, 2001: 171.

programming of machines where he views it as having achieved a greater level of control achieved over the movements. While this retrospective reading of al-Jazari's works provides yet another tendency in the greater teleology of the striving towards machines that achieve greater levels of control fits well into a cybernetic conceptualization of the history of automata, it fails to acknowledge the religious and cultural specificities that informed Islamic automation as that exemplified by al-Jazari. It is suggested here that the reasons for these elaborate mechanisms that Islamic engineers devised for their machines were informed by the religious world-views within which their works were conceptualized and made.

As discussed earlier, since the notion of Islam requires the human creator to always subordinate his creative interventions to those of God as creator, these devices need to be understood not as means to show how effectively and efficiently one could control the natural forces of air and water but as conduits of allowing these forces *to play out* their capricious movements that were pleasurable because they were conceived as *expressions of God's will*. It is not surprising therefore to note in several of the early texts on automata, specifically that of Banu Musa, the expression, "if God wills" accompanying their technical descriptions of several devices. The fact that this has become such a conventional expression in the everyday lives of Muslims, might make one doubt that these references are anything but conventionalized ways of speaking and writing in these societies and thus think it not worthy of serious attention. However, this notion of including divine will in mechanical treatises is peculiar to Islamic scholars of the medieval period and thus needs to be understood within the context of how religion mediates scientific and technological aspirations.

One of the most conspicuous uses of this expression in mechanical treatises is that of the Banu Musa. In describing one of their trick vessels (Model 20) which dispenses a variety of coloured liquids through a complex series of siphons, they state: "It is [also] possible for us to install floats and valves in this jar as we did in the pitcher that accepts [nothing], if God wills."[20] While many of their trick vessels rely on the subtle 'sleights of hand' of an accomplice servant who manages the flow or lack thereof through a hole that controls the aerostatic pressures in these vessels, some of them however are based on the motive power of hydrostatic and aerostatic pressures that are not easily subject to such artful manipulations. It is noteworthy that they begin using the expression "if God wills" in Model 20 in reference to a trick vessel of the latter kind.

It is impossible within the scope of the present essay to systematically study other comparable texts of this period and make an assessment of the significance these Islamic engineers placed on divine will in mechanical devices and processes. However, based on the organic context within Islamic science and technology developed as an extension of religious enquiry in the medieval period coupled with such explicit articulations, as noted above, of the relationship between divine will and mechanical processes, it is useful to remain attentive to these interconnections. It is pertinent here that the creative programming of these devices issues not from an engineering intent to achieve greater levels of control but as a means to show the sophisticated ways in which divine will operates in/on the world. Thus the elaboration and sophistication of these machinic processes seem to be aimed at ensuring the most conspicuous and viscerally pleasing expression of the wonders of divine will.[21]

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[20] Banu Musa, 1979: 80.

[21] It has been suggested that conceptualizing these machines as being structured to express submission rather than achieve control does not represent a radical difference in interpretation insofar as submission is nothing more than the dialectical flip-side of control. While it is true that one could conceptualize 'control-submission' as a dialectical relationship expressed within machinic processes, this does not problematize the fact that control-oriented discourses of cybernetics and the Industrial Revolution that have informed conventional histories

Untoward Automation

Some aspects of Islamic automation support a useful model for rethinking programming for robotics and automation in terms of untoward automation – one *where predictable movement is substituted by programming for untoward behaviour*. It should be emphasized here that programming for untoward behaviour is not the same as programming emergent behaviour as the former is unpredictable by structurally enabling difference without setting the parameters of such differential effects. According to Ifrah, one of the principal breakthroughs in programming that led to the development of the computers is "to devise a machine whose functioning would be controlled by a modifiable control unit governed by a sequence of instructions recorded on a malleable input medium that was independent of the material structure of the internal mechanisms".[22]

Interestingly and conversely, one of the features that enable Islamic automation to sustain its untoward behaviour is the fact that there is no such separation. The material structure of these automata, the motive power that drives them and the material elements that support the sequential programming are intricately interconnected. In the concluding parts of this essay, some unique features of this "untoward automation" are presented through the discussion of three kinds of automata developed by al-Jazari.

For the fountains (*fawwara*) that al-Jazari developed and describes in his book, he claims to have drawn some of his ideas from the Banu Musa. Al-Jazari had very specific ideas of how to improve on the designs of his predecessors, the Banu Musa. He claims that of the fountains that change shape (*tabaddala*), "I did not follow the system of the Banu Musa, may God have mercy upon them, who in earlier times distinguished themselves in the matters covered by these subjects. They made the alternation with vanes turned by wind or by water do so that the fountains were changed at every rotation, but this is too short an interval for the change to appear (to full effect)".[23] Al-Jazari was obviously more concerned with creating an aesthetic experience one could dwell upon rather than present such fountains as mere distractions. This concern towards prolonging, intensifying and diversifying the experiences of those who encounter these devices is also found in an another discussion (Category IV, Chapter 7) where he notes this of a particular musical automata of a predecessor he had personally examined: "even if the (water) wheel caused a number of rods to fall in succession it would not be slow enough to display the changes adequately." However, his designs were despite their attention to longer intervals between spurts, coordinated alternations and diverse shapes, only seemingly more programmed. The composite result of these programmes do not seem to be focused on creating more predictable fountains that had a regularized rhythm but to bring a greater level of variety and depth to the experience without compromising on the untowardness of the fountains' repertoire.

In the different phlebotomy (blood-letting) devices he constructed, al-Jazari incorporates elements into its automated operations that show sensitivity to the psychological state of the patient who is being bled (*al-mafsud*). He states clearly at the outset of the section where he discusses these devices that "it is based

of automation are radically different from those that informed medieval Islamic engineering of automata.

[22] Ifrah, 2001: 178.

[23] Al-Jazari, 1974: 157.

upon [the work of] a predecessor, that was simply a sphere for collecting the blood. I have excelled him with various designs".[24]

He describes how one of these devices incorporating two automated scribes is programmed to constantly switch between providing accurate information to the patient who is bled (*al-mafsud*) on the exact amount of blood that is filling the basin and distracting the patient from these indicators. He writes, "I decided to use two scribes because the scribe in the circle rotates and then his pen becomes invisible to the patient, and the scribe's back turns towards the patient's face, while the board (that reveals the measurements) is not concealed from him at all".[25] Al-Jazari also incorporates within this particular blood-letting device an elaborate mechanism for constantly distracting the patients even while reassuring them that the procedure is progressing smoothly. He has incorporated within the castle that forms the principal motif for this device, a series of twelve automated doors that open each time a specific quantity (in this case, 10 *dirhams*; an equivalent of 30grams) has been gathered in the basin, to reveal an automata (a young male servant) that carries a board indicating 'ten' so as to reinforce the measurement indicated initially by the automated scribe. One can easily imagine how the constant distraction provided by the rotating scribes and the successive openings of the doors that result therefrom would have helped a patient get through this painful procedure.

With regard to the Boat of Automata described above, Hill interestingly comments, "no method is described for imparting movement to the sailors, which indeed could only have been done while water was being discharged, not throughout the entire session" and also that "the interval between successive discharges would lengthen as the static head in the reservoir fell".[26] These comments indicate firstly, an inability on the part of Hill to fully appreciate the aesthetic appeal of the untoward automation that many of al-Jazari's automata seem to exemplify, where one's amusement derives not in the continuous and regular rhythms of automated performance but in the unpredictable and therefore necessarily surprising flurry of movements. For example, Hill has elsewhere noted that an important feature of Islamic machines is "the frequent occurrence of delayed-action mechanisms, which delayed the opening or closing, until a set period had elapsed".[27] However, it is noteworthy that Hill does not seem to consider the possibility that these delays were not always seeking to effect control over the timing of these automated movements especially since the delays did not mediate the motive power so as to effect a controlled movement. Very often what resulted from these delays was a movement that had an order that was within certain predefined but not completely controlled parameters. So these delay mechanisms might have been more focused on an elegant management and 'languishing within' the subtle caprices that resulted from them rather than their control.

Conclusion

This essay is a modest contribution to the displacement of al-Jazari from the linear and conventional histories of automata that view him as an early proponent of 'not so effective yet' methods of controlling machinic movements through programming. It has been argued here that the task of what has been referred to here as Islamic automation reflected in al-Jazari's works was not to achieve effective control over an automata but to present through these automated processes, a vicarious expression of divine will

[24] Al-Jazari, 1974: 136.
[25] Al-Jazari, 1974: 146; words in parentheses are mine.
[26] Hill, 1974: 256.

and the peculiar *manners of submission* inherent to those forces that provide the motive power for these devices. It has also been suggested that al-Jazari's work provides a useful platform to rethink automation in terms of untoward automation – a notion that might prove especially significant in developing new ways of working with robotic arts that are not informed by and therefore celebrate the departure from the instrumental logic of conventional robotic programming.

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[27] Hill, 1976: 233.