TRANSLATED into Chinese by Dr. Xiaodong Chen, University of Oklahoma

PDF page 1

[EN]

Robots and Other Amazing Gadgets Invented 800 Years Ago explores the origins of eight incredible inventions based on automation during a time when there was no electricity, circuit boards, or computers. In today's world of modern electric devices at our fingertips, this book encourages children to explore the natural world at its most fundamental level to gain a better understanding of the physical principles of engineering. An educational read for children ages 6-12, this book will inspire them to go outside to explore, watch, and think about how the world works.

[CN]

《诞生自 800 年前的机器人和其他神奇小工具》探索了八项基于自动化技术的惊人发明的起源，这些发明诞生在没有电力、电路板和计算机的时代。在电子设备触手可及的当今世界，这本书鼓励孩子们从最基础的自然世界出发，探索并更好地理解工程学的物理原理。这是一本为 6 至 12 岁儿童编写的教育读物，它将激励他们走出家门，去探索、观察并思考世界的运作方式。

[EN]

Robots and Other Amazing Gadgets Invented 800 Years Ago

[CN]

诞生自 800 年前的机器人和其他神奇的工具

[EN]

Faisal Hossain and Qishi Zhou

Illustrated by Hatice Sena Balkan

[CN]

作者：Faisal Hossain；Qishi Zhou

插画制作：Hatice Sena Balkan

PDF page 4

[EN]

For our Earth’s most precious resource: our children.

[CN]

献给地球上最宝贵的资源：我们的孩子们。

[EN]

Authors' Note

In today's world, we are exposed to automation from an early age. For children who are just beginning to develop their senses and explore their new world, this is sometimes the first experience they can remember. Thanks to the internet, computers, and on-demand services, our children are perhaps more "wired" than they have been at any point in human history. The COVID-19 pandemic has accelerated this exposure to automation due to the need for online schooling. As the fifth industrial revolution creeps into all walks of life, we have wondered about the psychological effects automation may have on our children. If our children are exposed to such extensive automation from an early stage, will they ever learn to appreciate or truly understand how the physical world works? Will they understand nature and the basic laws that govern the analog world we live in, or will they think that the internet has it covered?

Our curiosity about this issue led us to write this children's book when we accidentally discovered that the robot was not a modern invention. The first documented robot was invented almost 800 years ago by a polymath named Ismail Al-Jazari who lived in modern-day Iraq. Jazari predated Leonardo da Vinci and was a prolific inventor of automated devices including tea-dispensing robots, mechanical clocks, automated flutes, washing machines, and toilet cisterns, many of which are still used today. In many circles, Jazari is often called "the father of robotics and cellular automata." Our fascination with Jazari became addictive after we learned that all his inventions based on automation were created when there was no electricity, circuit boards, or diodes to control logic of an operation. Yet, Jazari found a way to automate a series of "instructions" by using water. He used concepts of hydraulics and hydrostatic forces to create his "circuit boards" running on water energy. We believe these medieval inventions provide a teaching moment for our children to help them think of the natural world at the most fundamental level, and make connections to electronic devices they are now getting increasingly exposed to.

While working on this book, we felt that if we could illustrate some of Jazari's inventions appropriately for our children and explain the basic concept behind them, they could be inspired to learn more about the physical world the analog way (without using the internet or an app). Basically, such a book could perhaps make our children want to go outside, watch, explore, and think about the everyday motions of trees, wind, birds, rivers, clouds, and how they all work. Our hope is that our children will also learn to appreciate that mastery of fundamental concepts is all we need to overcome challenges—not electricity,

LCD screens, or fancy phones and apps. If the solution is physically sound at the conceptual level, it will work and do the job of automation even at a crude level.

We sought help from a variety of sources in creating this children's book. First, we had to access Jazari's modern-day rendition of his book titled The Book of Knowledge of Ingenious Mechanical Devices that was originally published 800 years ago and translated by Donald Hill. This book was supplemented with a more recent and wonderfully illustrated book in Turkish titled Cezeri'nin Olağanüstü Makineleri: Herkes İçin Cezeri by Mehmed Ali Çalışkan. Our wonderful Turkish friends Mehmet Ozcelik and Bilal Çorbacıoğlu helped translate many of Jazari's key inventions. Our other and equally wonderful friends Merve Cirisoglu and Hatice Sena Balkan (of Animatick Arts) helped illustrate inventions from a child's perspective to explain the basic concepts that rule the natural world.

In total there are eight inventions shown here. Each invention has an illustration and an explanation of how it works. They are organized from the simplest and easiest to understand, to the more complex inventions with more moving parts. Our hope is that this book will inspire children to learn about and appreciate the real world we live in as much as their laptops and phones.

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[CN]

作者序

在当今世界，我们从很小的时候就开始接触自动化技术。对于刚刚开始发展感知能力并探索新世界的孩子们来说，这有时是他们能记住的最初体验。得益于互联网、计算机和按需服务，我们的孩子们可能比人类历史上任何时候的同龄人都更加"数字化"。借着对在线教育的推动，COVID-19 疫情进一步普及了这种和自动化技术的接触。随着第五次工业革命逐渐渗透到生活的方方面面，我们不禁思考自动化可能对孩子们产生的心理影响。如果我们的孩子从小就接触如此广泛的自动化技术，他们是否还能学会欣赏或真正理解物理世界的运作方式？他们会理解自然以及支配我们这个模拟世界的基本规律吗？还是他们会认为互联网已经涵盖了一切？

我们对这一问题的好奇心促使我们创作了这本儿童读物，而这一切始于我们偶然的发现：机器人并非现代发明。第一个有记载的机器人是由生活在现今伊拉克地区的博学者伊斯梅

尔·阿尔-加扎里（Ismail Al-Jazari）在大约 800 年前发明的。加扎里生活在比达·芬奇（Leonardo da Vinci）更早的时期，是一位多产的自动化设备发明家，他的发明包括茶水分配机器人、机械钟、自动长笛、洗衣机和马桶水箱，其中许多至今仍在使用。在许多领域，加扎里常被称为“机器人学和元胞自动机之父”。在我们意识到他的所有基于自动化的发明都是诞生于一个没有电力、电路板或二极管来控制操作逻辑的时代后，我们对他的痴迷变得愈发强烈。在那个时代，加扎里找到了一种利用水力自动化“指令”的方法：他运用液压和静水压力的概念，创造了以水能为动力的“电路板”。这些中世纪的发明为我们的孩子们提供了一个学习的机会，帮助他们从最基础的层面思考自然世界，并将其与他们现在日益接触的电子设备联系起来。

在本书的创作过程中，我们意识到如果我们能够以适合的方式向孩子们展示加扎里的一些发明，并解释其背后的基本概念，他们可能会受到启发，以类似的方式（即不使用互联网或应用程序）更多地了解物理世界。这样一本书或许能吸引我们的孩子们走出家门，观察、探索并思考树木、风、鸟类、河流、云朵等日常现象背后的运作方式。我们希望孩子们也能学会欣赏这样一个事实：基本概念——而不是电力、液晶屏幕或花哨的手机和应用程序——是我们解决所有问题所需要的基础。如果一个解决方案在物理概念层面上可行，那么即使是在粗糙的工程层面上，它也能发挥作用并完成自动化的任务。

在这本儿童读物的创作过程中，我们得到了许多帮助。首先，我们必须查阅加扎里的现代版著作《精巧机械装置的知识之书》，这本书最初于 800 年前出版，由唐纳德·希尔（Donald Hill）翻译。我们还参考了一本更新且配有精美插图的土耳其语书籍《Cezeri’nin Olağanüstü Makineleri: Herkes İçin Cezeri》，作者是穆罕默德·阿里·恰勒什坎（Mehmed Ali Çalışkan）。我们出色的土耳其朋友穆罕默德·厄兹切利克（Mehmet Ozcelik）和比拉尔·乔尔巴哲奥卢（Bilal Çorbacıoğlu）帮助翻译了加扎里的许多关键发明。我们的其他朋友梅尔韦·奇里索格鲁（Merve Cirisoglu）和哈蒂斯·塞纳·巴尔坎（Hatice Sena Balkan，来自 Animatick Arts）则帮助我们从孩子的视角绘制了这些发明的插图，以更好地向孩子们解释支配自然世界的基本概念。

本书共展示了八项发明。每项发明都配有插图及其工作原理的说明。这些发明从最简单易懂的开始，逐步过渡到更复杂、部件更多的发明。我们希望这本书能激励孩子们学习和欣赏我们所生活的真实世界，就像他们热爱他们的笔记本电脑和手机一样。

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PDF page 7

[EN]

Who Invented Robots 800 Years Ago?

The inventor's name is as long as his list of inventions: Badī‘ az-Zaman Abu l-‘Izz ibn Ismā ‘īl ibn ar-Razāz al-Jazarī. He is more commonly known as Al-Jazari, and he was born sometime during the twelfth century in northern Iraq. Considered a polymath, a mechanical engineer, and an artist, Al-Jazari is best known for his book The Book of Knowledge of Ingenious Mechanical Devices (in Arabic, Kitab fi ma'rifat al-hiyal al-handasiya). A polymath is generally someone who has a vast range of knowledge and expertise with ideas far ahead of their time, like a Renaissance person such as Leonardo da Vinci. Al-Jazari is known as "the father of robotics."

Keep reading to find out why!

[CN]

谁在 800 年前发明了机器人？

这位发明家的全名和他的发明清单一样长：巴迪·阿兹-扎曼·阿布·勒-伊兹·伊本·伊斯梅尔·伊本·阿尔-拉扎兹·阿尔-加扎里（Badī‘ az-Zaman Abu l-‘Izz ibn Ismā‘īl ibn ar-Razāz al-Jazarī）。他更为世人熟知的名字是阿尔-加扎里（Al-Jazari），出生于 12 世纪的伊拉克北部。他是一位博学者、机械工程师和艺术家，最著名的作品是《精巧机械装置的知识之书》（阿拉伯语书名《Kitab fi ma'rifat al-hiyal al-handasiya》）。博学者通常指那些拥有跨越广泛领域的知识并在思想上远远超前于同时代的人，比如像达·芬奇这样的文艺复兴时期人物。阿尔-加扎里被誉为"机器人学之父"。

请往后阅读，了解其中的原因！

[EN]

Ismail Al-Jazari was a polymath, an engineer, an artist, and a prolific inventor.

[CN]

伊斯梅尔·阿尔-加扎里（Ismail Al-Jazari）是一位博学者、工程师、艺术家，也是一位高产的发明家。

PDF page 8

[EN]

Water-Flowing Timer

Today, we have a timer or a stopwatch on our phones to measure a specified length of time. In the twelfth century, Al-Jazari came up with a water-flowing timer based on the concept of a sinking bowl inside a water container. He called the bowl “tarcehar,” and used the principles of Archimedes and some meticulous engineering to perfect the timer for use in mechanical clocks.

To understand how Al-Jazari’s timer works, think of a sinking ship, like the Titanic. As water seeps in the ship through the cracked hull, the ship becomes heavier and gradually sinks. If we could calculate the rate at which water seeps in, the time taken for the Titanic to sink completely could be calculated.

In Al-Jazari’s invention, the tarcehar is a bowl with a hole in the bottom that floats in water. When water seeps into the tarcehar through the hole, this makes the tarcehar slowly descend for a specified amount of time, which can be adjusted by the size of the hole. Once the tarcehar is full, it sinks rapidly to the bottom of the water container. Al-Jazari used this timed movement to great effect as a trigger or a fuse to operate many of his more complex inventions.

Al-Jazari placed a piece of agate stone on the water intake hole at the bottom of the tarcehar bowl. First, a very small hole was drilled, and the agate stone was attached to it with wax. The tarcehar bowl was then placed in water. Due to hydrostatic pressure, water started to seep in the bowl and the hole gradually enlarged. This caused the tarcehar bowl to sink after a specified time. The role of the agate stone is to act as a trigger when the tarcehar bowl is completely sunk. With strings attached to the stone, a variety of trigger mechanisms can be devised when the tarcehar sinks. The same principle is applied to record time or generate a new motion in mechanical clocks such as the Elephant and Boat Water Clocks, also invited by Al-Jazari.

[CN]

水流计时器

如今，我们的手机上都有计时器或秒表来测量特定的时间长度。而在 12 世纪，阿尔-加扎里发明了一种水流计时器，它利用一个在水里下沉的碗来度量时间。他将这个碗称为“tarcehar”，并利用阿基米德杠杆原理和一些精密的工程技术，将其作为一个时钟元件应用到机械钟表中。

要理解阿尔-加扎里的计时器是如何工作的，可以想象一艘正在下沉的船，比如泰坦尼克号。当水通过破裂的船体渗入船内时，船会变得更重并逐渐下沉。如果我们能计算出水渗入船内的速度，就可以计算出泰坦尼克号完全下沉所需的时间。

在阿尔-加扎里的发明中，tarcehar 是一个底部有孔的碗，漂浮在水中。当水通过孔渗入 tarcehar 时，碗会缓慢下沉，下沉的时间可以通过孔的大小来调整。一旦 tarcehar 装满水，它就会迅速沉到水容器的底部。阿尔-加扎里巧妙地利用这种定时运动作为触发器或引信，来操作他发明的其他更复杂的机械装置。

阿尔-加扎里在 tarcehar 碗底部的进水孔上放置了一块玛瑙石。他在碗底钻了一个非常小的孔，并用蜡将玛瑙石固定在孔上，然后将 tarcehar 碗放入水中。在静水压力作用下，水开始渗入碗中，孔逐渐扩大，导致 tarcehar 碗在特定时间后下沉。玛瑙石的作用是在 tarcehar 碗完全下沉时充当其他机械运动的启动器：通过绑在其上的绳子，玛瑙石可以在 tarcehar 下沉时触发出各种启动机制。这一原理被应用于记录时间或在机械钟表中产生新的运动，例如本书后文中将要介绍的同样由阿尔-加扎里发明的大象水钟和船形水钟。

[EN]

Modern-day stopwatch.

[CN]

现代秒表

[EN]

Al-Jazari’s Water-Flowing Timer.

[CN]

阿尔-加扎里的水流计时器

PDF page 9

[EN]

Four-Cycle Mechanical Gear System

Al-Jazari invented an animal-powered, four-cycle gear system to scoop water from a river or well for irrigation. The concept is very similar to four-cylinder engines used in motor vehicles today, where the motion of one of the pistons rotates the crankshaft by 90 degrees, and the other pistons follow. Here, the animal turns a shaft by 90 degrees, which leads to a vertical gear to rotate and lift a scoop that naturally stays immersed in water in the well or river at a lower level.

This system of gear implementation was not seen before Al-Jazari's time. Remember, Al-Jazari's inventions were made a few centuries before the European Renaissance and the Industrial Revolution. Al-Jazari built the four-cycle gear system having to consider angular motion and phased difference. In fact, today's simple concept of rotary motion leading to linear motion of a piston that is used widely in vehicles was actually first invented by Al-Jazari.

[CN]

四循环机械齿轮系统

阿尔-加扎里发明了一种由动物驱动的四循环齿轮系统，用于从河流或井中舀水灌溉。这一概念与当今机动车中使用的四缸发动机非常相似：其中一个活塞的运动带动曲轴旋转 90 度，其他活塞随之运动。在阿尔-加扎里的装置里，畜力将轴转动 90 度，从而带动垂直齿轮旋转并提升一个舀水的勺，这些勺子在运动前都待在井或河流中的较低水位处并浸入水下，被提升时就能将水带起。

这种齿轮系统的运用形式在阿尔-加扎里之前从未出现过：阿尔-加扎里的发明比欧洲文艺复兴和工业革命早了几个世纪。阿尔-加扎里在构建四循环齿轮系统时，必须考虑角运动和相位差。事实上，如今广泛应用于车辆中的简单概念——旋转机构驱动活塞做线性运动——就是由阿尔-加扎里首次发明的。

[EN]

A four-cycle gear system invented by Al-Jazari.

[CN]

阿尔-加扎里发明的四循环齿轮系统

[EN]

An animal-powered, four-cycle mechanical gear to scoop water for irrigation invented by Al-Jazari.

[CN]

阿尔-加扎里发明的由畜力驱动的四循环机械齿轮系统，用于舀水灌溉

[EN]

Today, four-cylinder engines are used in motor vehicles that incorporate the concept of a course-cycle gear system.

[CN]

如今，四缸发动机被用于机动车辆中，其中就融入了阿尔-加扎里的四循环齿轮系统概念

[EN]

Piston moving backward and forward based on circular motion.

[CN]

圆周运动机械驱动的活塞线性运动

PDF page 10

[EN]

Automatic Directional Control System

Al-Jazari came up with a water-based directional control system that surprised even himself! In his original design book he called this invention “strange and surprising.” Today, directional control systems are used in many applications to direct or stop the flow of pressurized air or oil to an appliance such as an HVAC system.

The idea behind this invention is to have water flow into two different streams, and the flowrate of each can be controlled as desired. One of the streams leads to a scoop that is paired with another at 90 degrees with each other. The other stream can be drained to a separate pipe. As the scoop collects water, it becomes heavier and starts to rotate downward, which causes the empty scoop to rotate upward. A point will come when the scoop with water will reach the position where all the water must drain at the same instant when the other scoop reaches a horizontal position under the other stream to start collecting water. This process repeats itself, but in the opposite direction after a fixed interval of time, as long as water is maintained in the two streams. The interval of time can be programmed according to flowrates and size of the scoop. With differing flow rates or scoop sizes, two different intervals of time can be made part of the repeat cycle for direction control.

[CN]

自动流向控制系统

阿尔-加扎里发明了一种可以控制水流流向的系统，而连他自己都对这一装置感到无比惊讶！在他的原始设计书中，他自己也称这项发明“奇特而令人惊叹”。如今，类似的流向控制系统被广泛应用于许多设备中，用于控制机械装置中高压空气或油的流动，例如暖通空调系统（HVAC）。

这项发明的核心概念是将水流分成两股不同的小水流，每股的流量可以按需调整。其中一股水流流入一个舀水勺，该舀水勺与另一个 与之成 90 度角的勺配对。另一股水流则可以被排入单独的管道。当水流冲向舀水勺时，它会变重并开始向下旋转，这导致空的舀水勺向上旋转。当装满水的舀水勺到达必须排空水的位置时，另一个舀水勺正好在另一股水流下达到水平位置，开始收集水。只要水流在两个勺子之间保持交替流动，这个过程就会以固定的时间间隔重复，而时间间隔又可以根据水流流速和舀水勺的尺寸进行调整。通过设置不同的流速或舀水勺大小，可以将两个不同的时间间隔纳入这一控制方向的重复循环中。

[EN]

Directional control of water flow simplified. When the piston is pushed down, water shown in blue flows from right to left from a tank on the right side. At the same time, water shown in light gray flows in the opposite direction (from left to right). With such a system, we can have water flowing in opposite directions and use it to start, stop, or withdraw flow from an appliance.

[CN]

水流流向控制的简化示意图。当活塞被向下推动时，蓝色所示的水从右侧的水箱中自右向左流动。与此同时，浅灰色所示的水则朝相反方向流动（从左向右）。通过这样的系统，我们可以让水朝相反方向流动，并利用它来启动、停止或从其他设备中抽出水流。

[EN]

A water-based directional control system invented by Al-Jazari. As long as water keeps flowing into the two different streams, any interval of time for changing direction from clockwise to counterclockwise can be programmed based on the size of the scoop.

[CN]

阿尔-加扎里发明的自动流向控制系统。只要水持续流入两股不同的流中，就可以通过调整舀水勺的大小设定从顺时针到逆时针方向切换的时间间隔

PDF page 11

[EN]

Water Horn

Al-Jazari invented the concept of pressurizing air with water to create sound that he used in a horn, and later in perpetual flutes playing alternate notes. It is quite ingenious, yet simple if you think about it. In today's world, we can think of this as a loud whistling kettle.

Water flows into an airtight container by gravity. As water rises inside the container, it pressurizes the air inside. There is a horn attached to the container on one end. This horn is basically a valve that lets air out only when it reaches a certain pressure. With water collecting in the container, the time it takes for the horn to blow and how often it sounds can be meticulously timed. The horn can even be set to go off at fixed intervals by having another pipe to siphon off the water.

[CN]

水号角

阿尔-加扎里发明了利用水压缩空气而产生声音的概念，并将其用于号角，以及后来的可以演奏多个音符的永续长笛中。这一发明非常巧妙，但仔细想来其中的原理却很简单。今天，我们可以将其简单视为一个响亮的鸣笛水壶。

水通过重力流入一个密闭容器。随着水在容器内上升，它会压缩容器内的空气。容器的另一端连接着一个号角。这个号角本质上是一个阀门，只有当空气压力达到一定水平时才会释放空气。随着水在容器中积聚，可以精确计算号角吹响的时间以及声音的频率。甚至可以通过另一根管道利用虹吸原理将水排出降低空气压力，使号角以固定的间隔响起。

[EN]

A water horn invented by Al-Jazari that works on the basis of pressurizing air with water.

[CN]

阿尔-加扎里发明的水号角，其工作原理是利用水压缩空气

[EN]

A whistling kettle that boils water uses the concept of pressurized air and water vapor flowing through a small opening to create a sound, and announces that the water is boiling.

[CN]

鸣笛水壶利用加压空气和水蒸气通过小开口流动产生声音的概念，通知外界水已煮沸

PDF page 12

[EN]

Automatic Tilting Buckets

For Alternate Motion Without realizing that he was pioneering “control theory” that had not yet been invented 800 years ago, Al-Jazari used water to control the perpetual motion of tilting buckets and control alternate motion. Today, we see such examples in water amusement parks where tilting water buckets splash a large volume of water once they are filled.

It’s another simple, yet genius concept. There are two tilting buckets placed next to each other like a balance. The buckets are shaped like the front hull of a ship and held with a pivot. Above them is a pipe carrying water that is pivoted in the center. Water will flow through this pipe only to one of the buckets when it is not balanced. The placement of the pivot for the bucket and the shape of the bucket are designed such that when the bucket is full, it never tilts over backwards due to a resting block below. When the bucket is filled with water carried by the tilted pipe above, balance is lost, causing the bucket to tilt forward and empty. Two actions are triggered with this draining motion. First, the rotation of the bucket causes the pipe to tilt to the other direction and start filling the other bucket. After a fixed interval of time, the water that drains from each bucket as it empties can be channeled in alternating directions to operate a variety of operations, such as alternating fountains or flutes.

[CN]

自动倾斜水桶

用于交替运动

阿尔-加扎里在 800 年前人类尚未发明“控制理论”的时候就能够利用水来控制水桶的翻转并实现两个水桶的交替运动。如今，我们在水上乐园中可以看到类似的例子，装满水的水桶在翻倒时会泼洒出大量水。

这又是一个简单却天才的概念。两个倾斜的水桶像天平一样并排放置。水桶的形状像船的前部，并通过一个枢轴固定。水桶上方是一根在中点与水源相连的输水管。当两个水桶不平衡时，水就会通过这根输水管流向其中一个水桶。水桶的枢轴位置和形状设计使得当水桶装满水时，由于被下方的固定块撑住，水桶会向前倾倒。当水桶被上方倾斜过来的管道输送的水填满时，平衡被打破，导致水桶向前倾斜并排空。这一排水动作会触发两个效果：水桶会顶起输水管使其向另一侧倾斜，同时水流开始填充另一个水桶。经过固定的时

间间隔后，从每个水桶排出的水可以被引导到交替方向，以执行各种操作，例如交替喷泉或长笛。

[EN]

Today, you can see giant tilting water buckets in amusement parks that automatically splash water down once they are full.

[CN]

如今，你可以在游乐园中看到巨大的倾斜水桶，它们在装满水后会自动泼洒下来

[EN]

Automatic tilting bucket for controlling alternate motion.

[CN]

用于控制交替运动的自动倾斜水桶

[EN]

Application of automatic tilting bucket for an alternately flowing fountain.

[CN]

自动倾斜水桶在交替流动喷泉中的应用

PDF page 13

[EN]

Automatic Priest For Blood Measurement

Al-Jazari also delved into medicine. One of his ingenious inventions is the automatic priest for blood measurement. During medieval times, bloodletting was a common medical practice in the Middle East, performed often by monks and priests. In the modern world, such a concept is used to monitor blood flow out of one's body during a blood donation drive.

To keep track of how much blood was drained from the patient, Al-Jazari devised a flat bowl that collects drops of blood that drain through the hole in the center and collect in a vertical tube. Inside the tube, there is a float connected by a string around a horizontal pulley and a counterweight at the other end. As more blood droplets accumulate in the tube, the float rises, causing the pulley to rotate steadily. The rotary motion of the pulley causes a miniature priest to rotate along the circumference of the bowl that is graduated with markings. The entire device appears as if the priest is automatically calculating the amount of blood that was let by pointing his stick to the specific marking. The sensitivity and precision of this device can be controlled by designing the right set of pulley, float, and diameter of the bowl.

[CN]

自动血量计量器

阿尔-加扎里还涉足了医学领域。他的一项巧妙发明是用于测量放血量的自动放血计量器。这一装置带有明显的时代背景：在中世纪，放血是中东地区常见的医疗手段，通常由僧侣和祭司执行。在现代，类似的概念被用于监测献血过程中血液的流出量。

为了记录从患者体内排出的血液量，阿尔-加扎里的这个计量器的主体是一个扁平碗，用于收集流经中心小孔的血滴，并将血液收集到一个垂直管中。管内有一个浮子，通过一根绳子连接到一个水平滑轮上，另一端有一个配重。随着血液一点点在垂直管中积累，浮子上升，促使滑轮水平旋转。滑轮的旋转驱动一个微型祭司模型沿着碗的圆周旋转，碗的外沿上标有刻度。整个装置运作时候看起来就像是这个绕这碗边沿行走的微型祭司在自动计算放血量，用他的棍子指向特定的刻度。该装置的灵敏度和精度可以通过精心设计的滑轮、浮子和碗的直径来控制。

[EN]

Automatic priest for blood measurement.

[CN]

自动血量计量器

[EN]

Inner workings of the automatic priest.

[CN]

自动血量计量器的内部工作机制

PDF page 14

[EN]

Elephant Water Clock

This is perhaps Al-Jazari's most famous invention. What makes this invention unique is that the clock is built on a perfect integration of many small mechanical devices that work in unison to produce an entertaining experience of time—800 years ago! The key concept is based on equal timing that can be controlled to the beginning of every half hour and the minutes in between.

The elephant water clock performs its timing with the slow sinking of a bowl (called tarcehar—also used in the water-flowing timer) inside the belly of the elephant. The clock gets its power from the force created at the time of the sinking of the bowl, and the potential energy of the balls that is released. As the bowl sinks at the end of half an hour, one of the bronze spheres standing in a row in the closed chamber at the top of the clock falls, and visual movements are formed.

Floating in the pool inside the belly of the elephant, the tarcehar bowl slowly sinks for half an hour by taking water from the hole on its bottom, while the clerk on the elephant's back slowly turns and shows the minutes with a pen in his hand through rotary motion, caused by the linear motion of the bowl sinking. At the end of half an hour, as the bowl descends and sinks, the bird on the top turns. At the same time, the sitting ruler above raises his hand on the beak of the falcon on his side, and holds the beak of the falcon on the other side with his other hand. All these motions are triggered by the conversion of linear motion to rotary motion of the sinking of the bowl and the release of balls.

A spherical ball falls from the beak of the freed falcon into the open mouth of the snake, which is ready to devour the falcon. When the snake's heavy head lowers, the ball is left in one of the two vases on the elephant's shoulder, and a gong sound comes out of the vase. When the snake's head gets lighter, it slowly rises, while the clerk returns to its former place. The snake that rises up also pulls the sinking bowl up and, thanks to its hinged tie, drains its water and makes it ready for the next half hour. In the meantime, the spherical ball enters the neck of the elephant after the vase, and the elephant driver hits the metal cap on the top of the elephant once with a mallet with one hand, and a pickaxe with the other.

[CN]

大象水钟

这可能是阿尔-加扎里最著名的发明。这项发明的独特之处在于，时钟建立在许多小型机械装置的完美配合之上，这些装置的协同工作创造出一种娱乐性的时间体验——而这一切都发生在 800 年前！其核心概念基于等时性（聪明的你也许已经猜到这是前面描述的哪一个装置了），可以控制到每个半小时时段的开始及相邻时段之间的分钟间隔。

大象水钟通过大象腹部内一个碗（称为 tarcehar，也用于水流计时器）的缓慢下沉来计时。时钟的动力来自碗下沉时产生的力以及释放的球的势能。当碗在半小时结束的那一刻下沉时，时钟顶部密室中有一排青铜球，其中的一个此时会落下，并形成外部可以观察到的运动。

漂浮在大象腹部水池中的 tarcehar 碗通过底部的小孔缓慢进水，半小时内逐渐下沉。与此同时，透过 tarcehar 碗缓慢下沉引发的旋转运动，大象背上的模型小人会慢慢转动并用手中的笔写出分钟数。半小时结束时，随着碗的下沉，顶部的模型小鸟会转动。同时，坐在上方的模型国王举起双手抓住猎鹰的喙。所有这些运动都是由 tarcehar 碗下沉的线性运动带动的一系列旋转运动以及青铜球的下落触发的。

一个球从张开的猎鹰喙中落到下方的蛇张开的口中，蛇正准备吞食猎鹰。当蛇被球压住而下降时，球又会掉进大象肩上的两个花瓶中，并发出锣声。当蛇头重新变轻时，它会慢慢升起，而模型小人则回到原来的位置。升起的蛇也将下沉的碗拉起，并通过其铰链连接排空碗中的水，为下一个半小时后的表演做好准备。与此同时，球在进入花瓶后接着进入大象的颈部，大象驾驶员一手用木槌，另一手用镐，敲击大象头顶的金属帽。

[EN]

Elephant Water Clock.

[CN]

大象水钟

[EN]

Spherical balls in the Elephant Water Clock that travel due to potential energy and cause rotary motion.

[CN]

在大象水钟内部，受势能驱动运动的圆球会带动飞轮旋转

[EN]

Inner components of the Elephant Water Clock.

[CN]

大象水钟的内部组件

PDF page 15

[EN]

A Robot That Washes Your Hands And Face

Al-Jazari made a fun, childlike robot that can wash the user's hands and face! This invention is one of the most striking of his creations.

When the robot is activated, a bird seated on top of a water jug held by the robot sings for a while. This singing is designed as a "waiting period" for the person to prepare for getting washed. When the singing ends, water starts to flow from the jug automatically. When the flowing water is about to stop completely, the robot extends a comb and a mirror from his hand to the person who just washed their hands and face. The system has three basic mechanical elements: a singing bird (sound created with pressurized water), a self-activating water fountain, and a mirror/comb extender arm. The robot executes the actions of singing, watering, and mirror/comb extension in sequence using the flow of water.

In order for the system to work, water is used in this robot, which the operator fills into the tank in its body through the hole under the robot's hat in the back room. When the operator brings the robot for public use, they turn a small knob on the neck of the robot. After that, the water inside the robot fills the jug gradually, causing the air trapped in the jug to pressurize and create a bird-sounding whistle through a nozzle. After a while, when the jug is full, water begins to flow from another nozzle, which acts as a siphon. When the water in the jug empties, the robot extends the comb and the mirror with the other hand. This movement is triggered by a float located inside the jug.

[CN]

可以辅助洗手洗脸的机器人

阿尔-加扎里制作了一个有意思且充满童趣的机器人，可以为用户洗手和洗脸！这项发明是他最引人注目的创作之一。

当机器人工作时，位于机器人的手持水壶顶部的鸟会鸣叫一段时间。这是一个"通知"，让使用者为清洗做好准备。当鸟鸣结束时，水会自动从壶中流出。当水流即将完全停止时，机器人会从手中伸出一把梳子和一面镜子，递给刚刚洗完手和脸的人。该系统有三个基本的机械元素：一只鸣叫的鸟（通过水流产生声音）、一个自动触发的喷泉，以及一个镜子/梳子伸展臂。机器人利用水流依次执行鸣叫、喷水和镜子/梳子伸展的动作（想一想这是前面哪个装置的功能？）。

为了使系统正常工作，机器人在体内储存水，操作员通过机器人帽子下方的孔将水注入其体内的水箱中。当操作员将机器人带到公共场所使用时，他们会转动机器人脖子上的一个小旋钮。之后，机器人内部的水逐渐填满水壶，导致壶内空气被压缩，并通过喷嘴发出鸟鸣声。过一段时间，当水壶装满时，水开始从另一个同时起到虹吸作用的喷嘴流出。当水壶中的水排空时，机器人会用另一只手伸出梳子和镜子。这一动作由位于水壶内的浮子触发。

[EN]

The robot washes your hands and face, and also gives you a comb and mirror.

[CN]

机器人会为你洗手洗脸，还会递给你梳子和镜子

[EN]

Key components of the robot.

[CN]

机器人的关键组件

PDF page 16

[EN]

About Faisal Hossain

Faisal Hossain is a teacher who enjoys interacting with students at all levels and disciplines as part of his day job as a professor in the Department of Civil and Environmental Engineering at the University of Washington. His night job, to which he devotes an equal amount of energy, is about filmmaking and the communication of science. He uses these to build bridges between communities and solve pressing problems for society. His research group at the University of Washington focuses on improving the quality of life in challenging environments through the application of science, technology, engineering, and math (STEM), with a focus on the supply of water, energy, and food. He initiated the nation's first Engineering Student Film Contest at the University of Washington in 2017, which is a biannual student film festival for STEM majors as a way to explore the arts.

[CN]

作者简介 – Faisal Hossain

Faisal Hossain 是一位热爱与各层次、各学科学生互动的教师。他的日常工作是华盛顿大学土木与环境工程系教授，他的“夜班秘密使命”则专注于电影制作和科普。他利用这些工具构建起不同社区之间沟通的桥梁，并籍此解决当今社会的紧迫问题。他在华盛顿大学的实验室专注于通过科学、技术、工程和数学（STEM）工具来改善我们在这个充满挑战的环境里的生活质量，重点关注水、能源和食物的供应。2017 年，他在华盛顿大学发起了美国首个工程学科学生电影竞赛，这是一个面向 STEM 专业学生的双年展，旨在探索艺术与工程的结合。

PDF page 17

[EN]

About Qishi Zhou

Qishi Zhou is an electrical engineering graduate student at the University of Washington, and an alumnus of the University of Minnesota, Twin Cities, where he completed his bachelor's degree in computer science. His research interests include satellites communication, aeronautics, and astronautics. He loves building robots and automation that serve society and solve problems. He most recently designed a rover called "HydroCUB" for the Washington State Department of Transportation to inspect culvert conditions to help fish swim through. His dream is to use his engineering knowledge to shape the world. In his spare time, he enjoys scuba diving, making fun gadgets, and is a private pilot and film photographer.

[CN]

作者简介 – Qishi Zhou

Qishi Zhou 是华盛顿大学电气工程专业的研究生，也是明尼苏达大学双城分校的毕业生，他在那里获得了计算机科学学士学位。他的研究兴趣包括卫星通信、航空学和航天学。他热爱建造能服务社会并解决实际问题的机器人和自动化设备。最近，他为华盛顿州交通部设计了一款名为"HydroCUB"的探测车，用于检查涵洞状况，以帮助鱼类通过。他的梦想是利用自己的工程知识塑造世界。在业余时间，他喜欢潜水、制作有趣的小工具，同时也是一名私人飞行员和胶片摄影师。