Research paper

A historical study and mechanical classification of ancient music-playing automata

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A B S T R A C T

The mechanical music automata have been developed since thousands years ago for mimicking sound of animals or playing a melody. They are documented and/or preserved in many countries, with solutions that reflect the evolution of mechanical manufacture and technology in these areas. In this article, a timeline of the ancient literature in both western and eastern countries is arranged to clarify the historical development of music-playing automata. The functional mechanical design parameters are arranged based on the four fundamental music characteristics as pitch, duration, intensity and timbre. Moreover, the mechanical music generators are also classified into wind, percussion, strings instruments and the steel music comb according to their composition. These music-playing automata are analyzed in four main units, namely power system, music generator, transmission and mechanical puppets. Finally, seven ancient automata are analyzed as illustrative examples from the viewpoint of mechanism design for these analysis and classification.

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1. Introduction

The music-playing automata are mechanical devices that act or sound automatically, and any operation or extra force is not required for their task of entertainment. This kind of automata can be traced back to long time ago. People tried to simulate the sounds of animals or music instruments through mechanical systems since the antiquity, and a lot of automata were invented during the past thousands of years. The materials that were used in those automata are mainly metals or woods. The power sources such as flowing water, steam, manpower, weight, spring, or rolling wheels are applied. They not only reflect the development of science and technology but also show local characteristics of the time period when they were made [1–4]. Before the invention of recorder or audio devices, it was difficult to describe the sound of bird chirp, and the music melody also could not be collected. Therefore, many inventors and artisans made automata with music-playing devices that make the sounds and music repeatable. And, several huge devices such as tower clocks can also transmit information in the cities or towns. Some of these automata are still preserved in many countries all over the world, and some of them are lost although they are documented in the literature especially in Europe and Asia.

In ancient Greek, Ctesibius (BC 285–222) and Heron of Alexandria (10–70 AD) described their designs such as mechanical singing birds [5,6]. In Arabic countries, the brother Banu Musa (lived in the 9th century) and Al-Jazari (1136–1206) recorded their inventions with illustrations, such as self-operated fluted [7,8]. In ancient China, Su Song (1020–1101) described a water clock tower with figures that tell time through striking drums or ringing bells [9–11]. Moreover, an odometer and a sand

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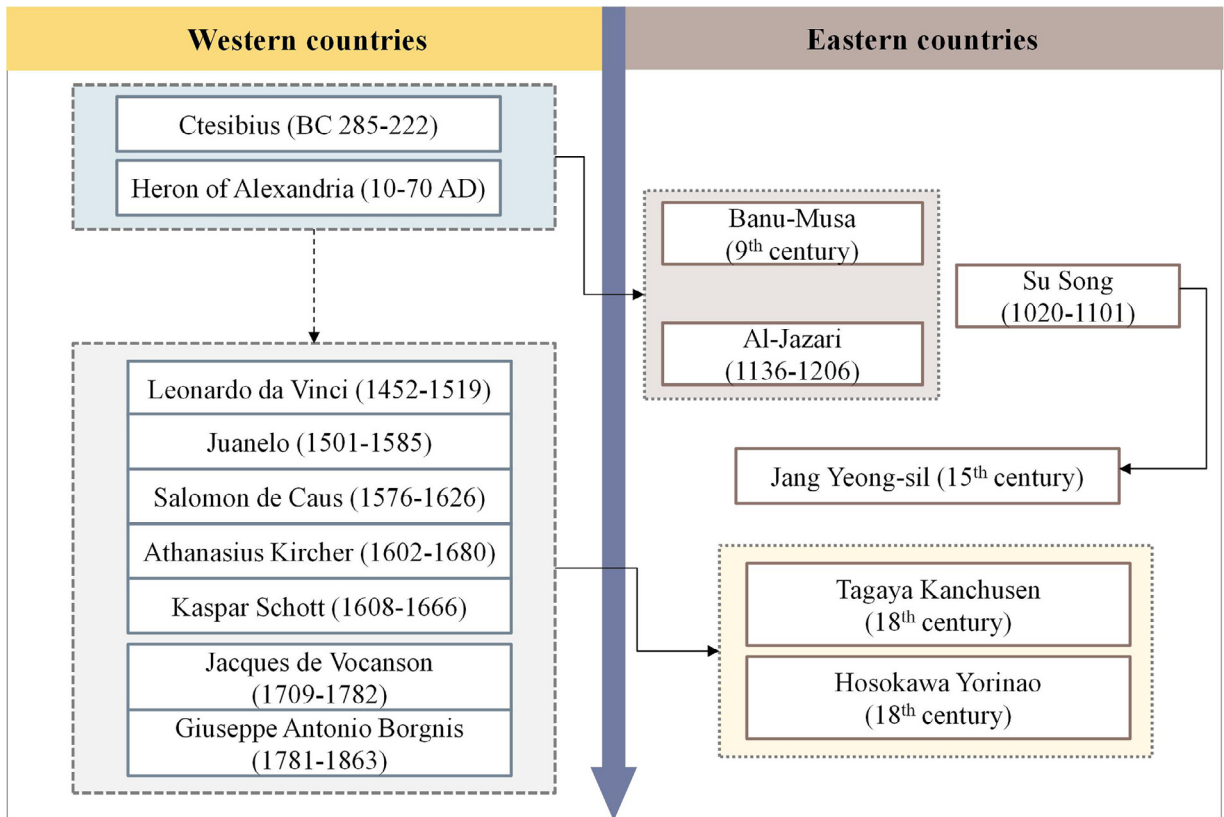
Fig. 1. Timeline of ancient literatures about music automata.

clock with ringing figures are recorded in Chinese literature during the 14th century [12,13]. In the 15th century, Korean Jang Yeong-sil described his water clock with time-telling figures [14]. In the 16th century, Italian Leonardo da Vinci (1452–1519) draw the automatic drums and a cannon musical device in his manuscripts [15]. In the 17th century, French engineer Salomon de Caus (1576–1626), German Athanasius Kircher (1602–1680) and Kaspar Schott (1608–1666) recorded their water-driven inventions that sounded automatically [16–18]. In the 18th century, Japanese Tagaya Kanchusen (unknown, the18th century) and Hosokawa Yorinao (unknown-1796) explained their automata puppets (so-called Karakuri) with illustrations [19–22]. In France, Jacques de Vaucanson (1709–1782) described figures with drum and flute [23]. In the 19th century, Italian Giovanni Antonio Borgnis (1781–1863) recorded a delicate device with a steel music comb and a cylinder [24]. The above mentioned designs are famous examples of automata evidence.

Fig. 1 shows a timeline of these ancient literatures. In western countries, although there are more than one thousand years empty during the 1st to the 13th century for which records are not available, the technology of music automata started at the ancient Greece, flourished after Renaissance, reached the top with the Industry Revolution, and decayed with the development of electronics. For the Eastern countries, although there were some ingenious works, most of they were neither inherited nor evolved.

Except the ancient literature mentioned above, a lot of ancient automata are still preserved. For examples, the Vienna lady [25] by Juanelo's (1501–1585), the musician automaton [21] by Pierre Jaquet-Droz's (1721–1790), and the bell ringers of clock tower at piazza San Marco in Venice, Italy. In addition, many studies of music automata on history and development were published in modern times about the preserved automata.

Rixford described many ancient and modern automata with illustrations of their internal mechanical structures [26]. Bailly and Teriault introduced the automata that were made in the 18th and 19th centuries based on Bailly's collections [27,28]. Yun et al. explained the mechanical components that were generally applied in the ancient clocks and automata according to their experience of maintaining the antique timepieces and automata [29]. Peppe introduced mechanical toys with explanation of the components and mechanism structures [30]. Leichtentritt provided a definition of mechanical music and introduced a variety of automatic devices such as music clocks, harps, sound box, and whistle [31]. Brett presented the research of "Pneumatica" in Byzantine time through the historical records and illustrations to arrange the development of science and mechanical technology [32]. Bowers wieldy introduced several music-playing automata during 1750 to 1940 as an encyclopedia [33]. Koetsier outlined many mechanical devices with the concept of programming, such as the music