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The Embodiment of Engineering in Renaissance Art Works

— Based on the Art Works by Leonardo da Vinci, Albrecht Dürer, and Mariano di Jacopo

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Abstract: During the Renaissance, many artists create pieces of work with the help of perspectives on different fields, like mathematics and engineering. The perspectives of mathematics and engineering are shown in different art pieces by different artists, such as Leonardo da Vinci, Dürer, and Taccola. They are discovered in the Codex on the Flight of Birds by Leonardo Da Vinci, the perpetual wheel with articulated arms by Taccola, and Dürer's Melodia. Together, the author discovered how the three pieces bring out the perspectives of mathematics and engineering, how art is combined with these perspectives in the different art pieces, and what it brought to or inspire people together. Through analyzing different pieces of literature and the art piece itself, the authors found out that art can relate to the perspectives of mathematics and engineering. These brilliant art pieces also did inspire future generations of people who continue to study this topic and the history related to this field.

Keywords: Renaissance, Engineering, Mathematics

1. Introduction

Renaissance originated in Italy, in the 15th century. At the time, Italy had the greatest level of urbanization in all of Europe. The feudal structure in Italy has slowly started to crumble, and businesspeople and corporations have taken over as the backbone of society. Some folk-art pieces also vehemently proclaim the desire for justice, fairness, and excellent leadership in the Republic. The people continue to pursue and uphold the idea of freedom despite the restrictions of the church and imperial government. The bourgeoisie has expanded quickly with emerging capitalism. They are more ready to escape the constraints of religion and in need of a fresh philosophy. In this context, the repression of human individuality greatly impedes the advancement and growth of science and art. During the Renaissance, many artists were inspired by the ideological enlightenment at that time to get rid of the shackles of the medieval period and have their creativity and more open ideas. Through the in-depth study of science, mathematics, and artistic techniques, artists explore the essence of beauty and the art of beauty and are also thinking about the complex and subtle relationship between form and aesthetic feeling such as Dürer. They promoted the prosperity of European culture and

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thought fields and laid the foundation for the emergence and development of European capitalist society. Especially in the field of sciences, such as engineering and mathematics, because many of the Renaissance scientific circles were not just painters, they were also proficient in many scientific fields, and their manuscripts contained many design drawings or mathematical theorems. Different from the Italian classical concept of ideal beauty, the aesthetic view is embodied in the establishment of a harmonious proportion of the appearance of the human body and a moderate sense of reality in line with nature, and on this basis conveys the independence of the painted object. The influence of the Renaissance on later generations in engineering is undoubtedly huge. Due to the combination of exquisite painting skills and scientific knowledge, artists have drawn very detailed design drawings. These valuable manuscripts from different painters and styles have inspired many modern scientists, and modern scientists have carefully studied those manuscripts, improved them, and eventually invented many new inventions, such as gliders and ornithopters.

In this article, a mathematical and engineering perspective was adopted to study three outstanding artists' work in the Renaissance and analyze how the science of the Renaissance was reflected in art.

2. The Artists in Renaissance

2.1. Leonardo da Vinci

Leonardo da Vinci is not only an outstanding artist but also a great scientist in the Renaissance. He was born in 1452 in Florence and then learned painting and sculpture skills with his teacher Andrea del Verrocchio in Florence. He frequently performed work for nobility in Florence and Milan after reaching adulthood, for example, he painted altarpieces for churches. He also spent a brief period working in Rome, where he attracted a lot of pupils who came to study those techniques that Leonardo was good at it. He spent the last three years of his whole life in France, finally dying in 1519. Leonardo da Vinci created many famous and valuable works in his life, such as Mona Lisa, The Last Supper, Vitruvian Man, and Codex on the Flight of Birds. His proficient painting skills related creation of art and exploration of science together, which produce plenty of vivid characters and fully embodies the spirit of humanism.

2.2. Mariano di Jacopo

An early renaissance artist Mariano di Jacopo also named Taccola was an Italian polymath, administrator, artist, and engineer who invented many hydraulic engineering machines. Although his true indignity has long been something like a mystery [1]. His work was widely studied and copied by later Renaissance engineers and artists, among them Francesco di Giorgio, Alberti, and Leonardo da Vinci [2]. He illustrated numerous methods for raising water and showed many brilliant engineering techniques in his inventions. He is known for his technological treatises De ingeneis (concerning engines) and De machines (concerning machines), which feature annotated drawings of a wide array of innovative machines and devices. Taccola's style has been described as forceful, authentic, and usually to be relied upon to capture the essential. His most famous work, his two technological treatises, includes sketches that made him responsible for being the inventor of the keel-breaker, a security device for ships, and the trebuchet, a siege engine.

2.3. Albrecht Dürer

The Nuremberg artist Duller was an outstanding representative of the late 15th and early 16th centuries. He was well known as a painter, sculptor, printmaker, and mathematician...The "instruction on the Fortification of Cities, Castles, and Towns" was published by Durer in 1527. Diirer introduced Some Roman myths that have become more integrated with northern Europe. through his

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understanding of the Italian Renaissance, which led him to become one of the most important artists of the Renaissance. At the same time, he had a lot of theoretical knowledge, including mathematical theorems, perspective, and head-body proportions.

3. Art and Science

3.1. Engineer in Art

3.1.1. Leonardo da Vinci's Codex on the Flight of Birds

It is in the field of flight that Leonardo's legacy is most recognized [3]. Codex on the Flight of Birds is a selection written by Leonardo da Vinci in 1505. He considered that anyone who could master the skies could indeed claim to have become a 'second nature' in the world [4]. There are almost 500 sketches about flights drawn by Leonardo da Vinci, meaning this artwork has multitudinous theories or key knowledge of different types of academic fields, such as those mechanical wings representing engineering or some unique flying methods belonging to birds that represent Zoology and Mechanics.

Engineering is presented in Codex on the Flight of Birds. Leonardo was not only focused on the creativity of his inventions, like those machines which could help human beings to fly, but also focused on the feasibility and that professional background knowledge of that machine. Image 17(see Figure1) of Codex on the Flight of Birds could illustrate his professionalism perfectly.

Figure 1: Codex on the Flight of Birds [5].

It's the joints constructed with strong leather laces and its ribs of very strong raw silk so that they can withstand the stresses and the speed of descent, with the actions already mentioned and is not used in the construction of any piece of metal, because this material breaks or wears away under stress, which is why there is no reason to complicate the job. [5] This citation is taken from the first paragraph, and it could prove that Leonardo also focused on the practicability of the mechanical wings. He based on the features of those materials, such as leather and silk, and considered the best use of their functions so that he could design an artificial wing that accorded with the Engineering principles. A, B, and C are the three movable connection points of this mechanical wing, respectively. And D is a lever-like existence, so AD can move the entire wing. (see Figure 2) [5]

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Figure 2: Codex on the Flight of Birds. (The order of ABCD is from top to bottom) [5].

This citation also proves that Leonardo always focused on the final utility of those wings. He would not only consider the viable materials of wings but also consider the probability that those wings could fly. For instance, he mentioned that point D is a crucial part of the whole wing that could control the movement of that wing (see Figure 2). So, he designed a lever on the position of point D and the main aim was to allow the whole wing to move scientifically. His engineering skills could be fully shown on this page from his solution that could solve the movement issue.

According to Leonardo da Vinci's achievements in different subjects, his identity as an artist and his identity as an engineer complemented each other and inspire him a lot in creativity. However, since the bird has been seen to be able to master a wide variety of sensitive flight ways, scientists can extract from these ways some of the most important and well-understood flight methods [6]. Leonardo also explained the reason why he was so obsessed with studying birds. Codex on the Flight of Birds (see Figure 3) could be an example to confirm this statement.

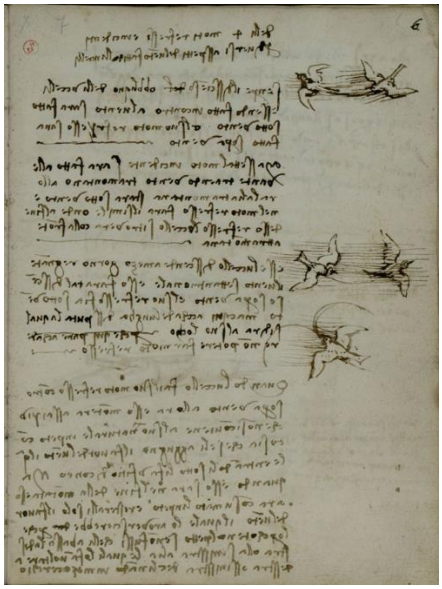

Figure 3: Codex on the Flight of Birds [5].

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Four ways that birds move according to the wind in different directions, especially how they fly up or down [5]. This page describes four types of motions that are used by birds when they are flying. If a bird is flying up in a headwind, it will have a faster speed than usual because the wind passing under the bird is like a wedge, so the bird's speed can benefit from it [5]. He described a position that birds would use to fly when they meet wind from different directions so that they could control their own body safely and assure they would not fall out of the sky. Leonardo also compared the wind which enters beneath birds to a wedge, a tool that usually appears in the Engineering field, so that others who study Leonardo's notebook could have an understandable realization about how the wind works on the flight of a bird due to the expressive analog. Next to his description of the movement when birds are flying, there are four sketches, which illustrate the action of birds vividly so that others could have a clearer understanding of his theory, although those readers have little background information about this subject. However, to be an artist, Leonardo could draw things more detailed and closer to nature that in his imagination, and to be a scientist, sufficient background knowledge could support those things that he designed to become more conform to science and have the possibility to operate. For example, based on his manuscripts, experts discover that there are different creations in it, which could give modern humans inspiration, such as his blueprints about helicopters, parachutes, and ornithopters. Due to his detailed description and drawings of those machines, plenty of his manuscripts have been invented as much as possible, and those valuable notes also benefit our modern Engineering.

3.1.2. Subtitle Taccol's Perpetual Wheel

The perpetual wheel (see Figure 4) with articulated arms is one of Taccola's inventions for raising water illustrated in 'De ingeneis' (concerning engines).

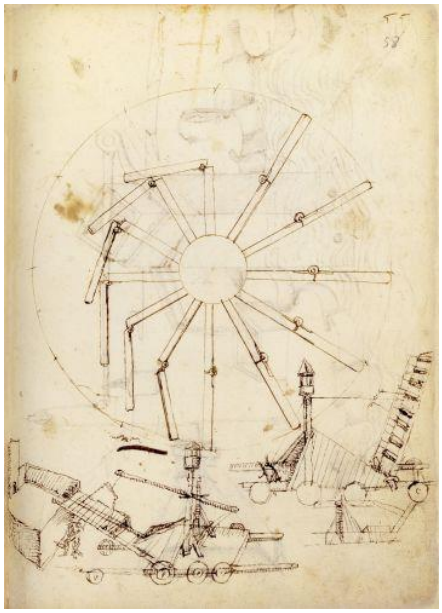

Figure 4: The perpetual wheel [7].

His first manuscript was published in 1419, where he showed many different drawings and annotations. He drew many machines that can move water. The Perpetual wheel with articulated arms is one of the most well-known ones that even artists like Leonardo da Vinci copied and re-created this machine because of his brilliant mechanics and engineering techniques.

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For an invention, the most basic or hardest part of achieving is its 'complex' but feasible engineering technique used. Observing and understanding Taccola's artwork will allow viewers to understand the relationship between different concepts and his brilliant skills used, like his sketch of the perpetual wheel with articulated arms and its relationship to engineering.

Taccola got his ideas from different figures such as animals, humans, and wind power. He then sketched many different inventions which connected with the different things he got inspired from and perfected them with new mechanical ways explaining how the invention works, showing us his unique, creative, and professional invention.

Engineering is shown greatly on the Perpetual overbalanced wheel. The robotic arm of the device is divided into two parts. In this way, when one of the parts is closed, the system is out of balance, so this causes rotation until the next new equilibrium condition is found. Since the wheel is made up of six pairs of manipulators, the sequence of unbalanced conditions will produce a perpetual motion machine. He also tried to install many objects at one end of the wheel to excavate and realize more possibilities. Taccola also tried to attach many objects on the end side of the wheel to achieve different functions such as digging and grabbing making the wheel into a multi-function invention, in other words, saying that it is 'to apply the idea of articulated arms as generators of force to the machine for digging, dredging canals or lifting water' [8].

3.2. Mathematics in Art

Dürer's Melenodia (see Figure 5) is the most admired masterpiece with one of the most mysterious veils in the history of western art, and it is also the pinnacle of sculpture art.

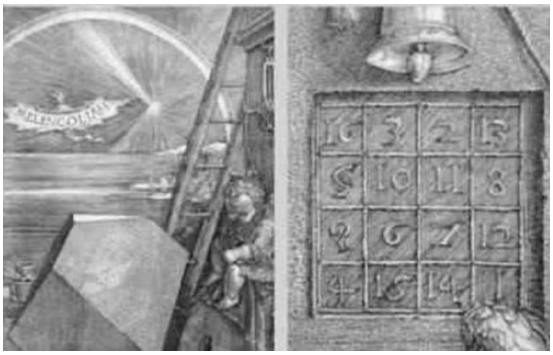

Figure 5: Melenodia [9].

It is all-inclusive and combines physics, geometry, surveying, and psychology symbols. With the Renaissance, this Melenodia also has the principles of the Italian Renaissance, perspective and proportion, as well as the purely visual experience and complex wisdom of these images.

The first is that Melenodia shows an unparalleled mathematical perspective and geometric elements, filled with many geometric elements in the whole picture, the fourth order magic square in the upper right corner, the sum of the horizontal and longitudinal oblique directions is 34, the sum of the numbers in the four quadrants, the sum of the four numbers in the middle and the sum of the four corners. What is even more surprising is that the 15 and 14 numbers in the middle of the last row make up the 1514 years of the painting. In the picture, the tall and strong-winged woman holds the compass, and the elements of the compass also mean that since mathematical theory can be used in artistic creation, we can see the relationship between art and mathematical science.

Secondly, people can see the perfect expression of perspective techniques in "melancholy". The lost magic square and those complex polyhedral bodies and spheres in the picture represent the mysterious

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mathematical world. The surface of the polyhedron in the picture seems to consist of two equilateral triangles and six irregular polygons.

4. Conclusion

Through the study and researching those artworks created by Leonardo da Vinci, Mariano di Jacopo, and Albrecht Dürer, the authors found that in the period of the Renaissance, plenty of scientists would connect their artworks with science, and the most two obvious sciences are engineering and mathematics. Therefore, science was perfectly integrated into and embodied in artworks at that time. The identity of artists and engineers complement each other and stimulate a lot of their creativity. Mathematics and engineering are also constantly being used and learned by artists in today's society. The treasure that the pioneers of the Renaissance left people is a treasure that allows us to explore. The study also gives some appropriate perspectives or help to those who continue to study this topic or the future history related to this field. For example, people can start with the three artists the paper mentioned and the list of artworks based on this paper to think about which artists or works they should look for and develop the inspiration for future generations so that the field can be expanded deeper and wider. However, this paper still has some limitations. The authors only list or propose the research views and understandings. In future research, people can try to use charts or the result of questionnaires to understand people's confusion or their understanding of the science and art of the Renaissance.

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