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3D Holographic Animation of Modern Mechanical Watch Escapements

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ABSTRACT

In the past 100 years, nearly all mechanical watches used a same escapement, called the Swiss lever escapement. In the past two decades, though, a couple of new escapements are invented, including the Girard-Perregaux Constant Force Escapement and the Dual Ulysse Escapement. Set aside to design and make these escapements, it is difficult to describe the movements of these complex escapements. In this paper, we use a simple pseudo 3D holography system to show the movements of these two escapements. This low-cost system can be used with a smartphone for display on site or used with a large screen TV for display in shops. It adds a new way to demonstrate the movements of complex mechanical watches and other mechanical devices.

Keywords: 3D holography, mechanical watch escapement, computer animation.

1. INTRODUCTION

Invented some 400 years ago, mechanical watches and clocks continue to fascinate many people today. Though few really understand the movements of the mechanical watches and clocks. Since 2007, we in the Institute Precision Engineering of the Chinese University of Hong Kong have been developing a virtual library of mechanical watches and clocks [5]]. There are few other similar websites such as Bretscher U's Page [1] and Mark Headrick's Horology Page [7]. These websites tell interesting stories and help to show the movements of different mechanical watches and clocks.

It is known that the "brain" of mechanical watch is the escapement. Throughout the history, approximately 100 different escapements were invented. In the past 100 years or so, though, it has the Swiss Level Escapement that dominated. Presently, more than 99% of the mechanical watches use this design. In recent years, though, a number of new escapements have been invented, including the Girard-Perregaux Constant Force Escapement [3] and the Dual Ulysse Escapement [2, 10]. Let alone to design and make, these complex escapements are rather difficult to just show. In particularly, since these escapements have several layers, the animation in 2D flat screen becomes imperative. This motivates us to use 3D holographic animation to show these complex escapements.

Holography is a rather expensive technique. Therefore, we adopted a pseudo holography system. It consists of a set of holographic plates, a smartphone (or a tablet computer, or a large TV connected to computer), as well as a computer software system.

The rest of the paper is organized as follows. Section 2 describes two modern mechanical watch escapements. Section 3 shows the setup of the holography system and the animation results. Finally, Section 4 contains conclusions and future work.

2. MODERN ESCAPEMENTS

2.1. Girard-Perregaux Constant Force Escapement

It is said that the basic idea of Girard-Perregaux Constant Force Escapement is from Nicolas Dehon, a watchmaker from Switzerland. He was sitting at a train station playing with his train ticket. He noticed that when bending the ticket to create a "C" shape and then applying pressure from the opposite side, the card snaps to the other side, mirroring its former position and supplying a force. This is known as "bucking". With more than 10 years of effort and thank for the microfabrication technology, the ideal is realized as the Girard-Perregaux Constant Force Escapement. Fig. 1 shows a watch with the Girard-Perregaus Constant Force Escapement [4].

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Fig. 1: The Girard-Perregaux Constant Escapement Watch.

Girard Perregaux Constant Force Escapement is based on the instability known as buckling. There is a blade of silicon of 14 microns thick [6]. Its function is employed as the accumulator of energy. The blade is given energy from the barrels such that it takes on a wave-like form, flexing at the point of instability whereupon an impulse causes the blade to buckle. The buckling action transmits the stored energy in the blade back to the balance wheel. Most importantly, the energy transmitted in the buckling of the blade is constant.

Figure 2 shows the CAD exploded model of the Girard-Perregaus Constant Force Escapement, which can show the structure of it in detail. It consists of an oscillator (balance wheel with hairspring), two escape wheels, a "moon" frame work (in blue color), a silicon blade, and a lever. Tab. 1 shows the movements of the GP Constant Force Escapement [9] in half a cycle. The other half cycle is symmetric. Its computer animation can be seen at http://youtu.be/kHLja1Yvz8I.

The Girard-Perregaux Constant Force Escapement has a number of nice features. First, it integrates a silicon blade into the escapement. The buckling of the blade gives a constant impulse force to the oscillator. Second, the two escape wheels and the lever are symmetric, which helps to improve the accuracy. Third, the blade does not waste any energy as it is just spring. These features help Girard-Perregaux won the 2013 Watch of the Year Award.

2.2. Dual Ulysee Escapement

The Dual Ulysse Escapement is invented by Dr. Ludwig Oechslin in 2004 [8,11]. Presently, Ulysee Nardin uses this escapement in its product line as shown in Fig. 3. The Dual Ulysee Escapement is perhaps inspired by the independent double wheel escapement invented in mid 1800s. Fig. 4 shows the CAD models of the Dual Ulysee Escapement and the double wheel escapement. From the figure, the similar is apparent.

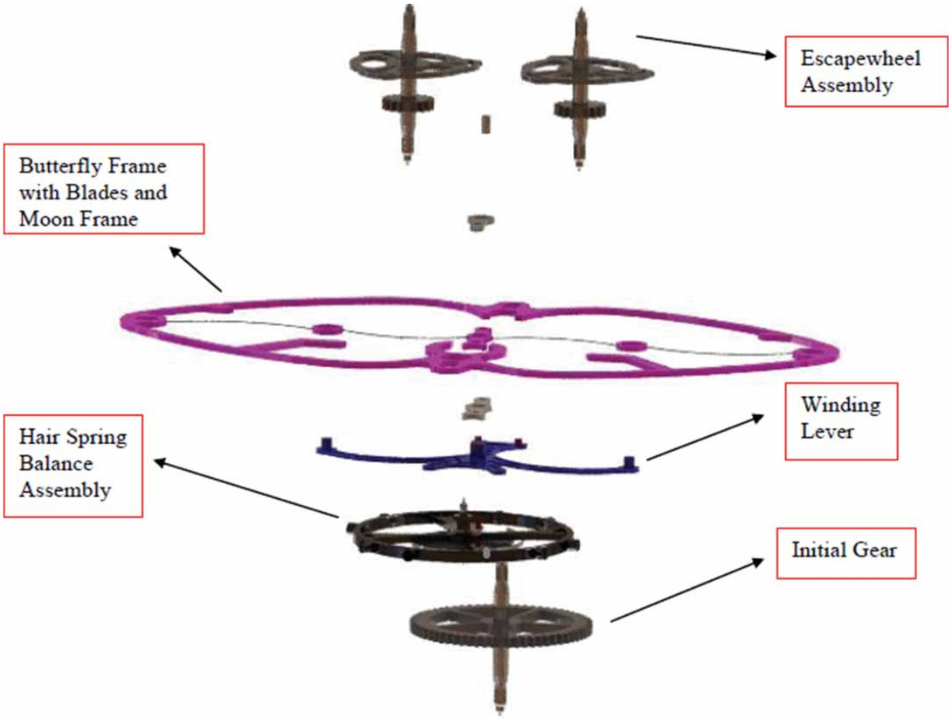
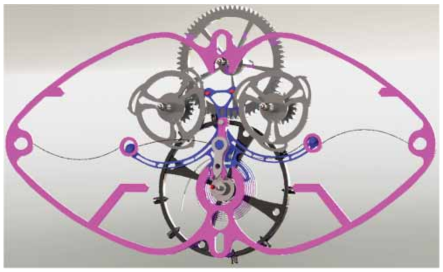
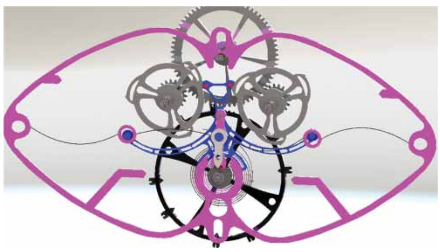
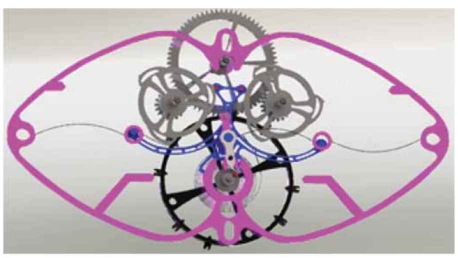
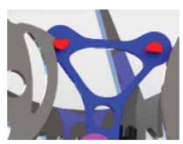


Fig. 2: The CAD model of the GP Constant Force Escapement.

Detail Movement		Working Principle
		Before the 1^{st} buckling • The escape wheels are locked by the lever. • The blade is curved downward and upward alternatively from left to right hand side • The oscillator rotates clockwise
		At the 1^{st} buckling • The oscillator and balance wheel rotates clockwise contacts the right horn of the lever, creating the 1st bucking and causes lever pivoting counter clockwise. • The blade buckles changing the position. • Right escape wheel is unlocked and swings clockwise. • Initial gear meshes with right escape wheel and swings counter-clockwise. • Left escape wheel meshes with initial gear and swings clockwise.
		After the 1^{st} buckling • The winding lever reaches locks left escape wheel. • The blade finishes buckling and is symmetric in direction with initial position. • Hair spring reaches its limit position. • As the tension of hair spring, oscillator starts rotating counter clockwise. • Another half cycle begins, which is symmetric.

Tab. 1: The movement of the Girard-Perregaux Constant Force Escapement.

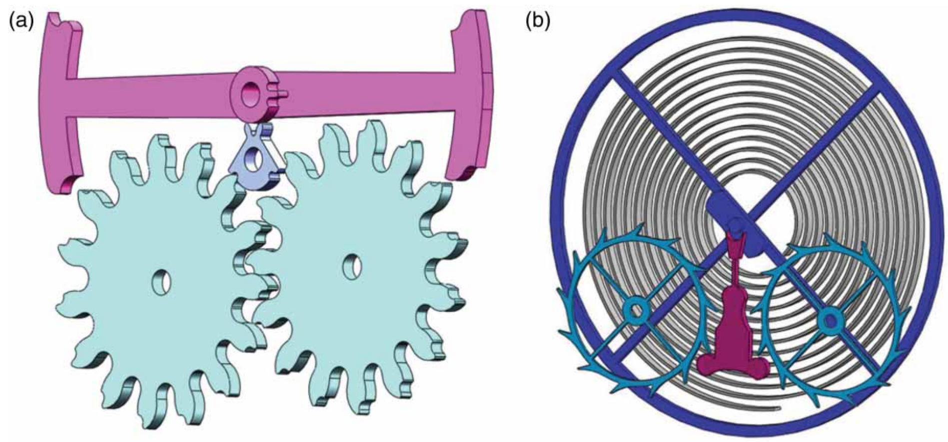
Fig. 3: Ulysee Nardin's Freak Blue Phantom.

The Dual Ulysse Escapement consists of an oscillator (balance wheel with hairspring), a triangle-shape lever with two horns and two recesses, and two escape wheels. There are also two pins used to limit the swing of the lever. Its most notable feature is the specially designed tooth profile of the two escape wheels, which is silicon made by microfabrication technology. They control the locking and unlocking of the escapement.

Table 2 shows the movement of the Dual Ulysee Escapement.

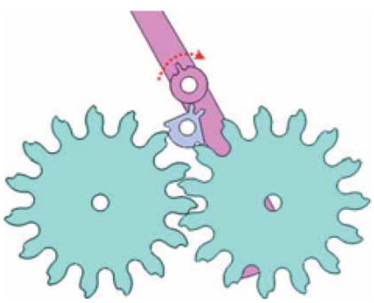
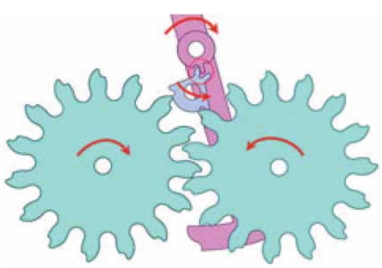
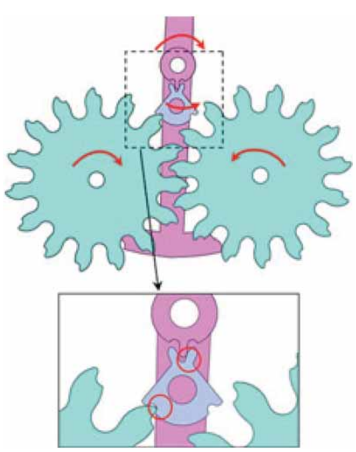
3. HOLOGRAPHY DISPLAY AND TESTING RESULTS

In recent years, 3D holography has been widely adopted in entertainment industry. Though, it is an expensive technology and hence, a number of pseudo 3D holography systems have been developed. We adopted a simple pseudo 3D holography system. It consists of a set of four holographic plates, a smart phone (or a tablet computer, or a large TV connected to computer), as well as a computer software system. The four holographic plates are assembled as a pyramid which can reflect the light field from the display effectively.

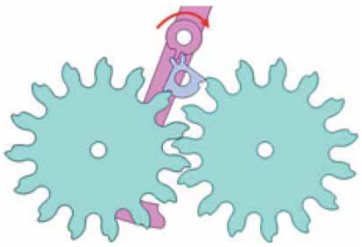
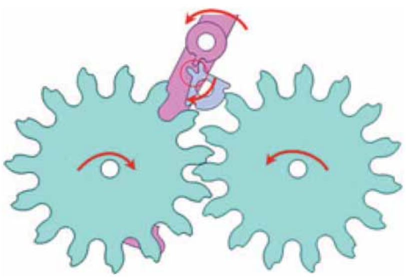
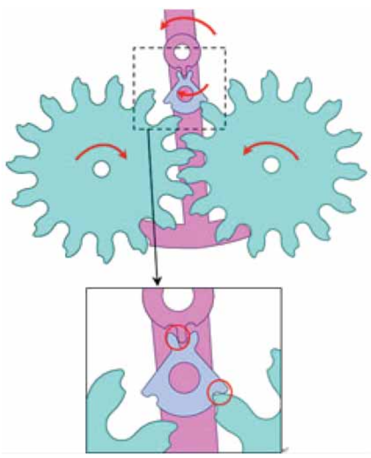
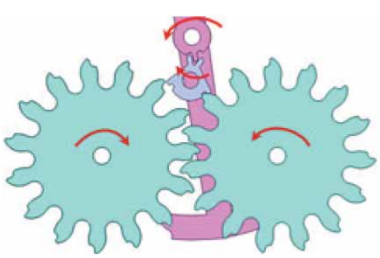


The Dual Ulysee Escapement | The Double Wheel Escapement

Fig. 4: CAD models of the Dual Ulysee Escapement and the double wheel escapement.

Detail Movement	Working Principle
	Before 1st Shock • Escape Wheel 1 is locked by the lower left corner of the lever. • Escape Wheel 2 is locked by Escape Wheel 1. • The lever is in contact with Escape Wheel 2. • The Balance Wheel is at its limit position and is about to swing clockwise.
	At the 1st Shock • The plate on the balance wheel contacts the upper left horn of the lever creating the first shock and causes lever pivoting counter clockwise. • The balance wheel continues swinging clockwise. • Escape wheel 1 is unlocked and swings clockwise. • Escape wheel 2 meshes with Escape wheel 1 and swings counter clockwise
	At the 2nd and the 3rd Shock • One tooth of the released Escape wheel 1 strikes the first recess causing the second shock and accelerates the lever to swing counter clockwise. • The upper right horn of the lever catches up the plate of the balance wheel causing the third shock. This also recharges the sprung-balance system. • The balance wheel continues to swing clockwise.

Tab. 2: The movement of the Dual Ulysee Escapement.

Detail Movement	Working Principle
	After the 3rd Shock • The plate on the balance wheel exits the contact with the lever. • The lever reaches locks Escape Wheel 2 by its second recess. • Escape wheel 2 locks Escape Wheel 1 and Escape wheel 1 locks the lever. • The balance wheel continues to swing clockwise
	At the 4th Shock • The balance wheel swings counter clockwise and its plate contacts the upper left horn of the lever causing the 4th shock. • The lever pivots clockwise, unlocking Escape wheel 2; Escape wheel 2 swings counter clockwise unlocking Escape wheel 1. • Escape wheel 1 meshes with Escape wheel 2 and swings clockwise.
	At the 5th and the 6th shock • One tooth of the released Escape wheel 2 strikes the second recess causing the 5th shock, and accelerates the lever. • Like it is in the 3rd shock, the upper left horn of the lever catches up the plate of the balance wheel causing the 6th shock. This also recharges the sprung-balance system.
	After the 6th shock • The plate is about to quit the contact to the lever and continues swinging counter clockwise. • Escapewheel 1 swings clockwise and then is locked by the lever. Escapewheel 2 swings counter clockwise and then is locked by Escapewheel 1. • The lever is about to reach its limit position, after which the next cycle begins.

Tab. 2: Continued

The basic operation principle is using the concept of light refraction. The hardware is made of acrylic sheets, which is used as different medium with air. When the object is shown in the screen, which also gives the light beam out in the air, then the light beam will enter the hardware. As a result, light refraction is occurred. Because of the refractive index of acrylic sheet, the light beam partially refracts to the centre of the hardware, then a pseudo 3D image can be seen. There are four sides regarding to the object, which can make the four side pseudo 3D image based on the above concept.

The key to use this technology is to generate the four images. We use SolidWorks® and Adobe Premiere Pro® to do that. Specifically, SolidWorks® is used for drawing and generating animation. Adobe Premiere Pro® is used to generate the four view animation. The procedure is as follows:

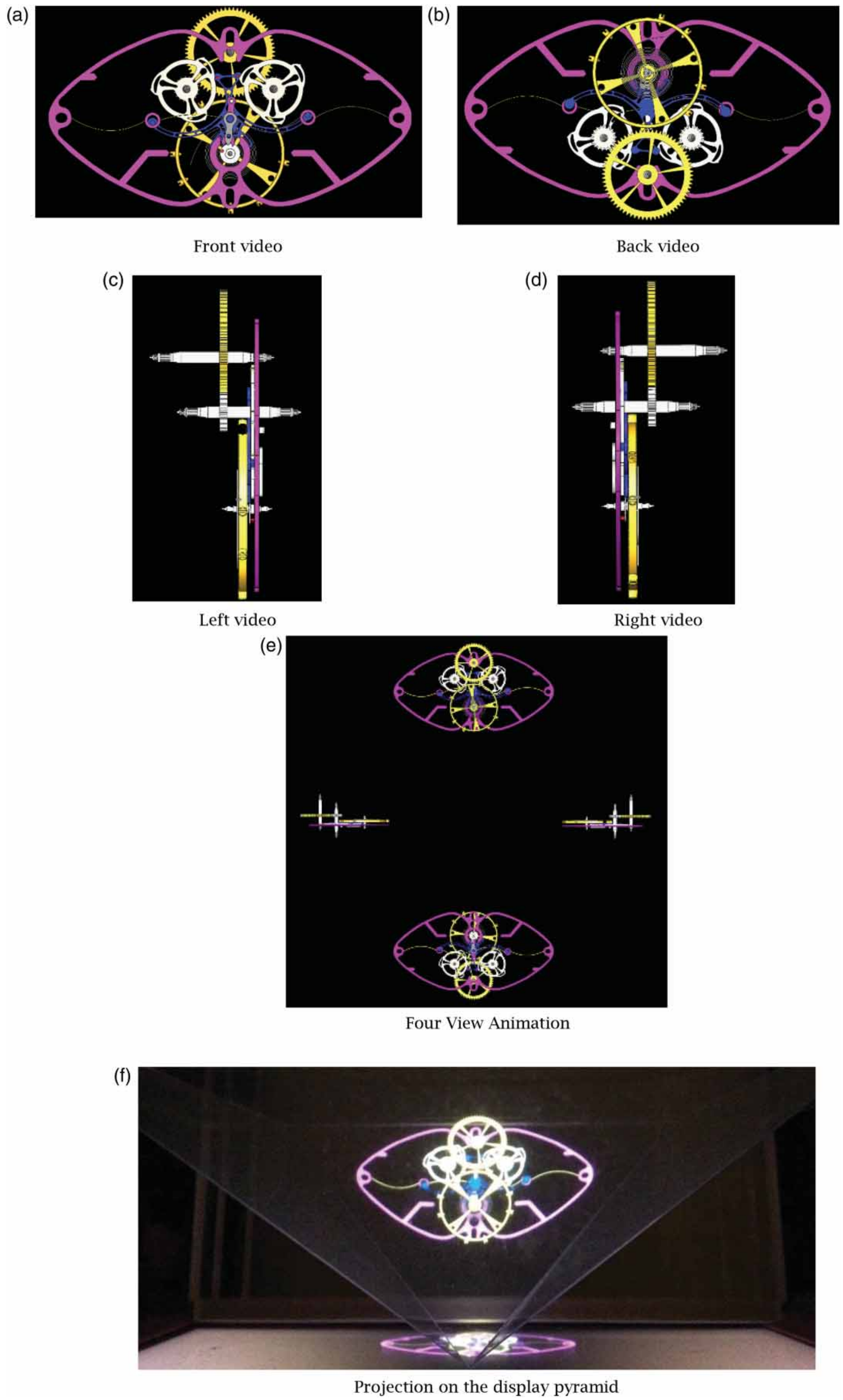


Fig. 5: Videos for making holographic projection and Testing Result.

(1) Develop the CAD model of the escapement (using SolidWorks®);
(2) Setup the four views (Front, Left, Right, Back) (using SolidWorks®);
(3) Generate the four view animation (using SolidWorks®);
(4) Generate the four view animation video clip (using Adobe®)
(5) Project the four view animation onto the display pyramid.

Figure 5 shows an example. Figure 5(a), (b), (c), (d) are the Front, Back, Left, Right views of the CAD model respectively. Figure 5(e) is the four view animation, and Figure 5(f) is the projection on the display pyramid. Note that one can see the video in four directions, which contain the details in 3D. Though, there is no image in 45°, 135°, 225°, and 315° directions.

The 3D holographic animation is very effective in showing the details of the movement of the modern mechanical watch escapements. One can look at the movement in four different directions.

4. CONCLUSIONS AND FUTURE WORK

In this paper, two complex modern mechanical watch escapements, the Girard-Perregaux Constant Force Escapement and the Dual Ulysse Escapement, are modeled based on the research and analysis work. To verify the correctness of the movements, we can use check the animation; if there is no collision existing, it means the escapement movement is correct. In order to show the complex movement of these escapements, a simple low-cost 3D holographic system is used. Based on the testing results, the animation can well demonstrate the complex movement. Such a system can be used with a smartphone on site or with a large monitor in exhibition halls or shopping centers. It is a good tool to demonstrate the complex mechanical systems.

The future work includes: (a) Develop a CAD module that can automatically generate the four views from a 3D model, (b) Develop an app that can launch the 3D holography, and (c) Develop a true 3D holography system.

REFERENCES

[1] Bretscher, U.: http://www.musketeer.ch/index.html, accessed on 10 February, 2014,

[2] Du, R.; Xie, L.: The Mechanics of Mechanical Watches and Clocks, Springer, 2012.

[3] GP Girard-Perregaux: Girard-Perregaux Constant Escapement L.M. The High-Tech Revolution in Motion, http://www.girard-perregaux.com/news/news-details-en.aspx?id = 513, accessed on 9 February, 2014.

[4] Hodinkee: In-Depth: The Girard-Perregaux Constant (Force) Escapement, Explained, http://www,hodinkee.com/blog/in-depth-the-girard-perregaux-constant-force-escapement-explained, accessed 20 September 2013

[5] Institute of Precision Engineering, The Chinese University of Hong Kong: Virtual library of mechanical watches and clocks, http://www.ipe.cuhk.edu.hk/Website%20v2/Website/index.html, accessed on 9 February, 2014.

[6] JMunchow: Girard-Perregaux Constant Escapement - Silicone, Silicon & the Future!, http://forums.watchuseek.com/f381/girard-perregaux-constant-escapement-silicone-silicon-future-892512.html, accessed on 10 April 2014.

[7] Mark Headrick's Horology Page, http://www.abbeyclock.com/tframed.html, accessed on 10 February, 2014.

[8] Oechslin, L.: Escapement for a Timekeeper, US Patent 6,708,576 B2, 2004.

[9] Stults, K.: In-depth: The Girard-Perregaux Constant Escapement Explained (Video), accessed on 20 September, 2013.

[10] Tam, L.C.; Fu, Y.; Du, R.: Virtual Library of Mechanical Watch Movements, Computer-Aided Design and Applications, 4(1–4), 2007, 127–136. http://dx.doi.org/10.1080/16864360.2007.10738533

[11] Timebooth: Ludwig Oechslin 2011, http://www.timebooth.com/watchmakers/38/, accessed on 9 February 2014.