

CCD Mechanical enhancement of imaging speed for commercial camera

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Abstract

Imaging becomes an advantageous technical tool in the recent decades. It enables many scientists to understand different phenomena. However, there are many high-speed phenomena that cannot be imaged using a commercial non – scientific cameras due to their low capturing speed compared to the phenomenon's. Such phenomenon, needs high-speed expensive cameras. Some of those phenomena can be monitored if the imaging speed of the current commercial cameras is slightly increased. Consequently, it is possible to increase the speed of the video recording for a commercial cheap camera using crank and piston mechanism. A phenomenon faster than the speed of the current commercial cameras had been created and captured with the aid of the present enhancement. Two cases are compared. In the first case, the phenomenon was at a speed faster than the imaging capability of the camera and without using the present mechanism. In the second case, the phenomenon speed was kept constant but the camera is now fixed on the piston. As expected, the video capturing process enhanced and the captured images are seen to be clearer by means of a visual qualitative (mere eyes) observation between the images of the two cases.

Key words: digital camera, frame rate, moving camera, crank and piston mechanism.

تحسين ميكانيكي لسرعة تصوير كاميرا تجارية من نوع CCD

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الخلاصة

أصبح التصوير أحد أهم الوسائل التقنية في العقود الأخيرة. فهي تمكن العديد من العلماء من فهم الكثير من الظواهر. رغم هذا، فإن هنالك الكثير من الظواهر العلمية السريعة والتي لا يمكن تصويرها بواسطة الكاميرات التجارية الغير علمية بسبب سرعتها القليلة مقارنة بسرعة الظاهرة. لذا فهي بحاجة إلى كاميرا عالية سرعة التصوير وثمينة. علما ان بعض تلك الظواهر يمكن تصويره باستخدام نفس الكاميرا التجارية فيما لو أصبحت سرعتها أعلى بقليل. لقد تمكنا في هذا البحث من زيادة سرعة التصوير الفيديوي ميكانيكيًا لكاميرا تجارية رخيصة غير علمية باستخدام آلية المحور المتعرج والمكبس عمليا. لقد تم تصوير حدث افتراضي، مصنع مسبقا، وهو أسرع من سرعة تصوير الكاميرا بواسطة التحسين الحالي. ولقد أجريت المقارنة بين حالتين رئيسيتين. في الحالة الاولى كانت سرعة الحدث أعلى من سرعة تصوير الكاميرا ومن دون استخدام التحسين الحالي، أما في الحالة الثانية كانت سرعة الحدث نفسها ولكن تم استخدام التحسين فيها. وكما كان متوقع، تحسنت سرعة التصوير حيث أن الصور التي نتجت من تحليل الفيديو للحالة الأخيرة لقيت تطابقا مع صور الظاهرة. واعتمد وضوح الصورة على أساس المقارنة بالعين المجردة بين الحالتين.

الكلمات المفتاحية: كاميرا رقمية، سرعة تصوير، كاميرا متحركة، آلية المحور المتعرج والمكبس.

1. Introduction

Commercial cameras are widely used throughout the world as they are very cheap comparing to the scientific high-speed cameras as well as are easy to use. In the last few decays, imaging became a scientific tool. Weinstein, et al [1] used a digital camera capable of frame rates up to 2100 pictures/second for measuring the speed of spherical particle during its travel in fluid filled column. The commercial camera are cheap but with a limited frame rate and the scientific cameras has a high frame rate but is expensive. Amano, et al [2] proposed a method to detect moving obstacles on image data those given from two cameras on moving vehicles. Although the vehicle is moving, when it is possible to regard the position of the camera as being at a standstill, the variation of image data from the camera that is mounted on the moving vehicle is caused by motion of the moving obstacles. Dani, et al [3] introduced a state observer for estimating the structure of a moving object with unknown different velocities seen by a moving camera. The object was moving in the plane ground while the camera was attached to a moving vehicle. Kim, et al [4] presented a detecting and tracking moving object using an active camera, which is mounted on a mobile robot. Byeong-ei An [5] used a circuit for sensing the movement of a subject and automatically initiates camera movement in the direction of movement by the subject. High-speed phenomena can be captured using high-speed cameras (scientific cameras). However, those cameras are not available in most academic institutes of the third world countries or at least they are available for a limited facilities due to the following major reasons: expensiveness (Economic problem), not available in market due to low demands, and requires high saving memory and processor (Electronic problem). It is much preferable to use cheap and at the same time good enough for doing some imaging tasks.

In this paper, the camera is allowed to follow the object in the direction of motion. This means that the camera must move along whatever the path's length was. This implies that the camera moves as long as there is a motion. It may be practical if "limited" motion of the camera is allowed. Limited motion of the camera for a continuous happening phenomenon may be advantageous because it only needs few centimeters length of the path and would be continuous when the motion of the camera became periodic. All previous works strongly approved that moving the camera with moving objects enhances the imaging process.

Accordingly, this research has its unique condition that is the comparison with the above literatures is not quite possible because most of the adopted modifications on those papers are either electronically inside the camera itself or by using a sophisticated algorithm for image processing. From a mechanical technique point of view, there may be a mechanism, which may help externally, to enhance the speed of imaging.

2. Mechanical Enhancement

It is intended in this study to use the piston and crank mechanism in the process of video imaging leading to produce a new technique as an external modification to the ability of the commercial cameras. An experimental device is suggested to hold the camera rigidly and allows only one direction of motion for imaging.

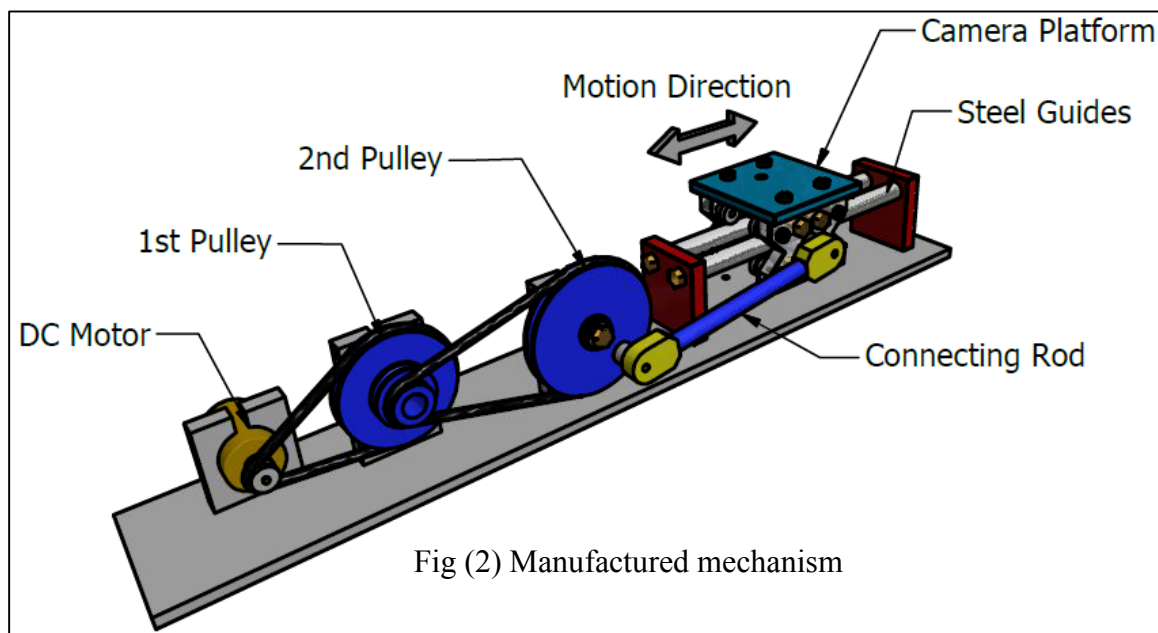
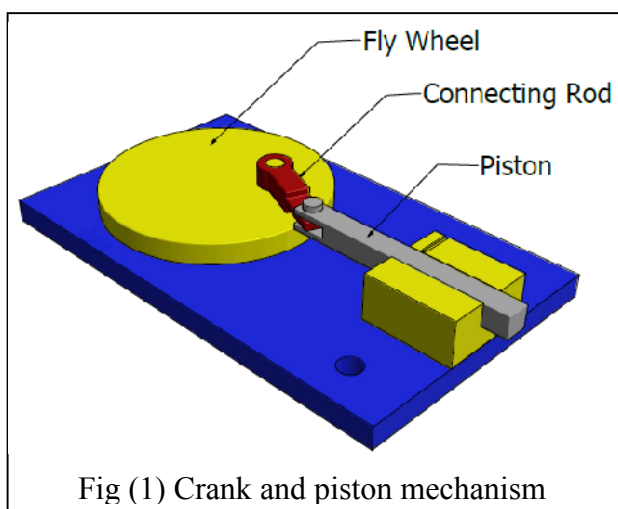
Any scientific research requires a set or sets of assumptions in order to simplify the problem and to make the problem solvable. However, those assumptions seems to be more

realistic since there are many phenomena and engineering applications of such or approximately almost having the same features. Those assumptions are:

- 1- Constant speed phenomenon.
- 2- The phenomenon is periodic (repeats itself regularly), and
- 3- One dimension motion.

3. Manufactured Mechanism

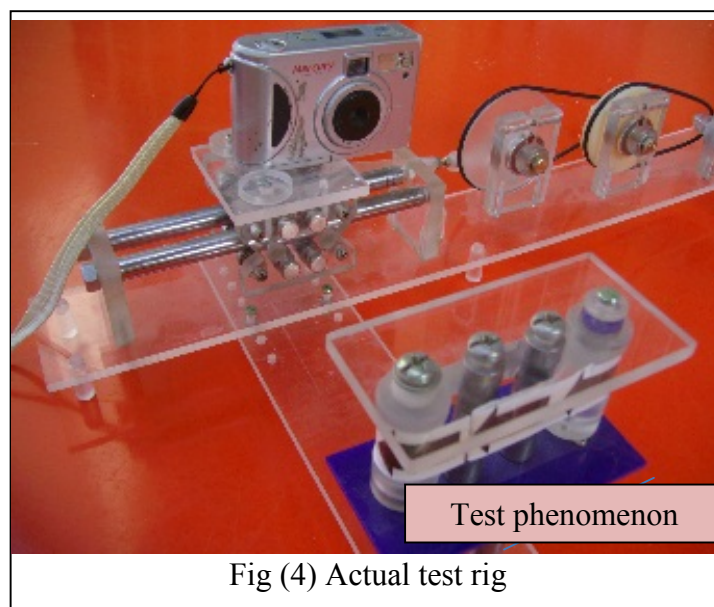
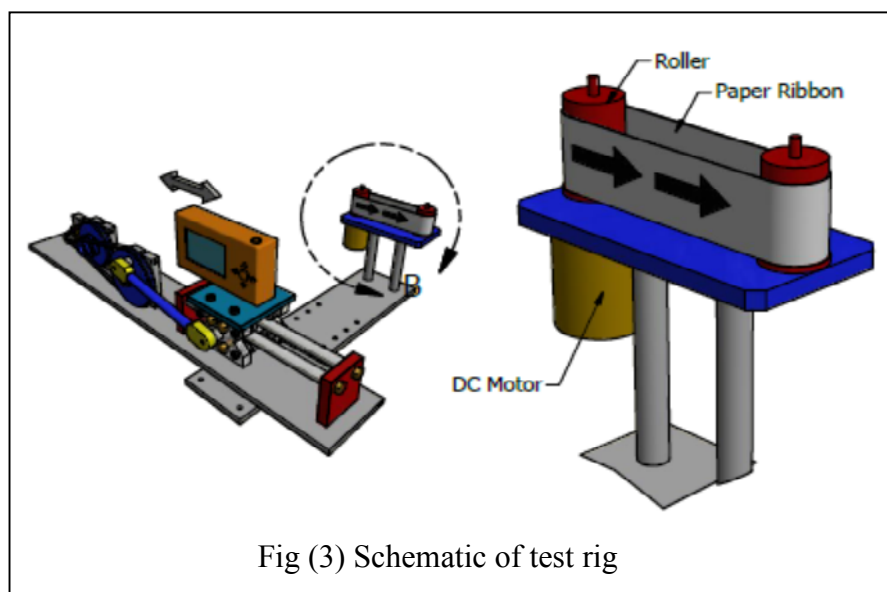
The test rig had been drawn using Autodesk Inventor software and manufactured locally. It includes the well – known crank and piston mechanism as shown in Fig (1). The piston in the crank and piston mechanism is replaced by a sliding platform, which holds the camera and moves on a steel guides, Fig (2).



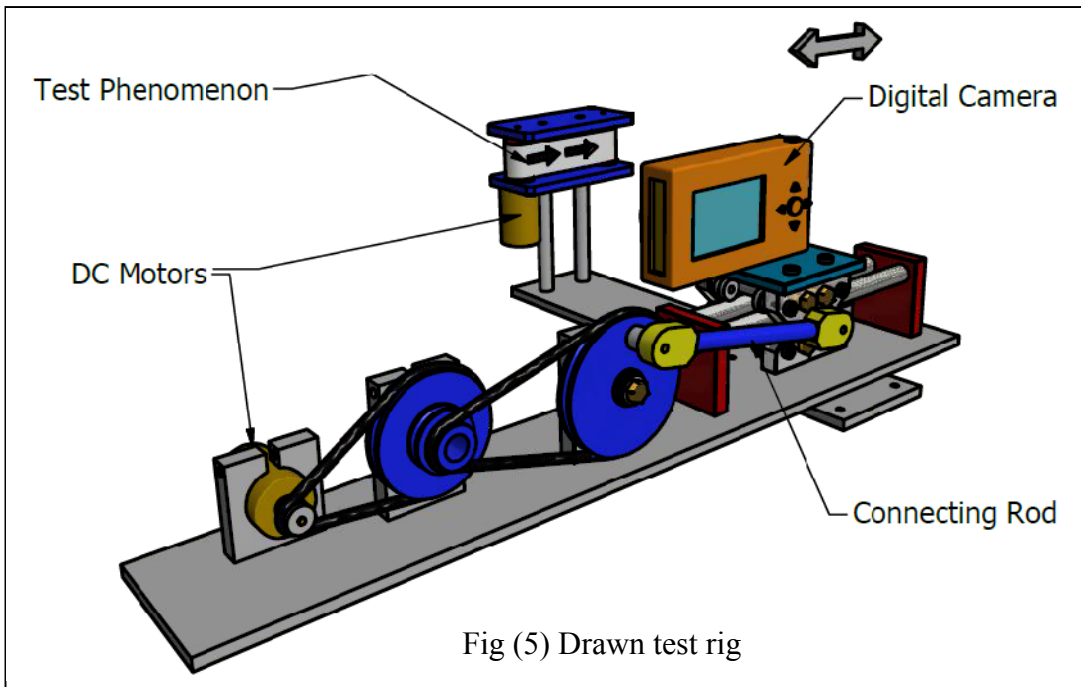
Two DC motors are used with two variable DC power supplies. One for the platform and the other for the tested phenomenon. Two reduction pulleys are designed in order to supply the required torque for moving the system when a small low power dc motor is to be used.

4. Tested Phenomenon

A phenomenon was made to simulate the presence of an event to be visualized and it satisfies our assumptions. It consists of few successive arrows drawn in a white paper ribbon on the same line to simulate one-dimensional flow. The paper is wrapped on two rollers. One of the rollers is directly coupled to small DC motor in order to give the paper a speed, Fig (3). The tested phenomenon is placed about (25 cm) in front of the camera as shown in Figs (4) and (5).



The velocity of a given phenomenon may or may not be known. It is to be measured experimentally or determined theoretically. By the voltage regulator, which is equipped with test rig, it is possible to increase the velocity of the platform from zero to the maximum ability of the DC motor. The velocity of the tested phenomenon is set to approximately (0.52 m/sec) so the camera could not be able to capture the arrows without using the current mechanism. The speed of the body of the camera is donated as (v_B), which is also the speed of the platform (sliding element). The first pulley consists of three different grooves having three different diameters.

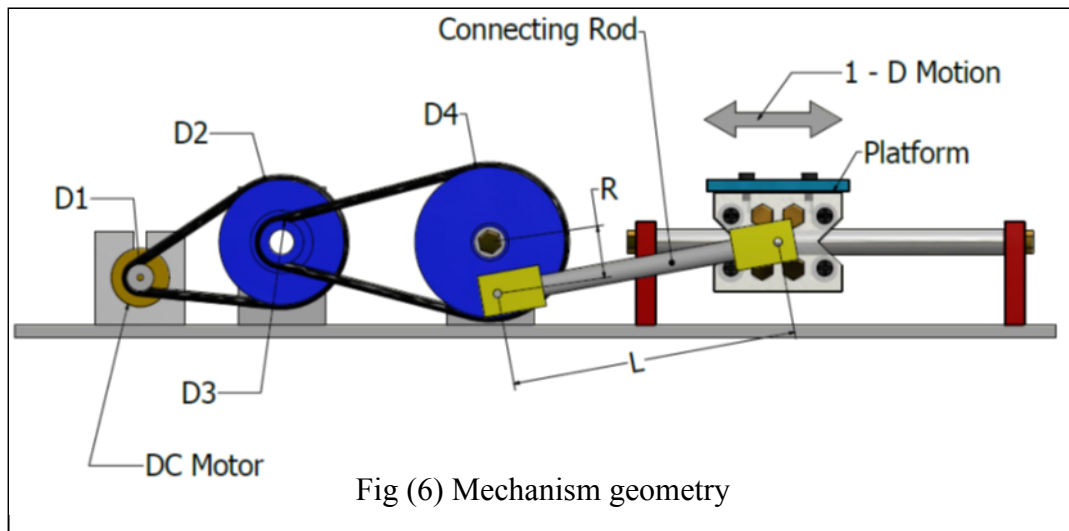


During test, the smallest and the largest diameter of the first pulley is used, as shown in Fig (6). The crank radius (R) is contained in the second pulley. The connecting rod length (L), transfers motion from the second pulley to the platform where the camera is fixed on. The following equation represents the velocity of body of the camera [6],

$$v_B = -R \frac{N\pi}{30} \left| \sin \left(\frac{N\pi}{30} t \right) + \frac{rR}{2L} \frac{\sin 2 \left(\frac{N\pi}{30} t \right)}{\sqrt{1 - \left(\frac{R}{L} \sin \left(\frac{N\pi}{30} t \right) \right)^2}} \right| \dots\dots\dots(1)$$

Where, t stands for time, N is the speed of the second pulley. The following table is showing the technical data of the experiment.

N (rpm)	R (mm)	L (mm)
120	15	170



5. Experimental Results and Discussion

Video clips for the tested phenomenon are recorded by using a commercial digital camera of 30 FPS (frame/sec). The phenomenon is an equally spaced arrows printed on a paper ribbon, Fig (7). Qualitative measurements are obtained by mere eyes when the arrows become as clear as possible.

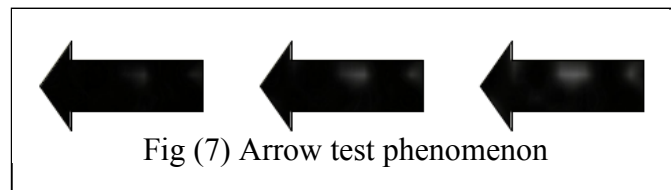


Fig (8) shows 30 extracted frames for a complete second of time duration taken from the movie of the visualization. All the frames are unclear because the speed of the test phenomenon is faster than the imaging speed of the camera and without using the mechanical enhancement. The arrows in Fig (8) appears as a long rectangular shape filled with black and white colors repeatedly and do not look much similar to Fig (7). That is due to the occurred interference between the black arrows and the white gaps between them.

Fig (9) shows few frames having almost clear view of the target objects, the arrows, after using the mechanical enhancement. About ten frames gave a good picture about the arrows out of thirty frames. While the rest twenty frames were a combination of a completely unclear and partially clear. This is because the platform of the mechanism with the camera is moving in the same direction of the phenomenon for the clear ten images as the relative velocity is approximately at its lowest value, while it is moving in an opposite direction for the rest of frames, relative velocity is almost at its maximum value. In addition, the only apparent objects on the ten clear frames are only the arrows. The background, which mainly consists of the rollers, motor, and the structure of the tested phenomenon except the ribbon remains distorted. This is because the camera is moving at a velocity close to the velocity of the arrows while the background is remained stationary (its velocity is equal to zero) leading to produce a greater relative velocity between the camera and the background, at the instance when the arrows and the camera are moving in the same direction. Fig (10) shows the velocity

of the tested phenomenon and the velocity of the platform. The average velocity of the platform, which is obtained experimentally by observing the distance it cuts in a second, is found to be about (0.15 m/sec) at the instance of a clear view for the arrows, red curve. A compensation due to the internal imaging velocity of the camera enabled the capturing process of the tested phenomenon of a (0.52 m/sec) velocity by a camera moving at an average velocity of (0.15 m/sec) . The only related part of the green curve in Fig (10) is the positive values which gives the lowest relative velocity and this condition is observed to be true when the arrows becomes clear at a velocity about (0.15 m/sec) in the direction of the arrows.

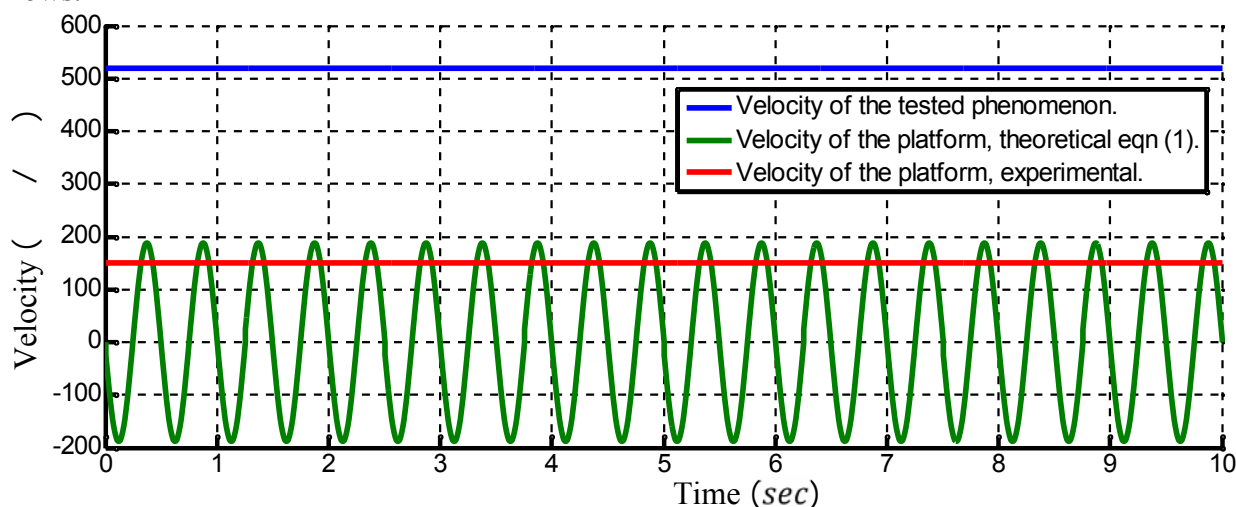


Fig (10) Velocity versus time

6. Conclusion

This work proves that using crank and piston mechanism may have another application in addition to its common usages. It is possible to visualize and get clear shots, which is about 10 frames per second. This enables the camera to monitor a faster phenomenon like the one used here without using a scientific camera. The main conclusions are summarized as follows:

- 1- It is not necessary for the phenomenon to be of an exact known velocity since there is a good speed compensation comes from the internal imaging velocity of the camera itself as shown in Fig (10). Only slight increase in the velocity of the platform is required to cope the phenomenon.
- 2- It enables using commercial cameras for scientific purposes .
- 3- Too many images, 1000 FPS for instance, which is usually come for scientific cameras requires a lot of time of mere observations. While, in the current research, there is only 30 frames for each second of time. Furthermore, too many images need a sophisticated computer algorithm for tracking the required target.

It is recommended to make another study for a two dimensional case for a more complicated phenomena using the same features of the current camera with a more advanced enhancing mechanism.

7. References

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The work was carried out at the college of Engineering.

Fig (8) 30 Successive frames without modification

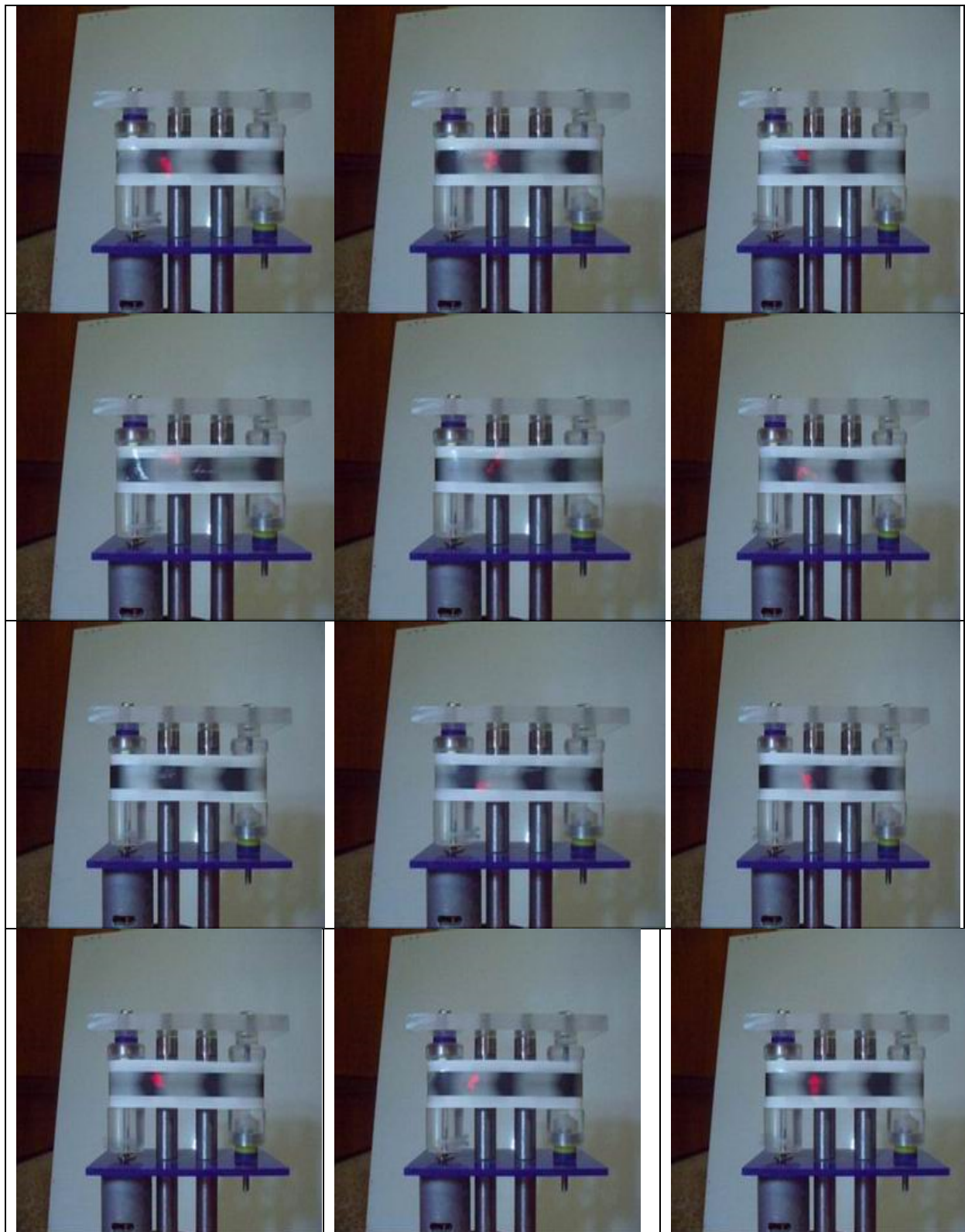


Fig (8) Conti.

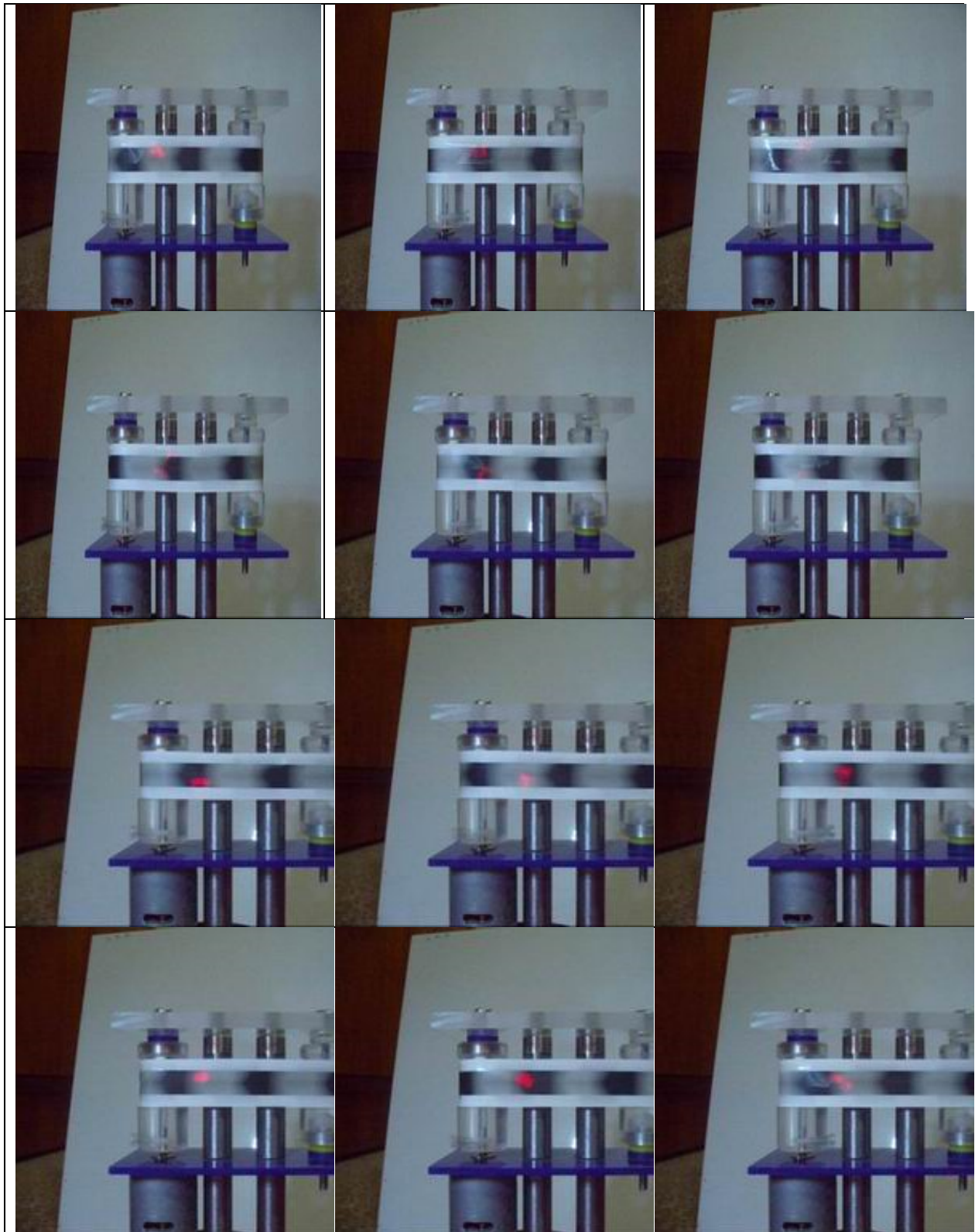


Fig (8) Conti.



Fig (9) 30 successive frame using the current mechanism





