Unconventional Methodology for Slow Motion Control Using the Arduino Platform

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***Abstract*— This article discusses a possible solution to the problem of slow motion recording, also known as slow motion, using the Arduino platform. The issue of slow motion is solved by using high-speed photography and the entire process is controlled by the Arduino platform. An integral part of this article is a set of selected experiments, which were realistically verified by the proposed methodology. Putting such a device into practice could be really useful not only for the needs of university education in the field of graphics, but also as a relatively attractive device for leisure activities. In the conclusion, mapping results are evaluated and compared with the real situation.**

***Index Terms*— Arduino; Animation; Control; Slow motion.**

I. Introduction

Slow motion records popularity is increasing these days especially in the film industry. However, slow motion record can be very useful for example for scientists, specialists from various fields, etc. Using sufficiently slow motion footage, we are able to capture processes which take place in a fraction of a second and then to explore their progress and evolution. A big problem is the high purchase price of cameras which can capture such a recording. In 2011, the scientists from MIT implemented a slow motion footage of one trillion frames per second thanks to a similar, but more sophisticated and of course more expensive, technology. They managed to capture a laser beam passing through a plastic bottle. However, this concept has practical applications, e.g. in medicine, industry, and other fields [6].

This work is focused on a particular type of slow motion, specifically recording of repeatable processes using a digital camera and the Arduino platform. It is a general description and tutorial on how to resolve this issue with an example of the resulting experiments. This solution is significantly cheaper, but is intended solely for processes that we are able to repeat many times. Conversely, a significantly higher frame rate could be an advantage compared with conventional high-speed cameras [6].

A. Slow motion

Slow Motion (commonly abbreviated as slowmo) is an effect in film-making whereby time appears to be slowed down. It was invented by the Austrian priest August Musger in the early 20th century. Typically, this style is achieved when each film frame is captured at a rate much faster than it will be played back. When replayed at normal speed, time appears to be moving more slowly. A term for creating slow motion film is over cranking (Figure1), which refers to hand cranking an early camera at a faster rate than normal (i.e. faster than 24 frames per second). Slow motion can also be achieved by playing normally recorded footage at a slower speed. This technique is more often applied to video subjected to instant replay, than to film. A third technique that is becoming common using current computer software post-processing (with programs like Twixtor) is to fabricate digitally interpolated frames to smoothly transition between the frames that were actually shot. Motion can be slowed further by combining techniques, interpolating between over cranked frames. The traditional method for achieving super-slow motion is through high-speed photography, a more sophisticated technique that uses specialized equipment to record fast phenomena, usually for scientific applications. Slow motion is ubiquitous in modern filmmaking. It is used by a diverse range of directors to achieve diverse effects. Some classic subjects of slow motion include [2]:

i. Athletic activities of all kinds, to demonstrate skill and style.
ii. To recapture a key moment in an athletic game, typically shown as a replay.
iii. Natural phenomena, such as a drop of water hitting a glass.

How slow motion works? There are two ways in which slow motion can be achieved in modern cinematography. Both involve a camera and a projector. A projector refers to a classical film projector in a movie theater, but the same basic rules apply to a television screen and any other device that displays consecutive images at a constant frame rate [3]. Over cranking (Figure1) and time stretching, see Figure 2. For a purposes of making the above illustration readable a projection speed of 10 frames per second (frame/s) has been selected, in fact film is usually projected at 24 frame/s making the equivalent slow over cranking rare, but available on professional equipment.

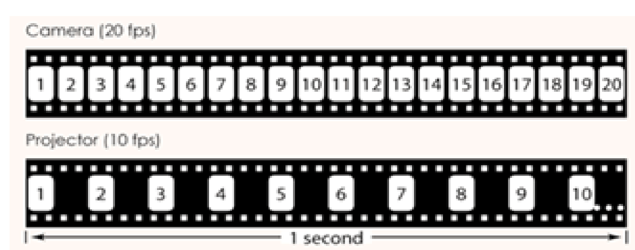

Figure 1: Over cranking

Frames marked with an X must be fabricated. The second type of slow motion is achieved during post production.

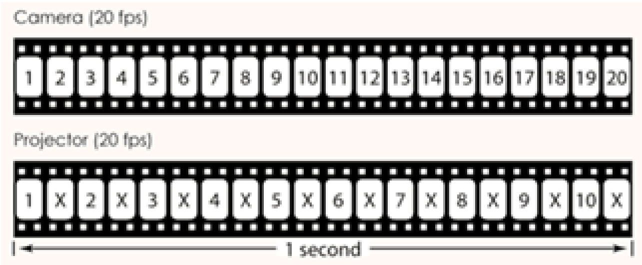

Figure 2: Time stretching

This is known as time-stretching or digital slow motion. This type of slow motion is achieved by inserting new frames in between frames that have actually been photo-graphed. The effect is similar to over cranking as the actual motion occurs over a longer time [2].

Since the necessary frames were never photographed, new frames must be fabricated. Sometimes the new frames are simply repeats of the preceding frames but more often they are created by interpolating between frames. (Often this interpolation is effectively a short dissolve between still frames). Many complicated algorithms exist that can track motion between frames and generate intermediate frames that scene. It is similar to half-speed, and is not true slow-motion, but merely longer display of each frame [3].

B. Works on the issue of slow motion using high-speed photography

Using and scientific experiments with unconventional slow motion methods are popular, as evidenced by the following scientific articles. Web article discusses the creation slow motion water drops falling on water surface [4]. A team of people put together quite a complicated assembly that seeks to minimize the number of manual operations using the Arduino platform. Their idea was to combine animated backgrounds for tracking a drop from the first phases of the flight until impact. Finally, an image containing over 2000 individual images was created. The first problem was the detection of flying droplets, see Figure 3.

Figure 3: One of the final composition images

As a solution was chosen laser detection and a photodiode, which together form a so-called photo-barrier. Another problem to solve was monitoring water drops during flight. This was solved using synchronization of two stepper motors. The result of this project is very effective, but relatively complicated. A more scientific use of this principle was used by the researchers from MIT (Massachusetts Institute of Technology) when in 2011 they created a system that can scan trillion exposures per second. This system was able to capture slow motion light beam. Although the light needs only a trillionth of a second to pass through a bottle, a camera needs over an hour for this recording. This camera contains a series 500 sensors, each is triggered with a delay of a trillionth of a second. Also the principle of the camera is different from the conventional solutions. This solution is very complicated and also expensive, but has great benefits for scientific or medical work. Given the complexity of the problem and its technical solution, it can be very difficult to criticize anything. If the device gets into real deployment, for example, in medicine, then its price will be high due to the technical complexity and the small number of produced pieces, but justified. For our work, we decided to use the technique of high-speed photography, but not in Muybridge's style, but with only one camera and platform Arduino, which will control the process. We want to use a similar approach to the used in the project on the site [4].

C. Arduino

Arduino is an open-source prototyping platform based on easy-to-use hardware and software. Arduino boards are able to read inputs - light on a sensor, a finger on a but-ton, or a Twitter message - and turn it into an output - activating a motor, turning on an LED, publishing something online. You can tell your board what to do by sending a set of instructions to the microcontroller on the board. To do so you use the Arduino programming language (based on Wiring), and the Arduino Software (IDE), based on Processing. Over the years Arduino has been the brain of thousands of projects, from everyday objects to complex scientific instruments. A management element our project we chose slow motion platform Arduino. Compared with the alternative, which may be for example Raspberry Pi, Arduino is much simpler and more suitable for the purpose of this work. Arduino’s advantage is also a programming language based on C / C ++, and last but not least, the price of the whole platform [2].

II. METHODOLOGY

The methodology described below is based on an analysis of current possibilities of the slow motion and its technical solutions. This methodology is based on the assumption that it will use only one camera, necessary sensors and one Arduino plat-form. In Figure 4, you can see a list of individual issues that has to be addressed and subsequently verified in real terms to achieve correct slow motion.

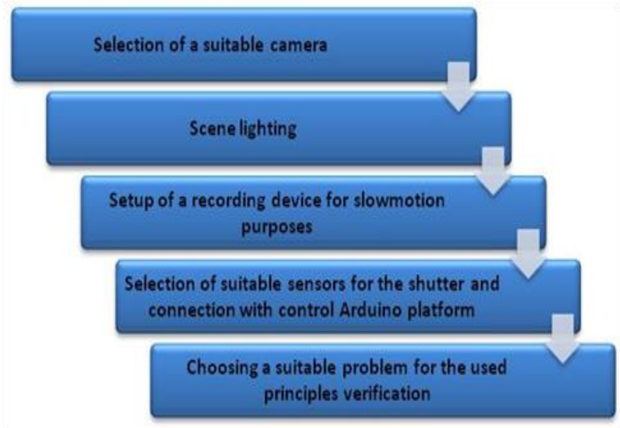

Figure 4: Individual steps of the proposed methodology

A. Selection of a suitable camera

In order to secure the functionality of the entire slow motion system using high-speed photography, it is obviously important to choose the right camera that will capture the image. Thus, it is necessary to choose a camera that supports semi-automatic modes or a full manual one. For the slow motion purposes, the manual mode appears to the best as we want to shoot at identical lighting conditions. Conversely, the automatic mode is completely inappropriate and the use of a semi-automatic mode does not seem appropriate either. The values calculated by the exposure metering could be different in each frame and thus influence the aperture value or the shutter speed and leading to misperception of the whole photography.

We highly recommend selected a camera with the manual exposure mode. This can avoid possible problems with the automatic or semi-automatic exposure modes. If we want to control the shutter via a remote control, it is necessary to check how big the delay is between sending the signal to the camera and opening the shutter. If this response is not fast enough, almost immediate, then the shutter remote control can´t be used for slow motion. In this case, it is necessary to control the shutter manually and use a higher shutter speed and use a speed light to illuminate the scene.

When choosing a camera, it is necessary to verify which fastest shutter speed the camera can handle and whether you can set this parameter.

B. Scene lighting

Photography is simply capturing photons with a sensor and converting them to image output. Therefore scene lighting is crucial for the look of the scene but also for the correct exposure. If we want to shoot a sequence of images for slowmotion using a very short shutter speed and external flash, then the flash has to support the HSS (High Speed Sync). This function provides synchronization between the flash and the mechanical shutter blades. Shooting slowmotion with a slow shutter speed and a flash can be done only with a simple manual external flash with a remote control realized either via a radio signal or a cable.

C. Camera settings for high-speed photography

This section is devoted to specific camera settings depending on scene lighting and the speed of the object that we want to shoot. Camera settings are based on a method that will be used in high-speed photography. The recommendations for correct selection of the ISO value should therefore be as follows:

i. Select the lowest ISO value - in most cases ISO 100.
ii. Take a test shot with a flash.
    a) If the image is too dark - increase the ISO value for additional step.
    b) If the image is too bright - increase the aperture value or decrease the flash power.
iii. Repeat step (ii) until we achieve a properly exposed image.

This brings us to the next step of setting and that is setting of the aperture value, f-number respectively. The aperture value affects the depth of field but also the overall sharpness of the image. The higher the aperture value is, the larger the depth of field is. It also decreases vignetting, spherical distortion and improves the overall sharpness of the image. The aperture value may be chosen according to the following recommended procedure.

i. Select the lowest ISO value and lowest aperture value.
ii. Take a test shot with a flash.
    a) Increase the aperture value if the image is too bright
    b) Increase the ISO value or increase power of the flash if the image is too dark
iii. If the image has too shallow depth of field or if is not sharp enough then increase the aperture value and repeat step (ii) to prevent loss of image brightness.

A similar methodology like setting of the ISO value can be used to set the flash. Get started on the lowest value and increase the power step by step if necessary. The advantage of this approach is the possibility to capture faster ongoing processes due to the speed of flash. It also makes implementation of the problem with the Arduino platform much easier since you can control only strobe lights and the camera can be controlled manually. Conversely, it may be more complex to set the camera and flash lights. When using a studio flash light, it is also important to ensure the maximum sync speed and flash rate. Setting the camera itself is very similar to that, except that the exposure time will be very short. The methodology of the setting is demonstrated in Figure 5 and 6.

This approach is straightforward and easy to understand. It is also more convenient thanks to the possibility of full automation, which eliminates the problem of synchronizing strobe lighting with the shutter. The disadvantage is the need for sufficient amount of light or expensive strobe lights with HSS function. We used laser module with the photo resist as a photo-barrier.

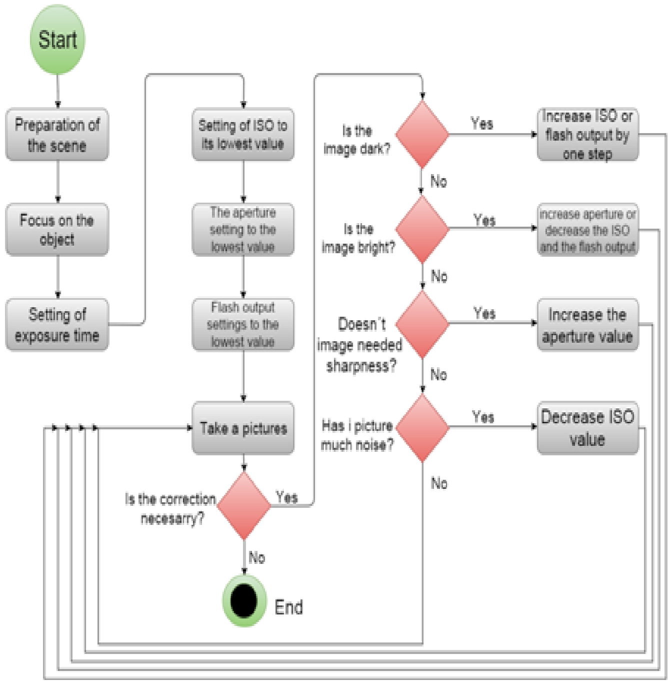

Figure 5: Diagram for recommendations of the camera and the flash

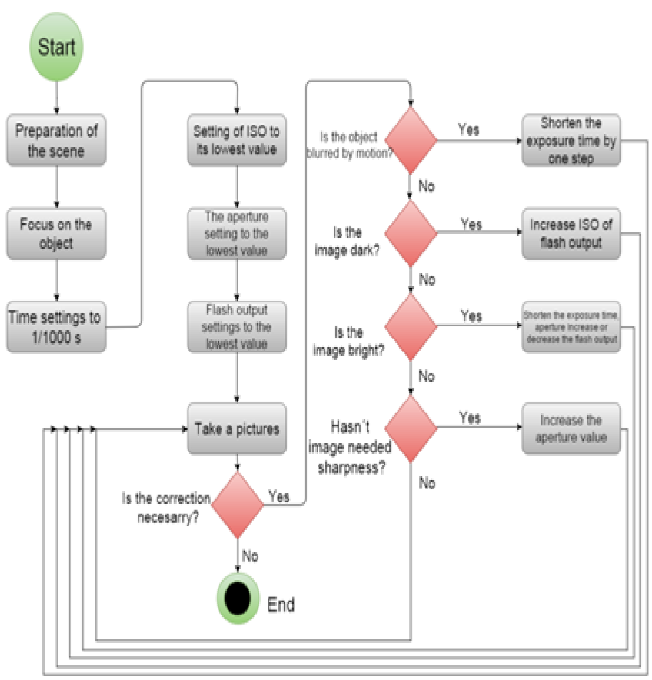

Figure 6: Diagram for recommendation of camera settings and lighting

D. Result animation

After shooting, a series of high-speed images is ready for the final processing of the resulting animation. We used compressed JPEG format for our experiments. We can practically use any video editor which allows you to work with image files. Adobe After Effects is one of many available software, which can compose slow motion animation and convert it into a video format. The following section is devoted to describing the equipment assembled on the basis of the proposed methodology. The whole device is designed for a given issue, namely a drop of water hitting a razor blade.

E. Describe of using devices

The following Figure 7 shows the entire device. Individual parts are marked with red numerals for better orientation.

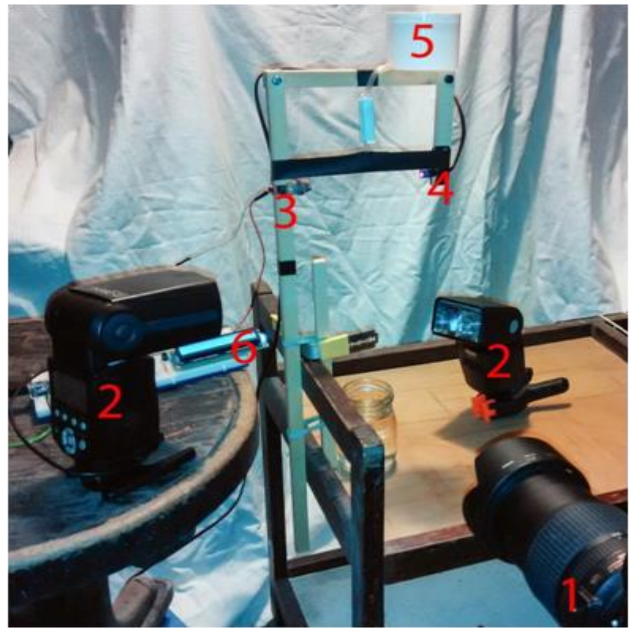

Figure 7: Using devices and components for experiments

i. As a camera, we chose Nikon D5100 DSLR with lens Nikon Nikkor 18-105 mm f / 3.5-5.6G ED VR AF-S DX. The camera was placed on a tripod in order to exclude any movement of the camera. The camera was set in manual mode, the following parameters: exposure time of 1 sec., Aperture f / 7.1, ISO 100, focal length of 105 mm.
ii. System flashes: The light source was a pair of lightning systems. The first of two flashes (left) is Yongnuo YN560-III, set to 1/64 power. This flash is connected via the PC sync port to board Arduino Nano. The second flash (right) Metz 48 AF-1 digital is set to 1/128 power and running in a subordinate (slave) mode.
iii. Laser Module: laser module in this case is used together with the photo resist as a photo-barrier. The laser module is connected to the Arduino platform, which controls it.
iv. Photo resistor: Photo resistor VT83N2 serves as a sensor for sensing light intensity. This sensor is connected to an analog port of the Arduino board.
v. Water container: We decided to record slow motion of water droplets. Therefore, we have designed a simple water tank with a hose and valve.
vi. Board Arduino: The control element was board Arduino Nano, which was located in Solder breadboard along with other components.

F. Connection diagram

The foregoing description of the device is quite general. This part shows the wiring of individual components to the board Arduino Nano. Below is a description of the components: 3x micro switch TC-0104, 4x resistor 1 kΩ, 1 x LCD Hitachi HD44780, potentiometer PC1621NAK100, bipolar transistor BD137-10 TO126, DIP6 VISHAY 4N26 opt isolator, 330Ω resistor, laser module F-LASER 1MW 6MM, photo resist VT83N2, PC Sync Cable, Arduino Nano clone, total price for all needed components was 30,- USD.

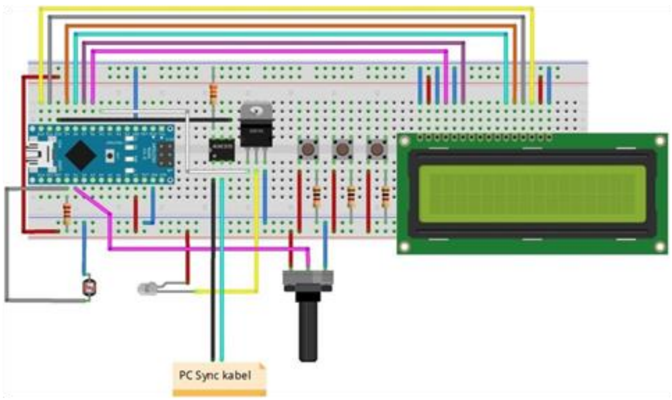

Figure 8: Connection diagram for Arduino.

III. Experimental Part

The previous section described a specific device which was compiled on the basis of the proposed methodology. This section describes the selected experiment, which was recorded as slow motion for the purposes of this study. The whole the final video including Arduino program code and connection diagram is available on the website of research group of Intelligent Systems OU, which is at [5] and also the YouTube video server [6].

As an experiment, we chose slow motion of water droplets falling on a razor blade. The goal of this experiment was to create an animation from a series of photos of various water drops which, however, will appear as the same drop. The following picture is one from the series of shots [7].

The components used to control the whole process are commonly available in electronics stores and are also affordable to the general public. The solution to this problem could be sale of DIY kits. Such a kit would contain all the necessary components, the controller, cables, detailed instructions, and so on. The user of this product would not have to worry about buying the parts, code writing and other activities. The product would be sufficient only to build and manage the manual.

Based on the proposed methodology, we were able to build a device designed for the process control of slow motion using high-speed photography controlled by platform Arduino. A sequence of images has been successfully converted to a video format. The real duration of action was subtracted from the display device after taking the last used photo. The total number of shots was several times higher than the number of the used ones. All unsuccessful or redundant photographs were discarded.

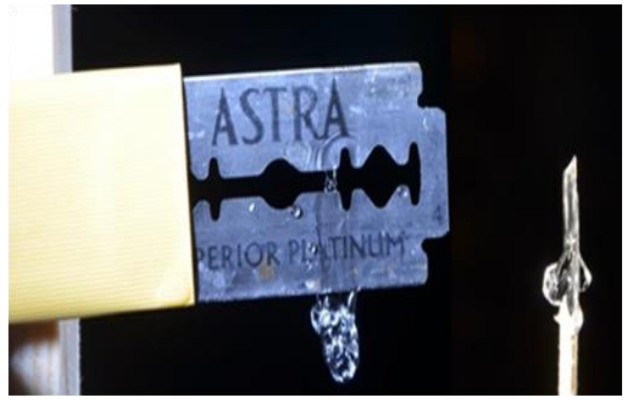

Figure 9: One of the images used for the resulting slow motion

Technical parameters of the recorded slow motion using proposed methodology:

i. The real happens duration: 70 ms
ii. The number of used images: 105
iii. The time difference between images: 600 microseconds
iv. The resulting frames per second at 1500 fps
v. Software used: Adobe After Effects CS6 or other
vi. Price: 30,- USD

Advantages: Price, resolution animation, automation, adjustable delay time.

Disadvantages: Can only be used on a repeatable process, occasional inaccuracy delays, the need to create animations.

In order to meet the purpose of this work, an experimental part described above was carried out. This consisted in water droplets hitting a razor blade. It is now possible to use the device for any arbitrarily chosen type of a problem, of course, being a subject to the size of the designated area for experiments, but it can also be used to capture high-quality images of selected dynamic processes [7].

IV. Conclusion

The aim of this work was to design a methodology to control slow motion recording, also known as slow motion, by using the Arduino platform and high-speed photography. Open-source Arduino platform was use here as a control element of the whole process. The motivation in choosing this theme of the work was the fact that cameras which allow slow motion recording are very expensive and unavailable for many people. For small financial requirements we may be able to achieve using proposed methodology truly quality results. The proposed methodology can be also potentially applicable to the study of swarm dynamics. The scope of this article obviously doesn´t correspond to all required description but we will also publish this issue in other conferences or journals.

Acknowledgment

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