Solution to Eliminate Vibrations of Mechatronic Device used in Filming Effects for DSLR Camcoders

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Abstract: The article presents the vibrations of a mechatronic solution used in linear guiding systems used to develop the filming “travelling” effect in cinematography on short distances (1 m). The guiding system is powered by an electric drive system developed especially to displace the DSLR camcorder according with the requirements of the filming effect. The device is made as a mechatronic system and software developed on a microcontroller to command the movement. The tested device includes a guided path, similar to the ones used in numerical command machines, that has a gliding trailer powered by step motors with a linear geared rack. The efficient command of the step motor is made using an ATmega8 microcontroller that sends signals, through the L298 circuit, to the step motor that will generate the micro-displacement in an open loop of 16 steps. The device can displace the camera with a high precision and a direct correlation between the travelled distance and time necessary to create high quality effects of time-lapse travelling.

Key words: Vibration Mechatronics, Stepper motor, Cinematography, DSLR, Dolly system.

1 Introduction
The new developing market for image and video devices is constantly trying to offer new and improved solutions for products that can offer comparable performance with professional devices used in cinematography. An impressive filming effect is that of time-lapse picture that can be made with any type of DSLR camera mounted on a
special displacement device. This filming effect technique requires that the frequency at which the frames are captured (the frame rate) to be much smaller than the frame rate used when showing the final movie. The effect is seen when the captured images are presented at regular speed so that the viewer has the feeling that time passes by very fast. As example when capturing frames at 1 second interval and exhibit the film with a rate of 30 frames per second the viewer will have the impression that the presented film runs 30 times faster than the reality familiar to him. The time-lapse effect is the opposite of the high speed effect. [1]

The combination of the time-lapse effect with the travelling effect is possible only in the case when the camera is moved with a very slow speed of less than 100 mm/min at constant speed. The technical solutions developed for the construction of such a device are presented in the following paragraphs. [2]

2 Materials, devices and methods used for research

The tested device presented in figure 1 has as main part the profiles guide (8) on which the gliding slide will move. On the gliding slide it is mounted the holder (1) for the DSLR camera. The step motor (3) command is made through micro-stepping by the controller (6) powered by the battery (5). The rotation movement from the step motor (3) is converted through transmission in linear displacement with the help of the rack-pulley (9) system.

The rack is a toothed belt fastened on the tensioning elements (2). The entire system rests on 3 placement points (10) in order to present a higher stability. Two of the placement points are at the edges of the rotational arm (4), and the third is at the edge of the left end of the guide support. For an easy manipulation of the device a textile carrying belt (7) was foreseen.

The operation diagram of the studied technical solution is presented in figure 2.

![Operation diagram of the device.](image1)

In figure 3 it is presented the driving element and the pulley-rack transmission. The step motor (1) is mounted on the guide slide. The displacement of the slide is made by the rotation pulley (2) geared with the silicone rubber belt (3) that also ensures some damping of the movement. The two wheels (4) aim to guide the belt in a parallel position with the guide. In order to minimize the friction, the wheels are foreseen with ball bearings.

![Driving system: 1 – step motor, 2 –rubber pulley mounted on the motor shaft, 3 – tooth belt, 4 – belt guide wheels with ball bearings.](image2)
“fast” or “slow”. The switch (2) is meant to allow the user to set the movement direction from left or right.[4]

Fig. 4 Controller box: 1 – potentiometer for fine adjustment of speed, 2 – switch to set the movement direction (left/right), 3 – power switch (on/off), 4 – switch to set the speed level (high/low).

3 Controller description. Optimization of the electronic part.

Following the requests of the project a microcontroller ATmega8 was chosen that could provide double command for both the step motor, used to move the camera on the guide, and the settings interface with the user for the adjustment of the working parameters.

The first tests were made using the standard solution, were the microcontroller sends tact and direction signals to the circuit L297.

The circuit L297 realizes the command sequence on the inputs of the H bridges from the amplification circuit L298 whose outputs are connected to the two phase lines of the step motor.

To achieve an optimized printed circuit for the electric assembly, the electronic schematic was improved by replacing the L297 circuit with a complex algorithm implemented in the microcontroller that commanded the step motor (figure 5).

4 Elimination of the problems related to the accelerations induced to the camera.

The camera displacement system must provide a movement of the filming device in such manner that the beginning of the movement must be made with a foreseen acceleration that will ensure a uniform displacement and just the same when stopping of the movement a precise deceleration must be ensured.

Initial calculations showed that the linear displacement distance required for one step is 0.25mm generated by the simple command of the step motor. This displacement rotates the driving pulley with an angular displacement of 1.80 degree.

For the situation of the mix command of the step motor, the step distance is reduced by half to a linear length of 0.125mm.

Even so, the step of 0.125 mm is not small enough to meet the requirements of the image quality desired in filming effects.

Since the accelerations and decelerations during the displacement of one step are high, the fix of the camera on the gliding device requires a special attention. In the first tests the fastening of the camera and the slider were made by using a support made out of 3mm thick aluminium sheet.

Since large accelerations are developed during the displacement of one step, the high elasticity of the holding system for the camera together with the values of the amplitudes induced camera oscillations that were often larger than the displacement step.

This situation was solved by modifying of the holding system with a more rigid steel material used in the fastening system.

The rigid fastening system improved greatly the behaviour of the system but further improvements were needed in order to shrink the step distance and to increase the step resolution.

These demands could be met by implementing the following actions:
- Mounting of a gear box with a transmission ratio that will provide a 1/5th of the 0.125mm displacement distance.
- Making the final gear out of a rubber material that is able to absorb the effects of small vibrations through its hysteresis properties.
5 Command the step motor to work with micro-steps.

Since gear box mounting would involve a growth in the production time and costs of the final product, a method of micro-step command for the step motor was developed as a solution to the vibrations from the dolly system.

The micro-step command represents the division of the step distance, 0.25mm, into 16 intervals that will result into a step with a displacement distance of 0.0156mm.

The first obstacle in implementation of the micro-step algorithm is the generation of a sinusoidal wave using the 8 bits microcontroller.

The math.h library, made available by the avrlibc, proved not to be reliable enough for this application. During the tests made using the function sin() some computation errors were detected.

The solving of the problem involved the creation of a data table with values of the sinusoidal function with values from 1 to 255. The table was then included in the command program as a vector, and so the values of the sin function were available in the software with minimum processor computation power.

This method was tested by using an open loop algorithm, so that the two H-bridges connected to the two phases of the motor will be activated through the PWM signals. In this method, each step is executed after the previous with evenly divided steps in 16 levels.

The drawback of this solution is that the control is made on the current and this leads to an imprecise functioning.

For small speeds of up to 16 micro steps per second this solution proves to be acceptable.

The higher frequencies of larger speeds presents vibrations that will be induced in the camera filming system working similar to the mix command system.

In figure 6 it is presented a logical structure of the algorithm.

For the function Next step the logical structure is presented in figure 7.

6 Research methods

The experimental research started with tests made on the controller using simple commands of the displacement system and it was seen that vibrations occurred in the filming system reflected in poor image quality.

A possible cause for these vibrations was identified not in the functioning of the step motor but in the activation of the internal lens stabilizer of the CANON 24-105L camera that reflected in a very low image quality. [7]
Tests made in similar conditions without the stabilizer active, showed that the captured images had a higher quality but still unacceptable for the final purpose of the project.

In order to develop a performance classification based on the system displacement an optic sensor was used to measure the distance.

The optic sensor works based on the triangulation during the displacement of the camera dolly and has the following properties:

- Precision: 1µm;
- Laser class: 3R;
- Number of points per second: 2000.

Comparing the two diagrams of the displacement (fig. 9 and fig. 10) over time by monitoring the movement using the Omron Laser sensor it can be seen that in the case of the micro-steps command a more smooth displacement is achieved resulting in a more fluent movement of the filming camera. [9]

In figure 8 it is presented the measuring method of the optic sensor. In figure 8 can be seen that the electric signal that comes from the sensor is amplified, converted in digital signal and sent to the RS232 serial interface to the COM1 port with the transfer rate of 9600 bits/sec without party bit.

The Smart Monitor software was used on a computer in order to determine an average of the signal and to export the measuring data into a data table.

7 Conclusions

Based on the researches made technical solutions were found in order to develop a suitable guiding device for the DSLR camera that runs on a single axis.

From the mechanical point of view the solution offers an enhanced stability of the guide system since it is foreseen with three placement points.

By optimization of the command solution of the driving device and final gear modification it was achieved a minimization of the controller box and a decrease of the production costs of the device.

Finally it could be concluded that the future in the image industry will provide manipulation devices that will make the DSLR cameras becoming more and more reliable resulting into better imaging effects as well as better picture quality adapted to the filming environment.

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