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## **1 Introduction**

In the recent times, the research on plenoptic images has become more popular, as the computational power of computers is growing and the potential uses of plenoptic data are closer to the real life applications than have ever been before. The outstanding possibilities offered by those systems constitute a significant improvement over auto-stereoscopic displays that are currently available. By offering more freedom and the possibility to display motion parallax in horizontal and vertical directions, the plenoptic systems are even closer to a true virtual reality.

The research on development of the free viewpoint television, conducted in the **MPEG FTV** workgroup, and on the development of new still plenoptic image compression, conducted in **JPEG Pleno** workgroup, both require the usage of light-field test materials of acceptable quality and of a sufficient scale. In this document we propose a set of light-field images that can be used by the research community as test images.

## **2 Light-field acquisition system**

In order to obtain test data for research activities in the field of plenoptic vision, we have built a device for the acquisition of the light-field data. During the construction, we made the following assumptions:

- The device must be able to capture the light-field in both horizontal and vertical parallax.
- We assume that only static scenes will be recorded with our device, therefore we assume that a single camera will be used and it will be moved linearly in both horizontal and vertical directions.

- The device needs to maintain sufficient mechanical stability to allow the acquisition of light-field data with sufficient accuracy and should maintain the calibration when not moved.
- It has to be characterized by cheap construction, in order to allow for numerous application and uses. We believe this may potentially boost the interest in carrying out research in the light-field area.

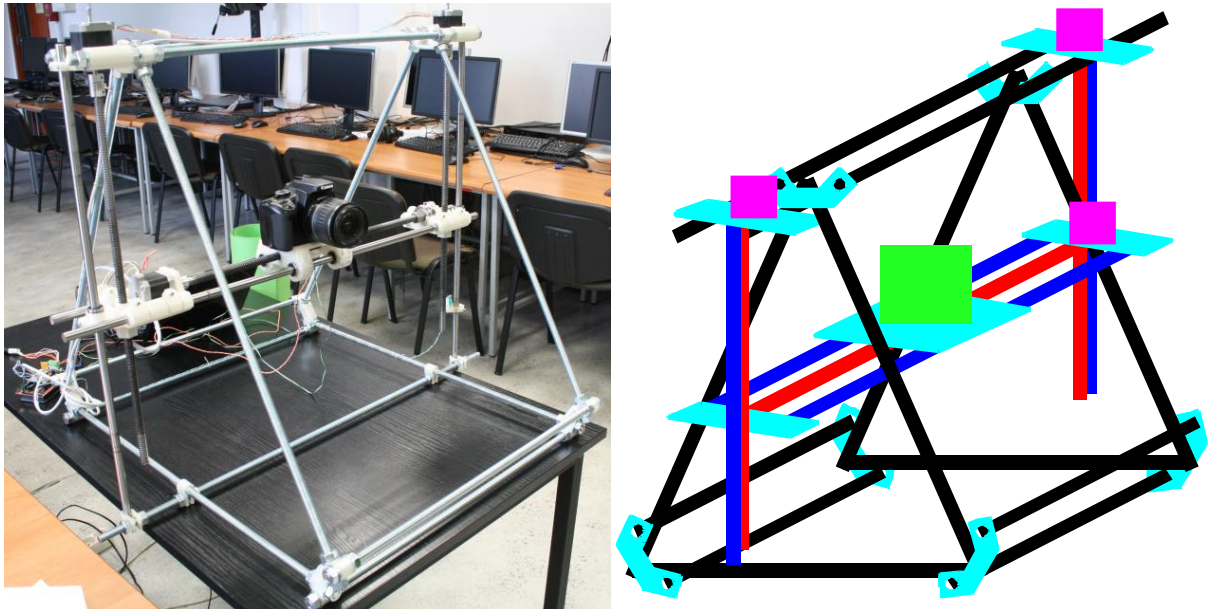


Figure 1. A general view of the device ready to work (left) and a simplified sketch of the device (right). Red – trapezoidal threaded rods, blue – plain rods, black – regular threaded rods, magenta – step motors, cyan – custom printed plastic parts, green – camera.

## 2.1 The design

Our project is based on a 3D printer construction known as Mendel Prusa i2 [1] with several modifications and simplifications.

First of all, the whole front-back motion system with printer bed was removed as it is not needed for photography. Second, the whole design was scaled up by a factor of 1.5 in order to increase motion range and to fit a bigger camera on the carriage. In order to preserve rigidity of the construction, we used 12 mm diameter threaded rods instead of 8mm as in the original Mendel Prusa design.

The most important modification is the re-design of the horizontal motion system. Originally, the 3D printer used a belt driven system, which is good when high motion speed is desired. In our application, the accuracy is more important, so we introduced a screw-driven motion system. Therefore, we used a trapezoidal threaded rod of 12 mm diameter, which is coupled to a stepper motor on one side via an elastic coupling. The rod is supported by a ball bearing on the other side. Close-up photos of both ends of horizontal motion system are shown in Figures 2 and 3. The sketch of the device is shown in Figure 1.

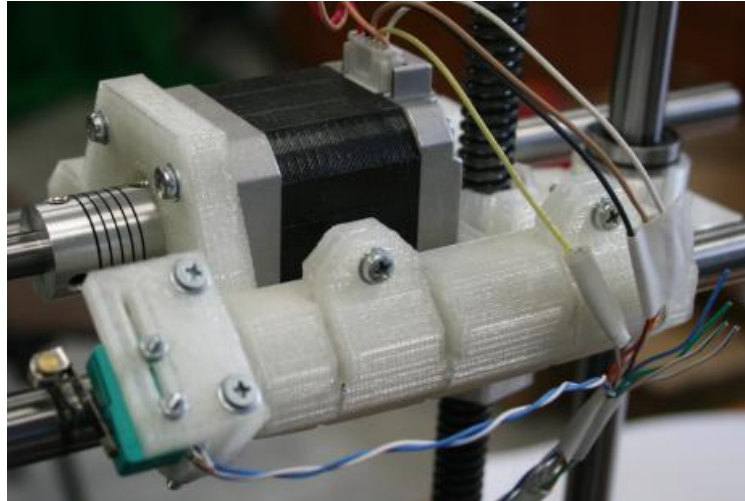


Figure 2. Stepper motor and the coupling of the horizontal drive screw.

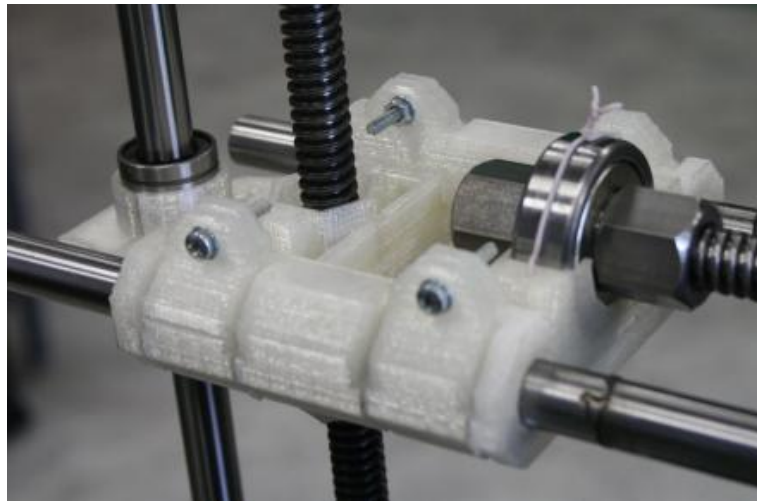


Figure 3. The opposite side – ball bearing fitting of the horizontal drive screw.

The modification of horizontal motion systems enforced a modification of the vertical drive system also. The main concept of the original construction was kept intact, however both parts that support vertical drive engines were designed from scratch in order to fit the new design. A photograph of vertical drive motor fitting is shown in the Figure 4.



Figure 4. Vertical drive motor fitting.

The camera carriage was also designed from the scratch. It is a two-part element which encloses a trapezoidal nut. The nut is responsible for driving the carriage. The carriage slides on two 10 mm-thick support rods and is attached to them by means of four linear bearings. The vertical drive is provided by two trapezoidal screws, one for each side of the device. The screws are driven by two stepper motors that are controlled simultaneously. Such approach, with two motors and two drive screws, ensures the proper motion in up-down direction while maintaining the horizontal position of the carriage rails. It also provides enough torque to lift the rails and the carriage together with the camera with an acceptable speed.

The main part of the device – the carriage with a mounted DSLR camera is shown in the Figure 5. The platform is fitted with a standard screw, so mounting of any type of camera (even a video camera) is possible.



Figure 5. The camera fitted on the carriage together with automatic release and external power circuit.

## 2.2 The controller

As a controller and motor driver we used some very popular (and therefore cheap) 3D printer control electronics: Arduino board [2] with RAMPS 1.4 shield [3]. Our controller is equipped with three stepper motor drivers. A single driver controls horizontal drive motor while two other synchronized drivers control two vertical drive motors. The Arduino board is programmed with Marlin firmware [4]. The firmware was configured appropriately for the used mechanical configuration. All other non-necessary functions (extruder control and temperature control) were configured as disabled. The control protocol is identical as for a 3D printer.

During taking light-field photos with our system using a Canon DSLR camera, we discovered that the camera battery does not have sufficient capacity to shoot as many photos as can fit on the memory card. Therefore, the battery capacity was limiting our light-field

resolution. Therefore, we designed our own external power supply system using an old battery case. With this modification, the only practical limit is the memory card capacity, as it limits the number of photos we can take. Our camera does not support image transmission over USB.

### 2.3 The software

The stepper motor controller electronics receives commands via serial interface through a built-in USB-to-serial converter. The control software is written in Python language.

The graphical interface allows to input a starting position, step and number of steps for each movement axis.

During the light-field photo capture, a sequence of commands is issued to the control electronics. First a “move to position” is sent which causes the camera to be moved to a desired position. After the motion is complete, the camera is triggered via “change output pin state” command that causes an electrical signal to be sent to it. The software makes a short delay for the camera to complete the photo exposition. Then the cycle repeats for a new camera position.

A photo of our application running on a laptop connected to the control board is shown in Figure 6.

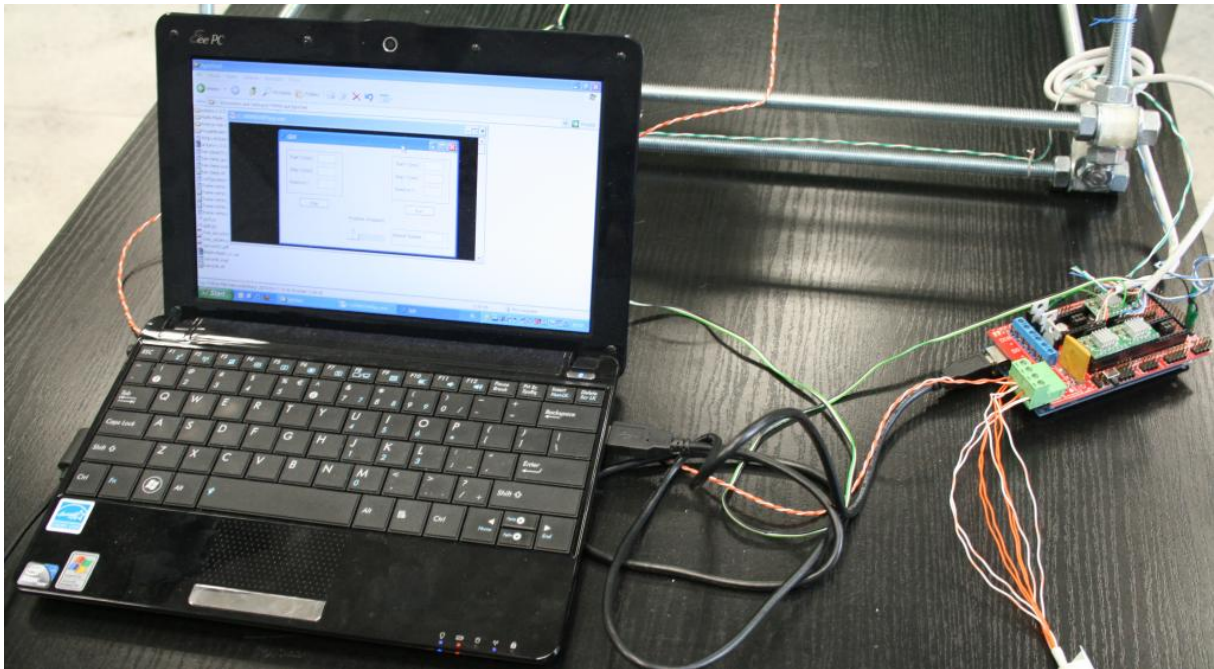


Figure 6. The controller board built using Arduino board and the computer running the control software.

## 3 Acquired Light-field images

The acquisition was performed using the Canon EOS 400D. It is equipped with 10 MPix APS-C (22.2x14.8mm) sensor. In order to obtain high quality data, we saved all images in lossless RAW format. Unfortunately, in the case of formerly acquired shot (“Poznan Laboratory”) [5] JPEG compression of each view was used.

### 3.1 Light-field images

The following light-field images (see Fig 7 and Table 2) have been captured so far and are available for research purposes upon request. All the light-field images were captured using the step of 10mm in both directions.



Poznan Laboratory 1



Poznan Laboratory 2



Poznan Cones 1



Poznan Cones 2



Poznan Bicycles 1



Poznan Bicycles 2

Fig 7. Examples of the available light-field images.

Table 2. Parameters of the available light-field images.

Light-field image set name	Image format	Number of images	Step	Focal length	Principial point
Poznan Laboratory 1	JPEG	31×31	10mm	X:1773.80	X:990.67
Poznan Laboratory 1		20×20		Y:1771.91	Y:609.77
Poznan Cones 1	RAW packed	30×30		X: 9630.01	X: 2082.81
Poznan Cones 2		30×24		Y: 9625.88	Y: 1149.39
Poznan Bicycles 1	in 16-bit TIFF	35×30		X: 4041.56	X: 2073.62
Poznan Bicycles 2		35×32		Y: 4035.41	Y: 1305.11

### **3.2 Camera parameters/ lens distortion removal**

As for every light-field image, it is necessary to perform calibration and then several steps need to be applied to the images.

For our light-field images, the intrinsic parameters and lens distortion model parameters were estimated using the widely known Zhang's algorithm [6]. The calibration pattern was presented to the camera system before and after taking all of the shots, in order to increase the accuracy and verify the rigidity of the system. The results before and after calibration were found to be very close to each other. The calibration parameters of distortion model were used to remove lens distortions in the following step.

The final extrinsic parameters assumed to have only X and Y translation components, so it is necessary to perform a pseudo rectification transformation on all the images. This process is based on the extrinsic parameters obtained from the Zhang's algorithm. Each camera image is processed with an appropriate, individual transformation. The result of this step is a set of images that correspond to the ideal planar structure of capturing devices as close as possible.

### **3.3 Image rectification**

The process of image rectification uses simple image warping and does not use any preliminary depth information. It is, therefore, only able to correct minor deviations from ideal settings of the cameras.

The algorithm that was developed for the purpose of rectification is the following: first, a set of 4 feature point sets are found in each image belonging to the set of 4 boundary (corner) views. Then, the position of the feature points in other views is interpolated.

It is assumed that when the calibration is performed properly, the feature point positions must form horizontal / vertical lines in all views for any given feature point. So the rectification process works by assuring that the lines are straight and parallel to the image axes.

The lines are straightened by applying a certain 2D homography to the images. The calculation of the transform coefficients is straightforward, as it only aims to warp the images so that the lines joining the feature points become parallel to image axes. The fact that the feature points lay along a straight line for a given row or column of images is assured by performing a distortion removal step that effectively removes any significant radial distortions from the images.

## **4 Availability**

The sequences remain the property of Poznan University of Technology but they are licensed for free use within ISO/IEC JTC1/SC29/WG11 (MPEG) and ISO/IEC JTC1/SC29/WG01 (JPEG) for the purposes of research and development of standards. These sequences can be also freely used for research purposes outside MPEG and JPEG as well. Any other use is prohibited unless an explicit permission is given by Poznań University of Technology, Chair of Multimedia Telecommunications and Microelectronics.

Acknowledgements are appreciated if the material was used in research and are **required if the material is to be used in publications**. The acknowledgement should use the reference to this document.

The abovementioned video sequences are available at <ftp://multimedia.edu.pl/ftv> ftp server. User credential will be provided upon request (see email to the authors). The license is stored along with the data and contains the following information:

## Copyrights

Individuals and organizations extracting sequences from this archive agree that the sequences and all intellectual property rights therein remain the property of the respective owners listed below. These materials may only be used for the purpose of developing, testing and promulgating technology standards and for academic usage. Acknowledgement and reference to the following source document:

*Marek Domański, Krzysztof Klimaszewski, Maciej Kurc, Robert Ratajczak, Olgierd Stankiewicz, Krzysztof Wegner, "Super-multi-view light-field images from Poznan University of Technology", ISO/IEC JTC1/SC29/WG11 MPEG2015/M36566, June 2015, Poland, Warsaw* are required in all documents that report any usage of the materials. The respective owners make no warranties with respect to the materials and expressly disclaim any warranties regarding their fitness for any purpose.

Owners of the sequences:

Name	Owner
"Poznan Laboratory 1" "Poznan Laboratory 2" "Poznan Cones 1" "Poznan Cones 2"	Poznan University of Technology, Chair of Multimedia Telecommunications and Microelectronics, Polanka 3 60-965 Poznań Poland

## 5 New test data

The described system can be used to produce a different set of test data upon a request. In particular, different parameters of the acquisition can be used (e.g. different, more dense step), or different types of scenes (but anyways must be still).

We would also bring to the attention of the group that also moving multi-view sequences from Poznan University of Technology are available [6]. The views of those sequences are not so densely spaced as those presented in this document, because they are captured by a set of sparsely spaced 9 cameras. Nevertheless, upon request, they can be brought to JPEG.

## 6 Acknowledgement

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## References

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