Sensopoda
An Alternative Sensor Assisted Auto-focus System
for Filming With DSLRs

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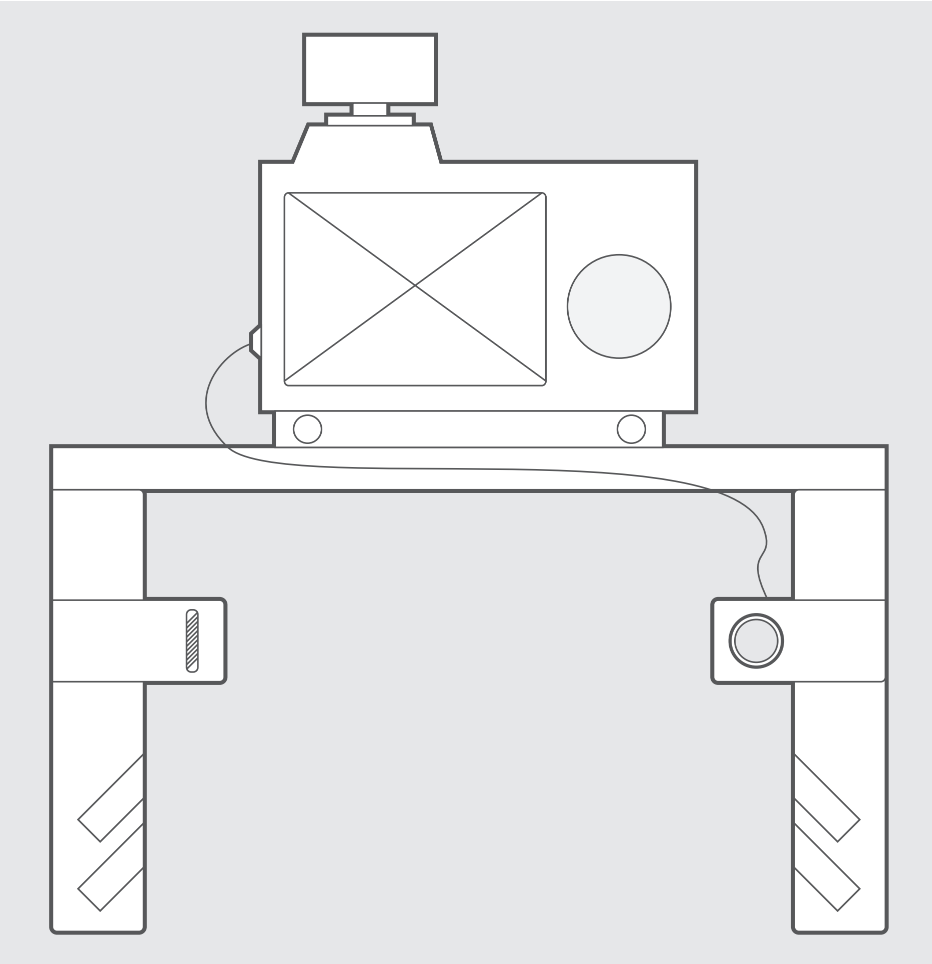
Sensopoda is a system, that bridges a technology gap of a more flexible auto-focus with DSLR cameras while filming. It supports the filmmaker with pulling the focus automatically with the help of a mid-range proximity sensor and thus gives him more freedom to concentrate on his own movement and the composition of the frame.



So, our problem in particular is connected to the autofocus. While working with a small camera crane we experienced a difficulty in pulling the focus remotely or automatically. It‘s especially very bad if you try to pan or tilt towards an object in your scene, which is on another sharpness level than the previous object or subject. Certainly one can say, the camera has an autofocusing system which works quite well, but most DSLR cameras don‘t support the fast autofocus in video mode or you don‘t have great control over the system to capture what you think is important or changing the object of interest.
This is why we came up with the idea of an „external“ auto- or follow focus that works semi-automatic based on a distance sensor.
And here is the clue: you can remotely pan and tilt the sensor, thus that the system will automatically focus on where the sensor is directed to. Basically this sounded like a simple piece of hardware, but in fact there were quite some obstacles in our way to a working prototype. We needed to find a sensor setup that suits our needs in the means of update rate, distance areas, accuracy and power consumption. A setup that additionally wipes out possible side effect like the red dot of a laser-based distance sensor. Furthermore we would be confronted with the challenge of taking the measurements and translate them into a precise motor movent to correctly „set“ the focus according to the target. And to control all of this with a most simple interface. Since our concept evolved from a diy- and gadget hacking-movement we decided to keep it: simple, small, affordable and easily reproducible.

Background

While working on a filmmaking project, we stumbled upon some flaws in working with DSLRs cameras while shooting video. Since we‘re used to film on DSLR cameras, there are several limitations to the system. One of the major flaws with older cameras is, that they lack the ability to focus on one subject and follow the focus through the frame. This is due to hardware restrictions: the onboard CPU is either to weak or just plain too old to have this feature implemented and also, the hardware design is not thought to use the camera in such fashion.

> › The name of the project **Sensopoda** is loosely based on the idea of having a core system - a head - which has many arms and can control them at any point of time, just like an Octopus. These arms don’t have to be tangible in any way: they can be just fragments of code, which are responsible for different interactions in the system or can be real cables to the outside world and also there can be as many arms as needed. ‹

One simple put explanation is this: In photomode, the system can use it‘s line and cross-sensors to distinguish between different points in the frame. This is a passive method, which allows the camera‘s sensor to pick the right object and pull the focus there, but it only works when the mirror is flipped into it‘s normal position.
When filming, the mirror will be flipped up and a constant stream of light enters the camera and the processor itself has to divide the incoming data into frames and keep them continuously in the frame buffer and save it to the memory card with some kind of compression method. On top of this, when the filmmaker wants to follow the focus on some object/subject, the processor has to fall-back to a edge-contrast detection algorithm, which is really slow in comparison in to the phase/line/cross focussing. Nowadays, more modern bridge/system cameras support some kind of auto-focusing while in video mode, but since we found out the problem with our own DSLRs, we wanted to put an emphasis on this branch of filming tools and find new ways for us but also other so-called „indie“ filmmakers with their already set equipment.
Another thing we found out, which is more of a workaround for the focus problem, is the focal length. When picking a higher focal length, e.g. 50mm or 85mm for portraits or even higher, the compression of the image also gets higher at the same time, meaning that: if you put the focus on something in the foreground and the background has a reasonable distance to the foreground, the background will appear wonderful creamy blurred out. Speaking in terms of photography, the background will have a nice Bokeh and the viewer exactly knows where to look at. In many sports and action videos, the filmmaker chooses a rather wide lens with a lower focal length, eg. 24mm, 16mm or less, combined with a wide- or fisheye-lens. Due to the nature of wide-lenses, the compression of the image is exactly the opposite of a light tele or high-tele lens and thus almost everything appears to be in focus. The filmmaker now just has to get very close to his subject to put it into the center of attention of the viewer, although the background is still clearly sharp. This is a rather unaesthetic way of filming and doesn’t fit into the realm of classic cinematography.

In our research for prior art and already existing solutions, we stumbled upon many DIY hardware hacks and gadgets that are supposed to support workflows with DSLRs in a clean and simple but manual way. None of these projects lived up to what we wanted to achieve: a simple, modular product, that can be attached to the side of any DSLR + lens combination and then pulling the focus automatically with the help of a proximity sensor and a precise stepper motor.

State of the (Art / Technology)

fig. 1

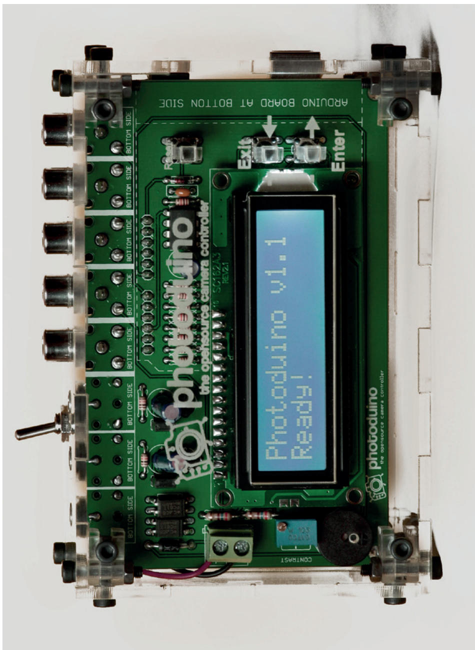
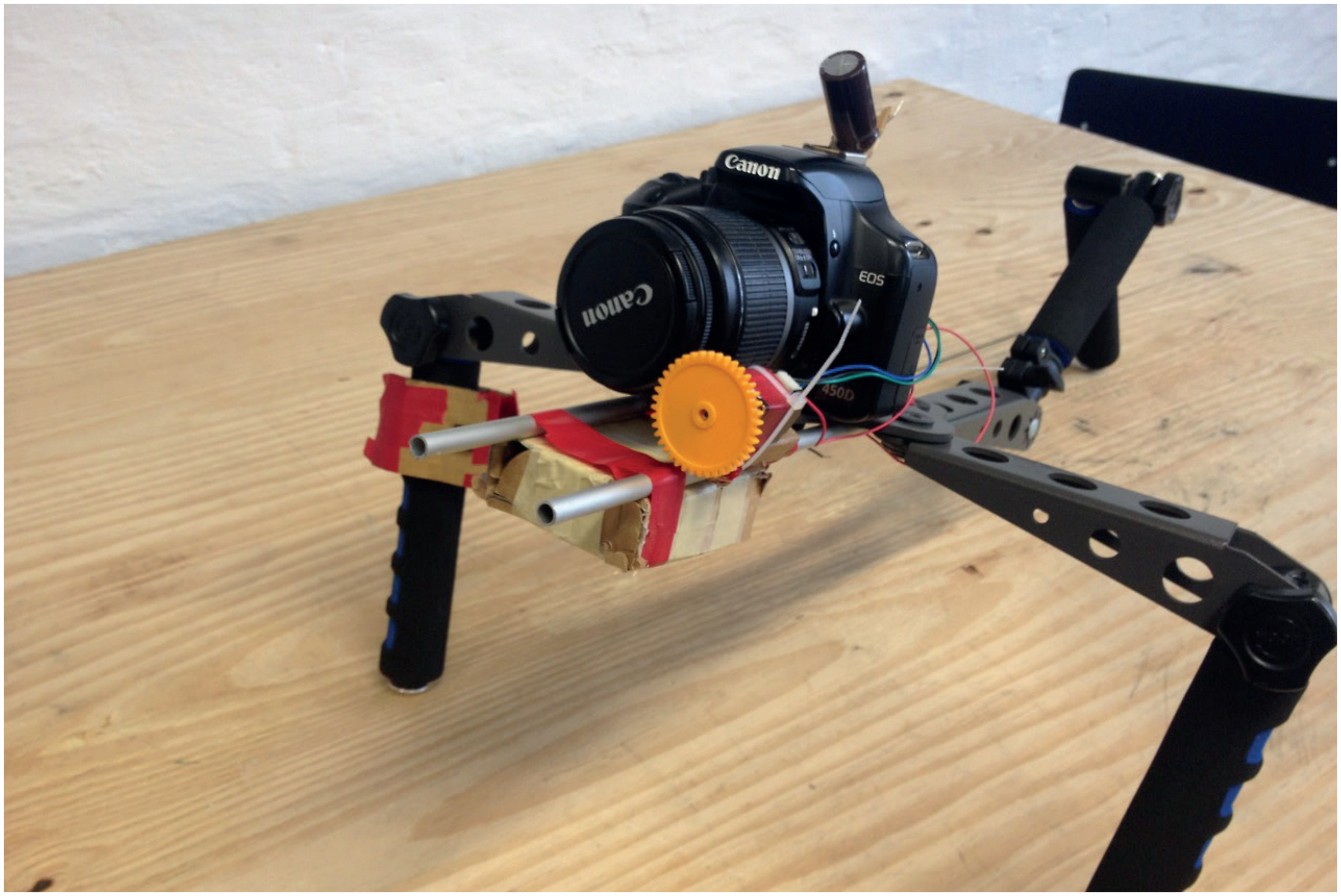


fig. 2

sources
* 1 http://freeflysystems.myshopify.com
* 2 http://photoduino.com

In our concept we were inspired by already existing projects that include external sensors to achieve new possibilities of working with DSLRs.

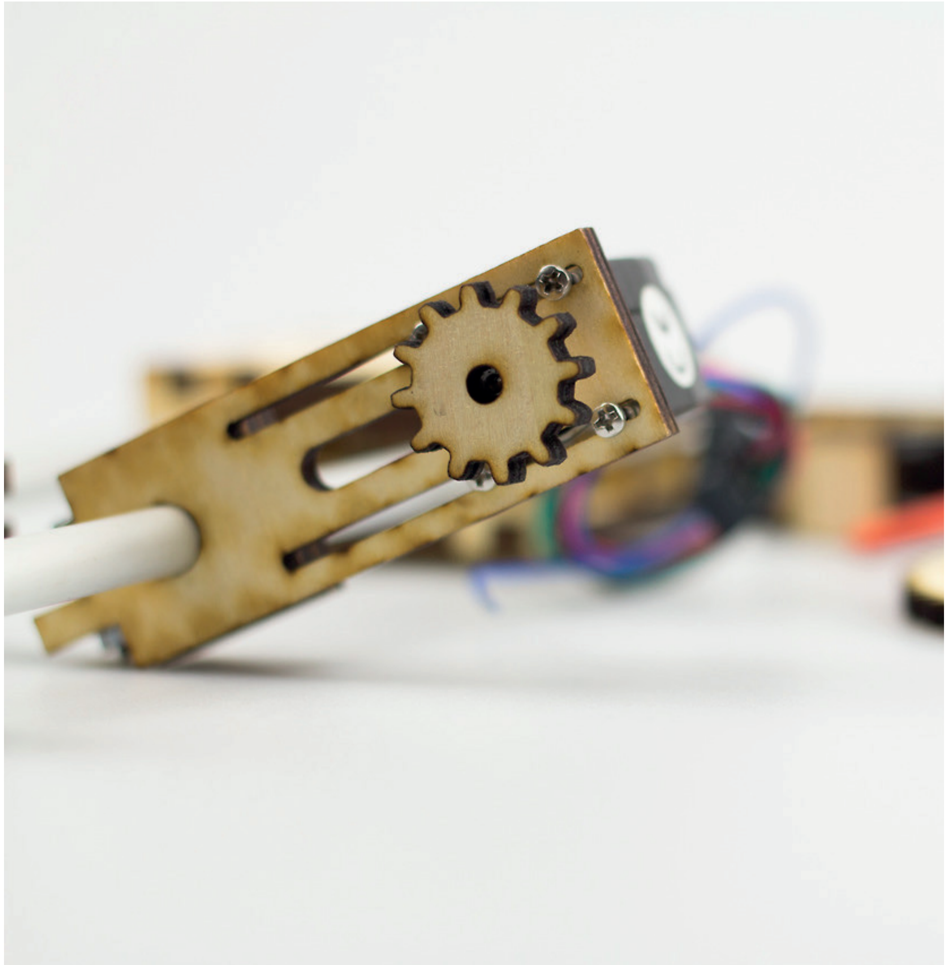
The MôVI camera rig emerges from the background of a steadicam paired with additional hardware to control the level of the camera via Accelerometers / Gyrometers and the focus and thus enabling a filmmaker to accomplish one wonderful shot after another. While the MôVI Rig became a professionally produced product resulting in a pricetag of $15.000 the
PhotoDuino is a DIY solution based on the popular microcontroller Arduino and let‘s you connect different sensors to your PhotoDuino and control your camera in quite a few new ways. There are for example: a trap focus - proximity sensor to detect if something is within close range and then take a picture, light sensor for „lightning“ photography or sound sensor, which can react to loud noises and then snap away.

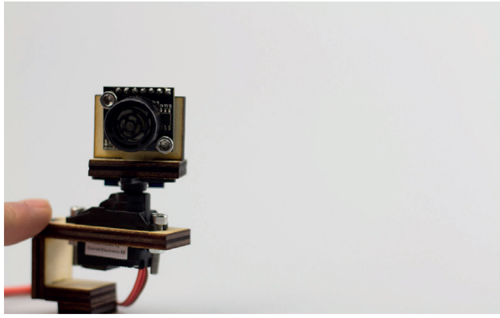


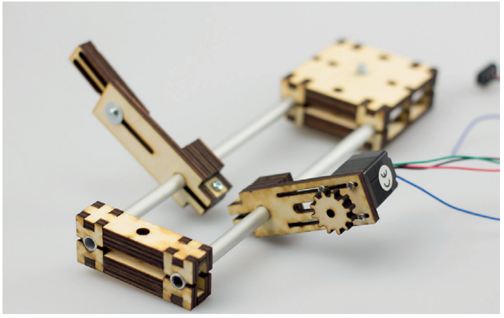
Cardboard mock-up with approximated components on an existing
rig to get a rough feeling for sizes, positioning and handling

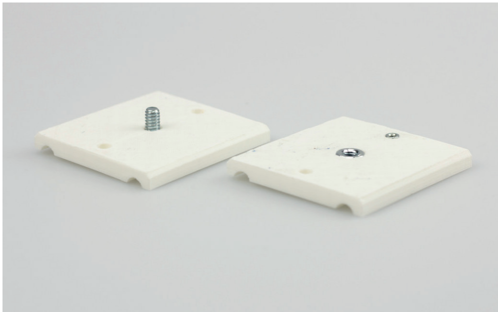
Possible Outcomes

We thought from the very beginning that our project has great potential, besides the skills we would acquire over time working on it we wanted to make more out of it. There were plans to sell the idea to a company or a “specialized” filming start-up and give way to more filmmakers out there. If that wouldn’t work out, there were other options, such as starting our very own crowdfunding project on plattforms like Kickstarter.com or IndieGoGo.com or, to come back to the DIY conception, just sell the construction plans to people in the DIY filming communities. Our best option which we are pursuing right now is a patent. With the help of the patent research company “Innowi” and the Hochschule für Künste Bremen, we’re trying to get a proper patent on Sensopoda.
This is option would allow us to keep the project running while still concentrating on our ongoing studies.



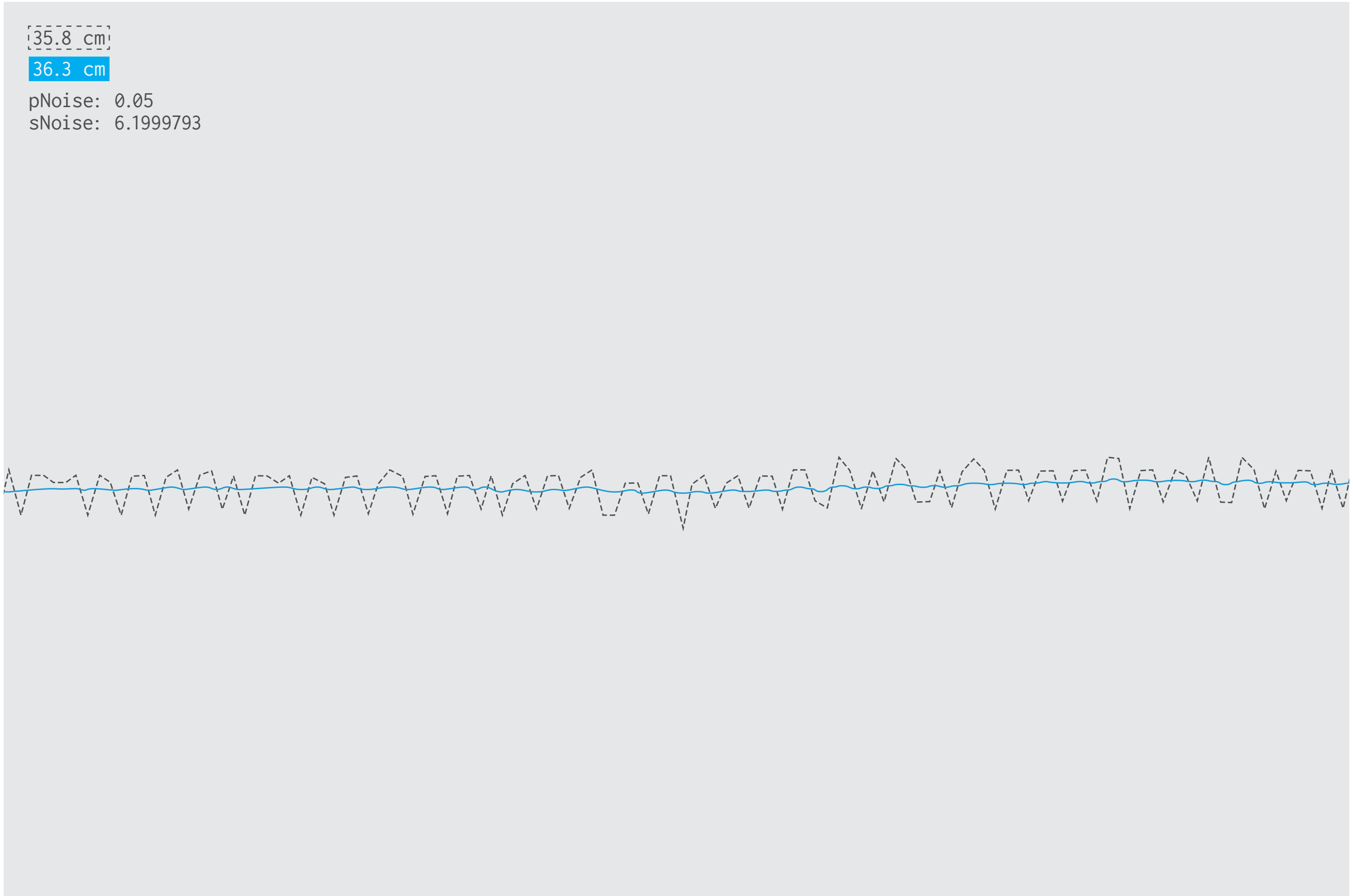






Technological Design

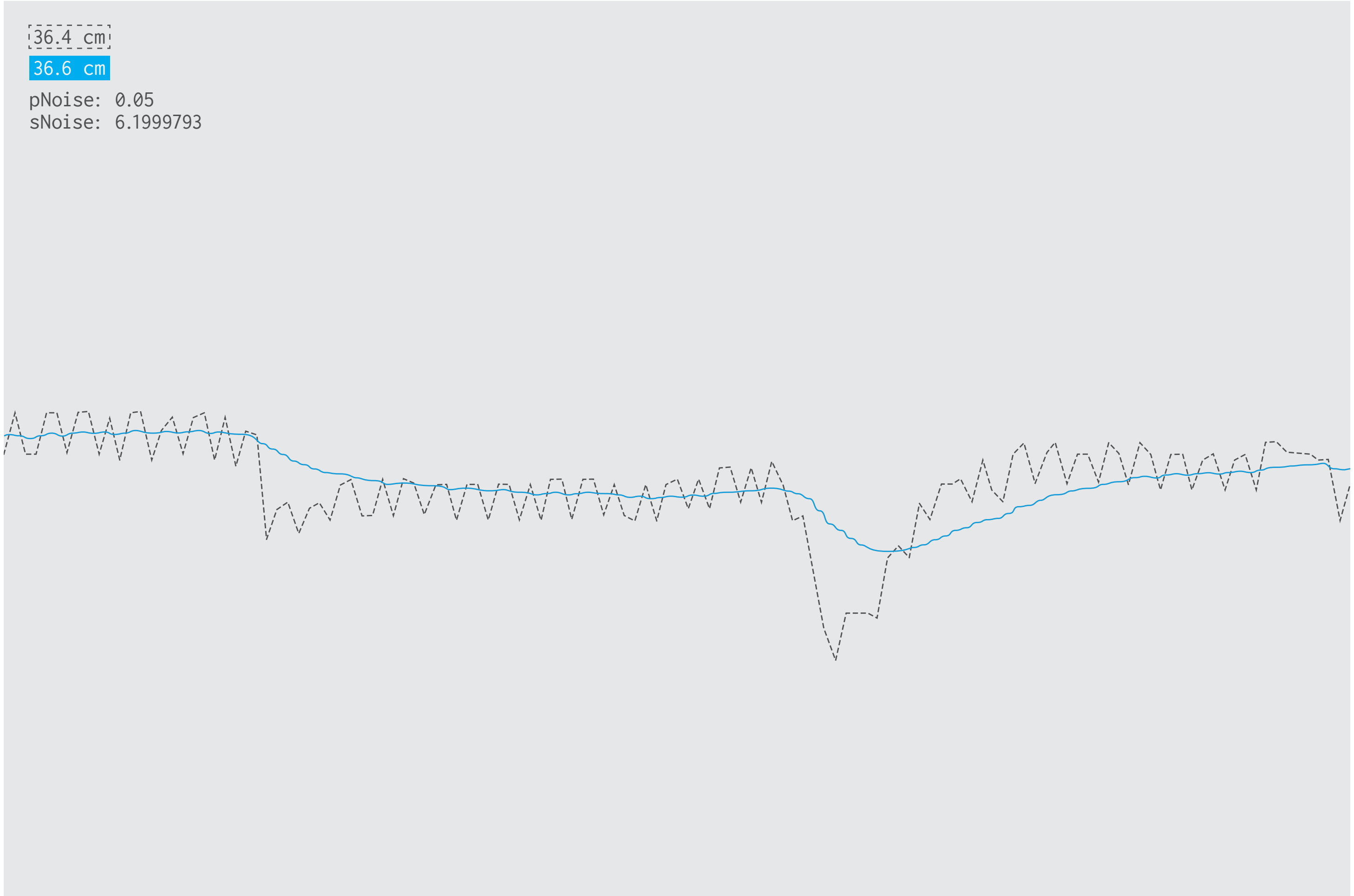
In terms of technology we heavily relied on the Arduino microcontroller as the processing unit in prototyping different iterations. We started out with the Arduino Uno and for now put aside the idea to squish the logic into smaller Arduino boards since the flexible pluging system we don't want to miss took up quite some space. In the running project we tried out different distance sensors like infrared and Ultrasonic and also did a research about hacking laser-rangefinders. While each of them working in their own way, having their own pros and cons we decided to settle with a HRLV-MaxSonar-EZ sensor, a low voltage ultrasonic rangefinder that operates in range from 30 - 600cm with an accuracy of one millimeter.
We also experimented with different stepper- and servo motors to control the direction of the distance sensor and the angle of the focus ring on the lense. We designed custom casings and carrier with CAD software and the intention to utilize a 3D printer but switched back to using a laser cutter and layered plywood due to piling up imprecise and failing 3D-prints. With the technological environment set up we were challenged with implementing the underlying logic and therefore connecting the input to the output and coming up with a simple way of interacting with and controlling this process. To develop the underlying logic we first had to understand some physical properties about camera lenses in general and, to keep it flexible, where they differ from each other. We found out, that with linear rising distance to the object of interest the angle of the focus has to be turned logarithmically to the base of 2. Additionally to this different lenses come with different angle ranges and even different turning directions to set the focus. In order to stay lens independant but also to know the range of our testing lens we came up with a simple calibration method that has to be done whenever you start up the setup or change the lens. Similar to the calibration process inside a plotter we used a adjustable microswitch to detect the maximum angle. The stepper slowly turns the lens step by step until it hits the microswitch which was previously adjusted to the maximum position. In that way the system knows the minimum and maximum angle of the lense and therefore the range we can map our measured values to. With a setup like this, able to take an input and calculate a correct output, we realized that while our sensor was basically very precise there were still sources of noise in the measurements to eliminate. In order to achieve a cleaner and more stable flow of measurements we utilized a simplified kalman filter to minimize the variance in the measurements resulting in smoother motor movements. While this filter can be very powerful it is also very slow towards big changes in the measurement when used in its full potential. This is why we decided to let the user control the strength of the filter in order to use its full potential in stable shots or turning it down for faster movements. Speaking of control we thought through every feature of our setup and which parts of it needed to be adjustable or executable by pressing a button. We came up with a minimal interface consisting of only two buttons and two sliders. One button to switch between automatic- and manual mode. One button to trigger the recording mode in the camera. Using sliders offered us a range of different configurations for two other aspects that needed to be variable. The strength of the sensor filter and the direction of the sensor itself. Similar to other parts of the project we were considerate of flexibility in the control elements. Since they are only plugged in by an ordinary audio cable and feature a clamp mechanism they are easily extendable, exchangeable or attachable to different rig or tripod setups. Also the recording button rather triggers a selfbuild infrared remote instead of connecting directly to the camera and is therefore able to trigger cameras independent of model or manufacturer. Upon reaching this stage in our technological design it was about time to get rid of loose cables in breadboards and to design our own circuit board. It still took us three iterations from this point on to reach the current prototype but the technological foundation was set.



Sensor studies with a simplified Kalman-filter

Case 1 - Reading values from the range sensor with no interruptions in the path

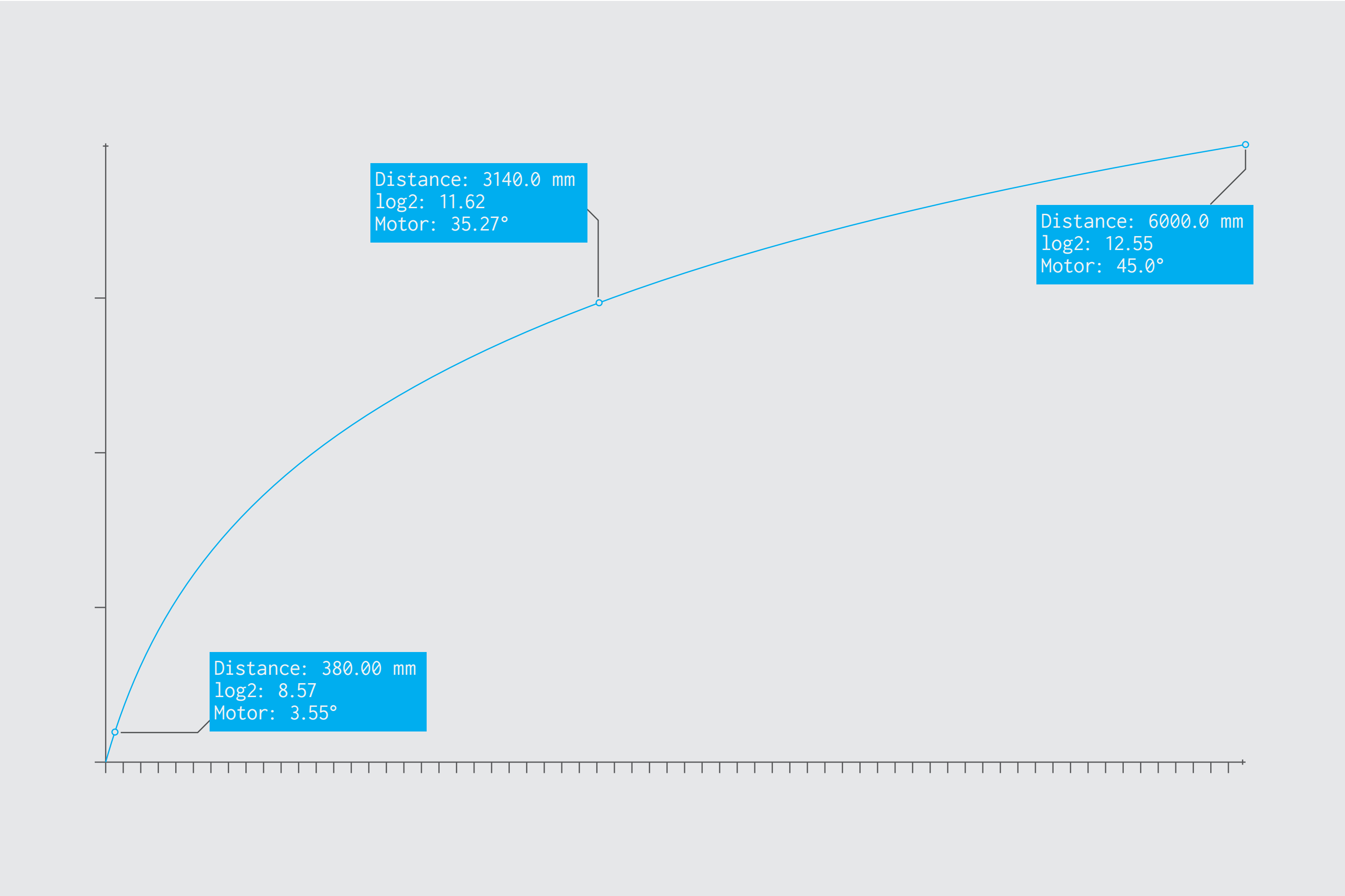
Dotted line: Unfiltered values
Blue line: Filtered values (smoothed)



Sensor studies with a simplified Kalman-filter

Case 2 - Blocking the sight of the range sensor by putting an obstacle between in the path and then quickly remove it again

Dotted line: Unfiltered values
Blue line: Filtered values (smoothed)



Correlation between the sensor's linear distance reading and the turning angle for the motor on the lens

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map(log2(distance), log2(minDistance), log2(maxDistance), minLensAngle, maxLensAngle);
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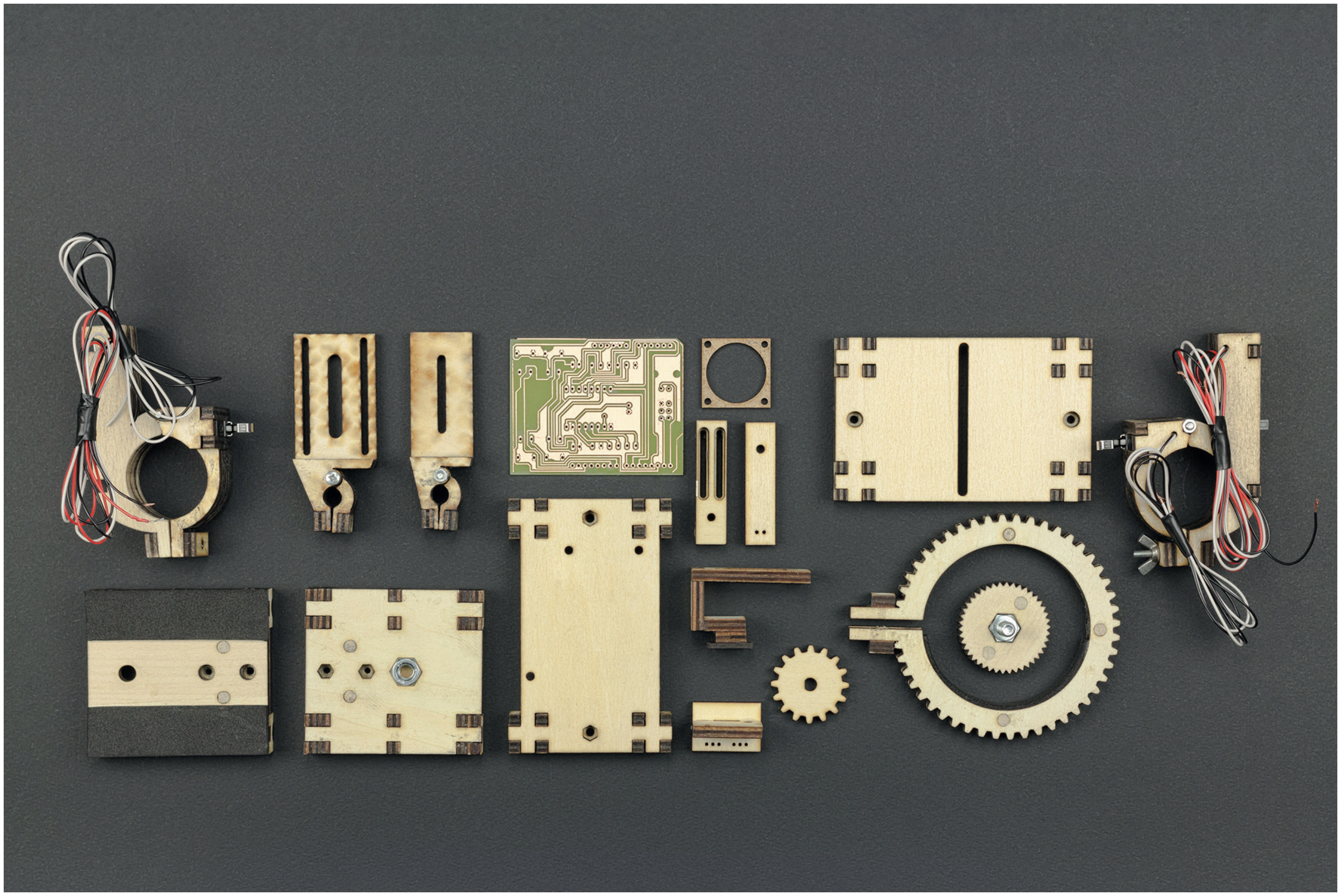
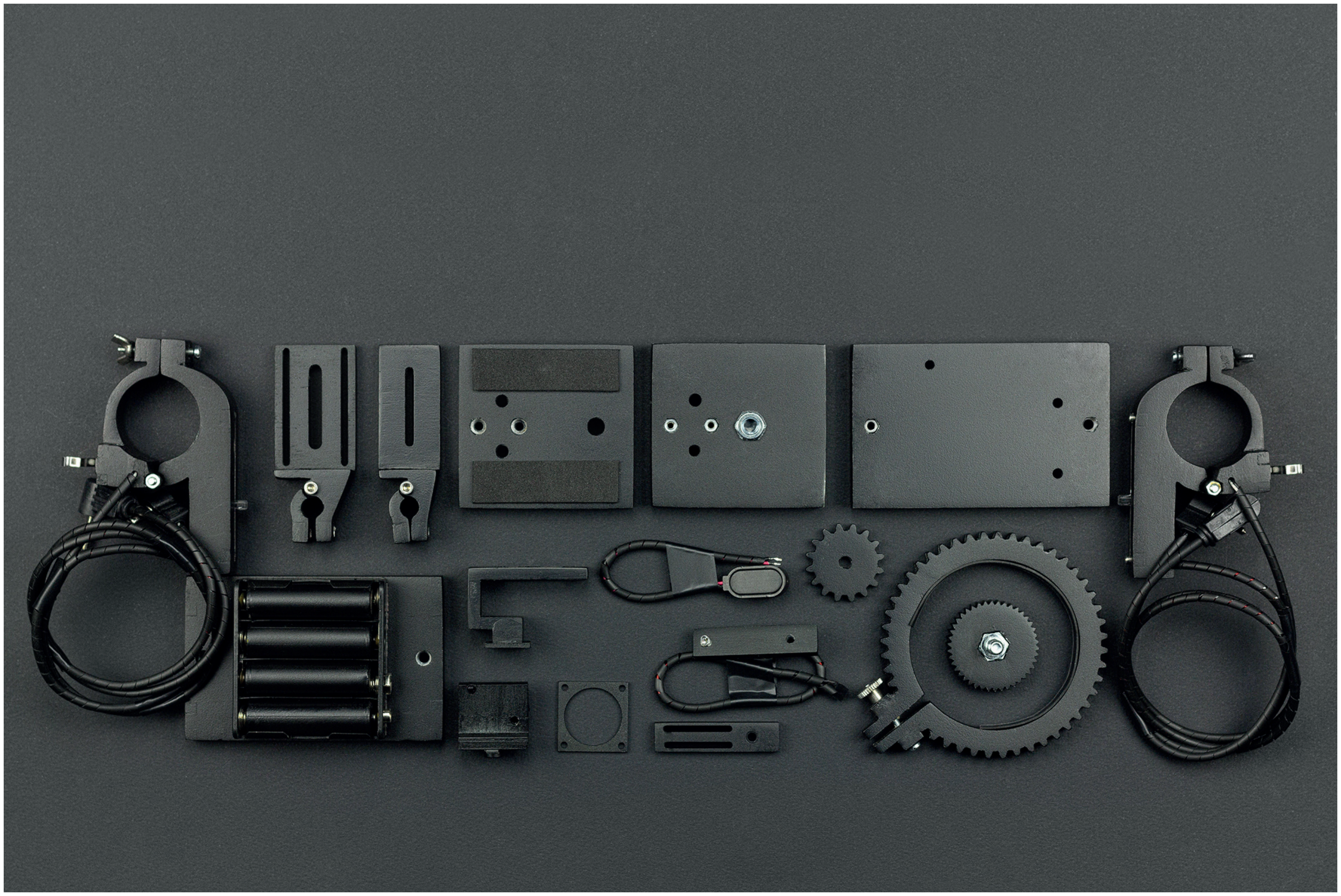
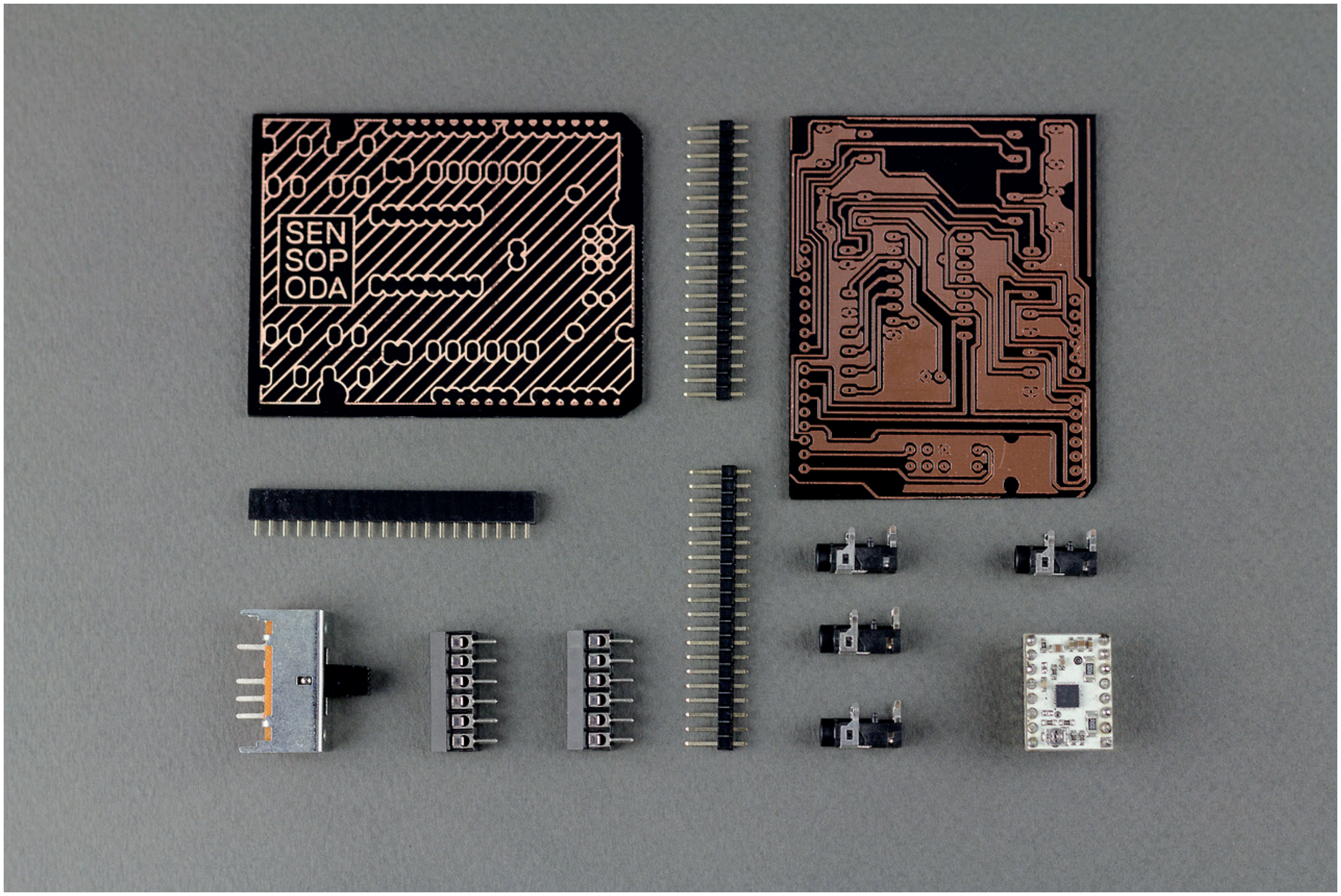


Disassembled and knolled-out set “iteration II”



Disassembled and knolled-out set “presentation”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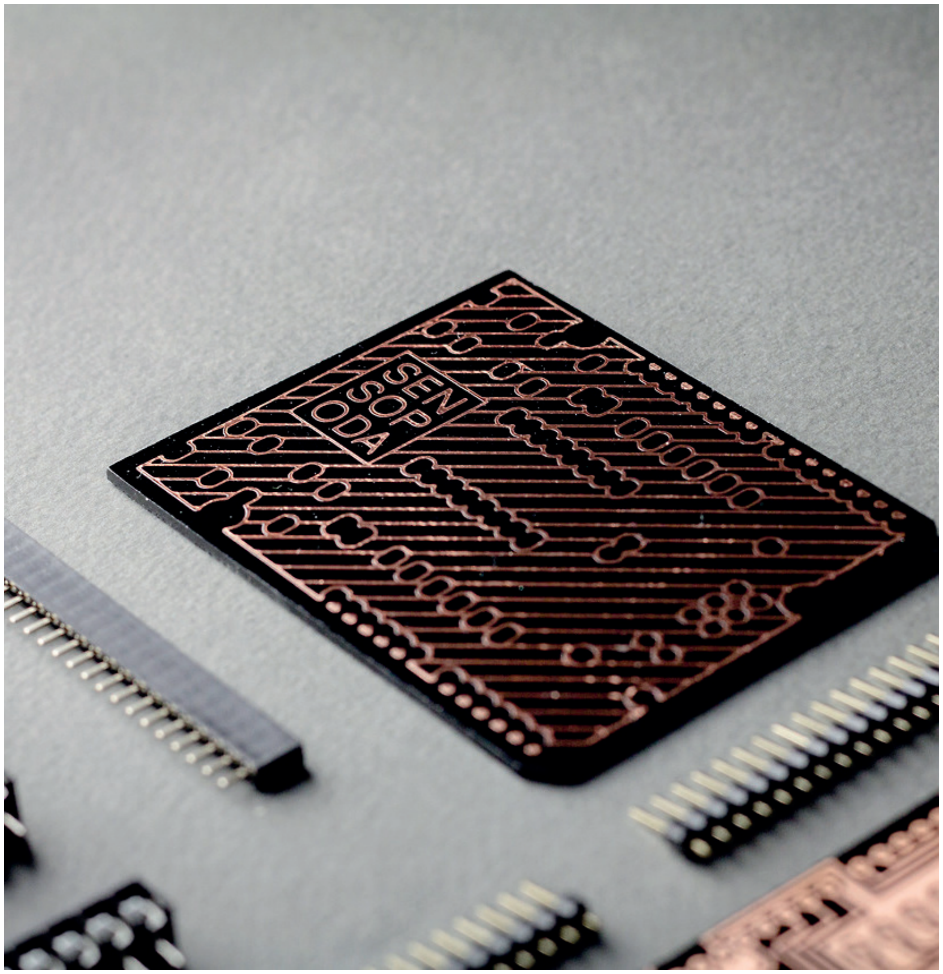
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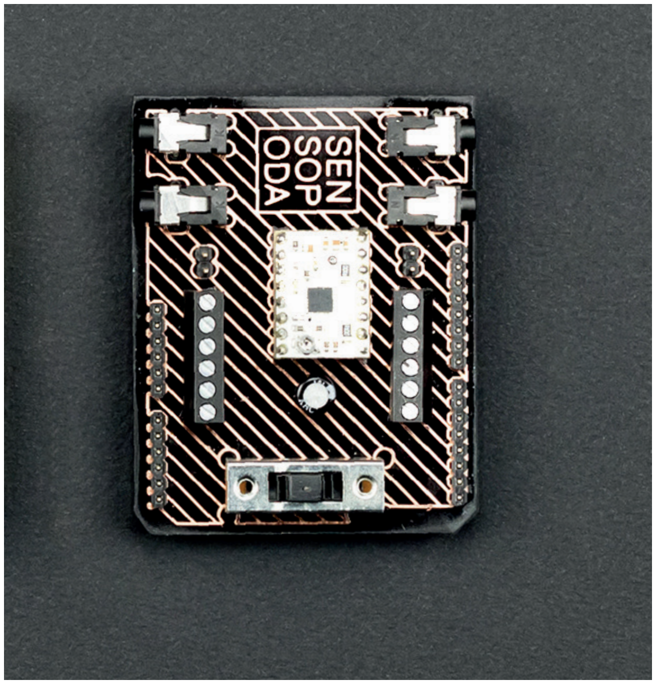
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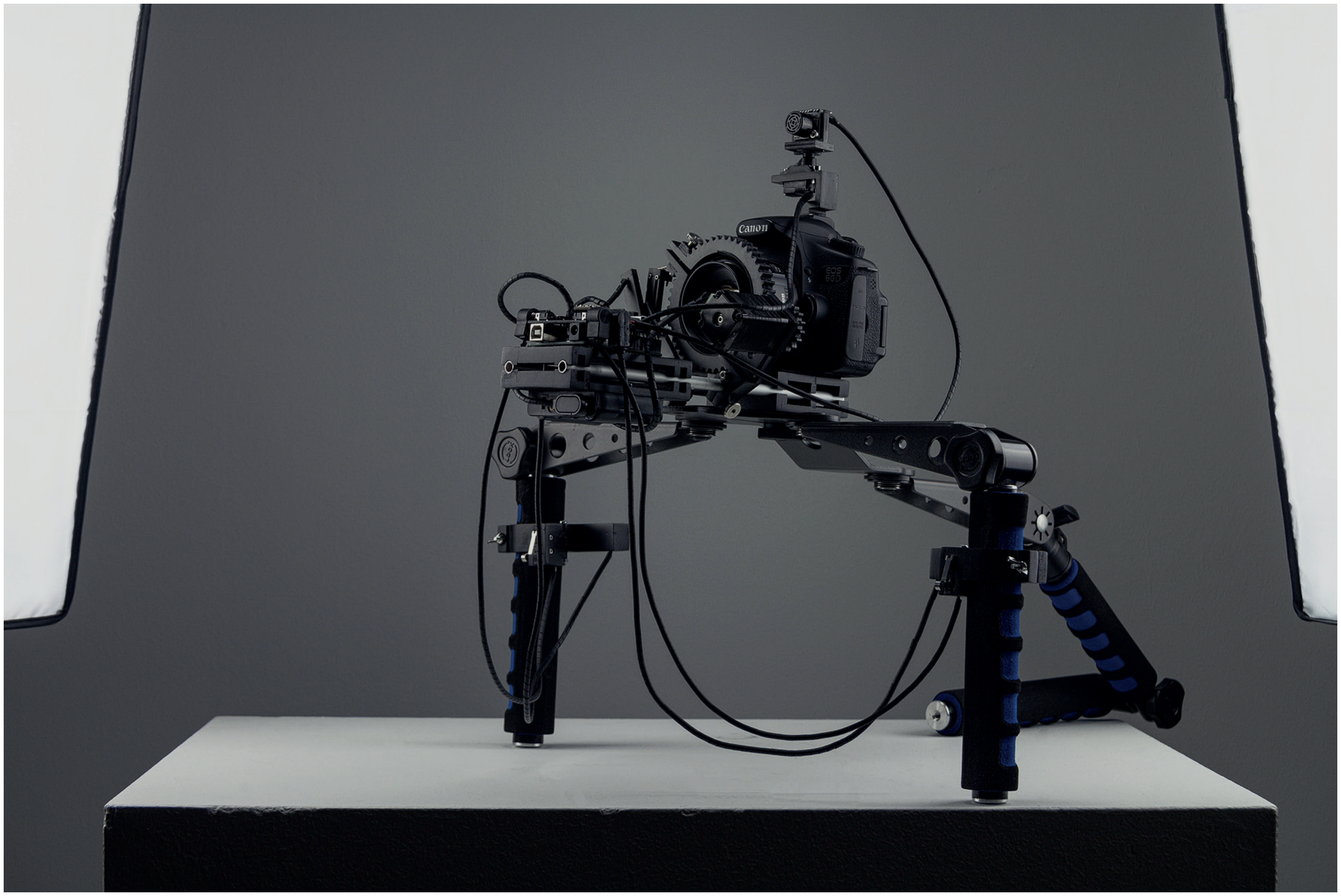
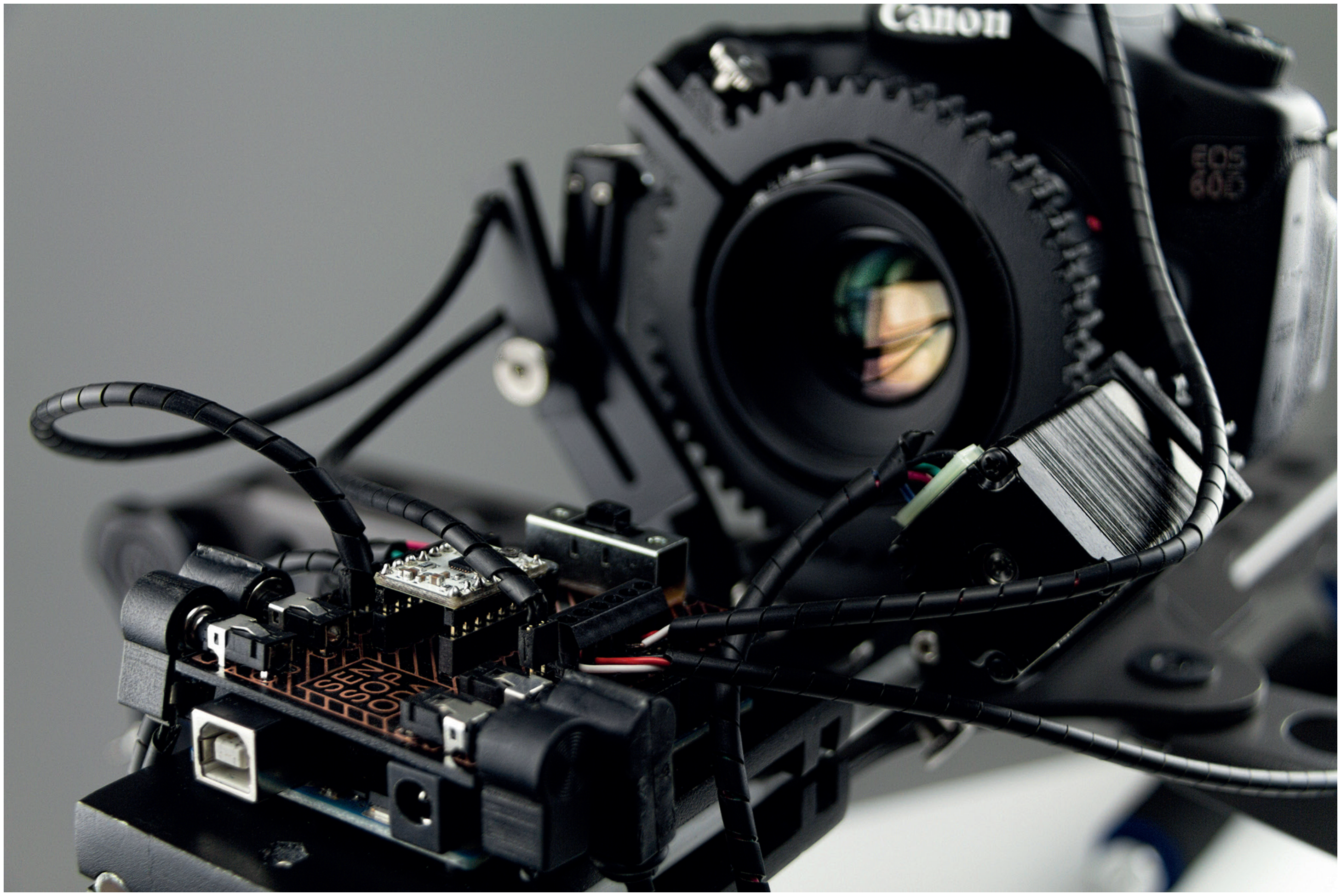
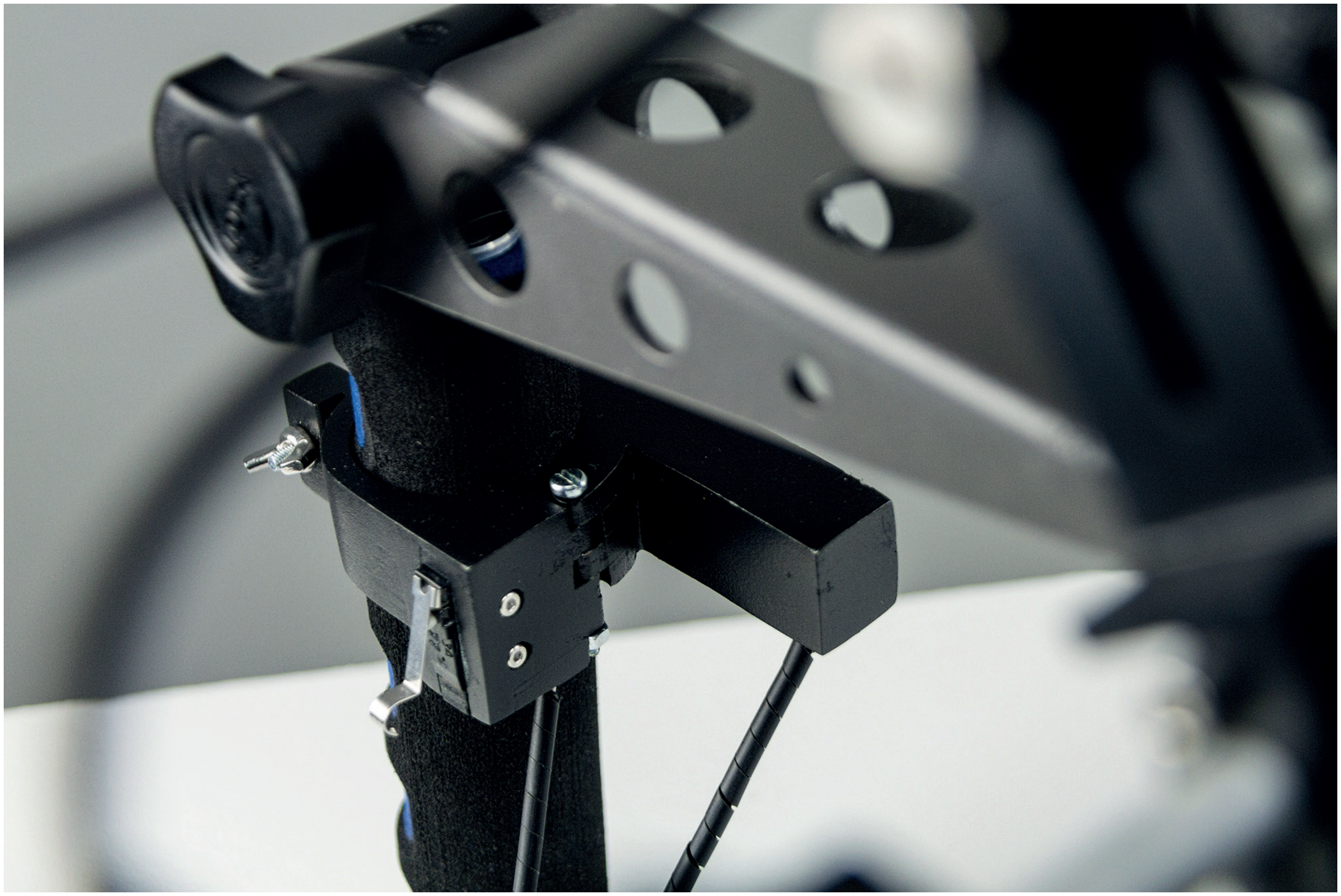

Canon


Canon
EOS
60D




Canon

Future Prospects

For further improvements to the already working prototype we are planing to exchange the big and heavy battery packs for smaller rechargeable batteries. We also encountered some problems with the position of the distance sensor which is seated too high in some use cases and therefore needs a redesign in terms of placement and pivoting range. While at it there will also be the possibility of shrinking the whole setup into a lighter and more portable format. Last but not least we are looking forward to further evaluate our idea additionally to our own trials and the feedback from few insiders and Innowi by handing out prototypes chosen filmmakers from the target audience. We are excited to see how they will use it and what they think of it.