Assembly Instructions

This document is dedicated to replicate the prototype.

Prototype

For the user study a flying navigational device should be built, that can project instructions on the ground and onto screen in front of it. The prototype consists of a DJI Phantom 2 quadcopter carrying a Pico projector on a wooden baseplate and a controllable mirror in front of it. Additionally, an Arduino is mounted on it to control the movement of the mirror and to provide a wireless network for all parts to communicate. In the following sections, each part of the prototype will be described in detail.

1 Quadcopter

The quadcopter used during the course of this project is an unmodified drone from the Chinese manufacturer DJI with the product name “Phantom 2”. It weights 1kg without any payload and can reach velocities up to 54 km/h. If own economically the Phantom 2 is able to reach flight times of 25 minutes from its 5200 mAh battery. The drone can be controlled with the help of a smartphone Application and additional equipment via Bluetooth or with the 2.4 GHz remote control delivered with the drone. The latter should make distances of 1000m between drone and controller possible, according to the manufacturer.

Figure 1: Picture of the complete prototype

2 Projector

The projector used for the prototype is a Phillips PicoPix pocket projector. It is a 10,5 x 10,5 x 3,15cm small DLP projector. It has built in WIFI capabilities and an Android-based operating system that allows to execute custom programs written for Android 2.3.1. Its internal battery lasts about one and a half hours and in battery mode the projector reaches a luminosity of 60 lumens. To display navigational instructions for the prototype and user study, an Android application was written, being able to receive commands send to it via the TCP-protocol. The Application has several predefined images integrated that are displayed, depending on the command received. To make things slightly more complicated the image projected has to be mirrored in case the mirror is flipped down. With the help of a simple Boolean ag that is updated every time a command to the mirror is sent this is easy to accomplish. The update is initiated by another command received the same way as the command to display a certain image. This means the actual initiation of the updating process has to be done on the command sending side, together with sending the command to the Arduino Yun, as the projector and the Arduino are two different endpoints and cannot read each other's communication, due to usage of the TCP-protocol.

3 Wooden Base

To create a mounting space for the projector underneath the drone a wooden base was designed. The parts were made from 3mm plywood with a laser cutter. The base consists of three parts that can be assembled with four screws. The big base plate is 13 cm long and13cmwide,withabulgeof6x5cmatthefront. Ithasaholefora1⁄4inchscrewto xate the projector onto the plate. Additional xation of the projector against twisting or skidding, induced by the vibration of the rotors, is provided by several Velcro stripes. On the bulge at the front there is a heightening with another Velcro stripe on top of it to t the servo controlling the mirror. The base plate is held in place by two wooden struts of 19cm length, connected with four screws to it. The struts prevent the base plate to fall down but also to move back or forth by locking with the four legs of the Phantom 2. On the four ends of these struts hooks were attached to provide xation points for two rubber bands, holding the Arduino in place (see gure 5.2).

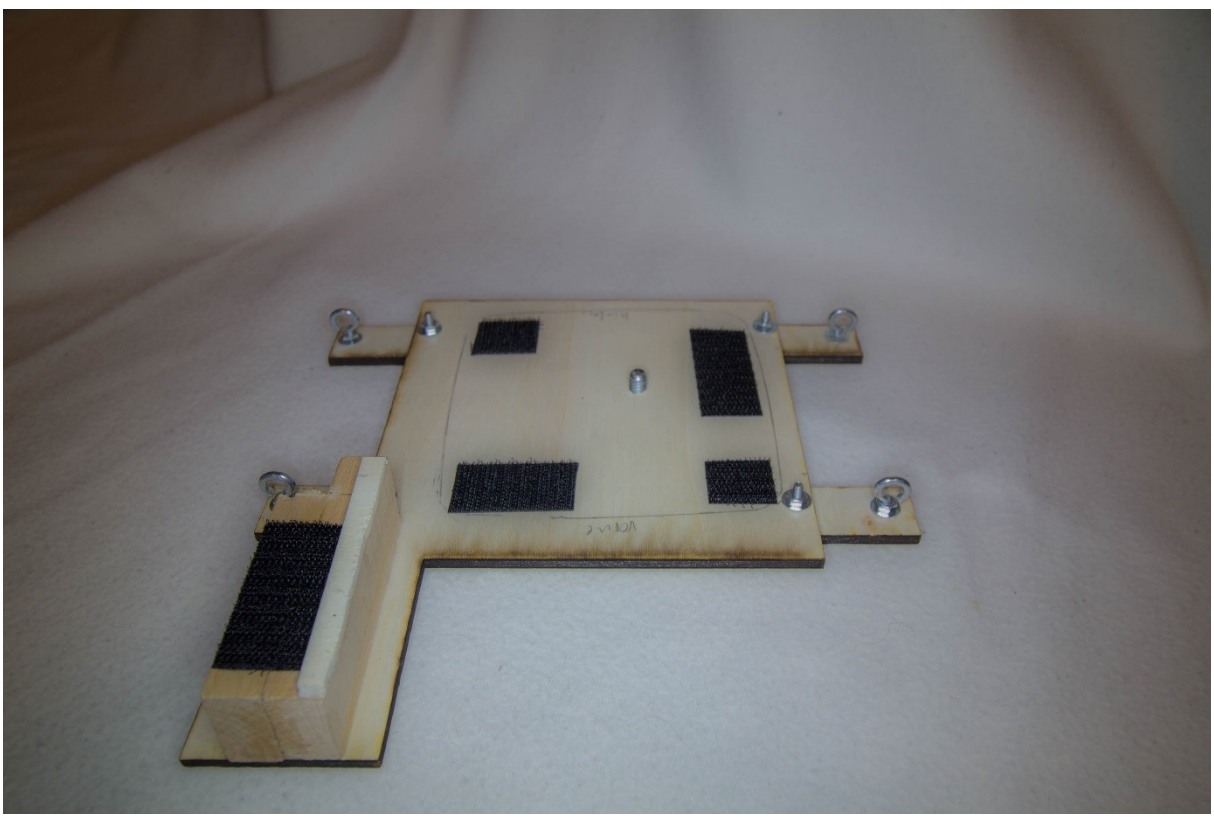

Figure 2: The wooden base plate with all screws in place.

4 Mirror

As the projector is pointing directly ahead a method had to be found to deflect the image onto the ground. As suggested by one of the participants of the focus group (see chapter 4.3) this was accomplished by using a mirror on a servo motor. The mirror measuring 6,0 x 4,5 cm is connected to the servo motor with two small brass rods and hot glue. Being controlled by the Arduino the servo can rotate the mirror up and down to either allow projections directly ahead or onto the ground. Depending on the rotation angle the projection can be on the ground in front of the quadcopter, directly underneath it or slightly behind it. To keep things simple, the servo was mounted on a small heightening (see figure 3), allowing straight projections if the mirror is rotated to 0° and therefore being above the projection.

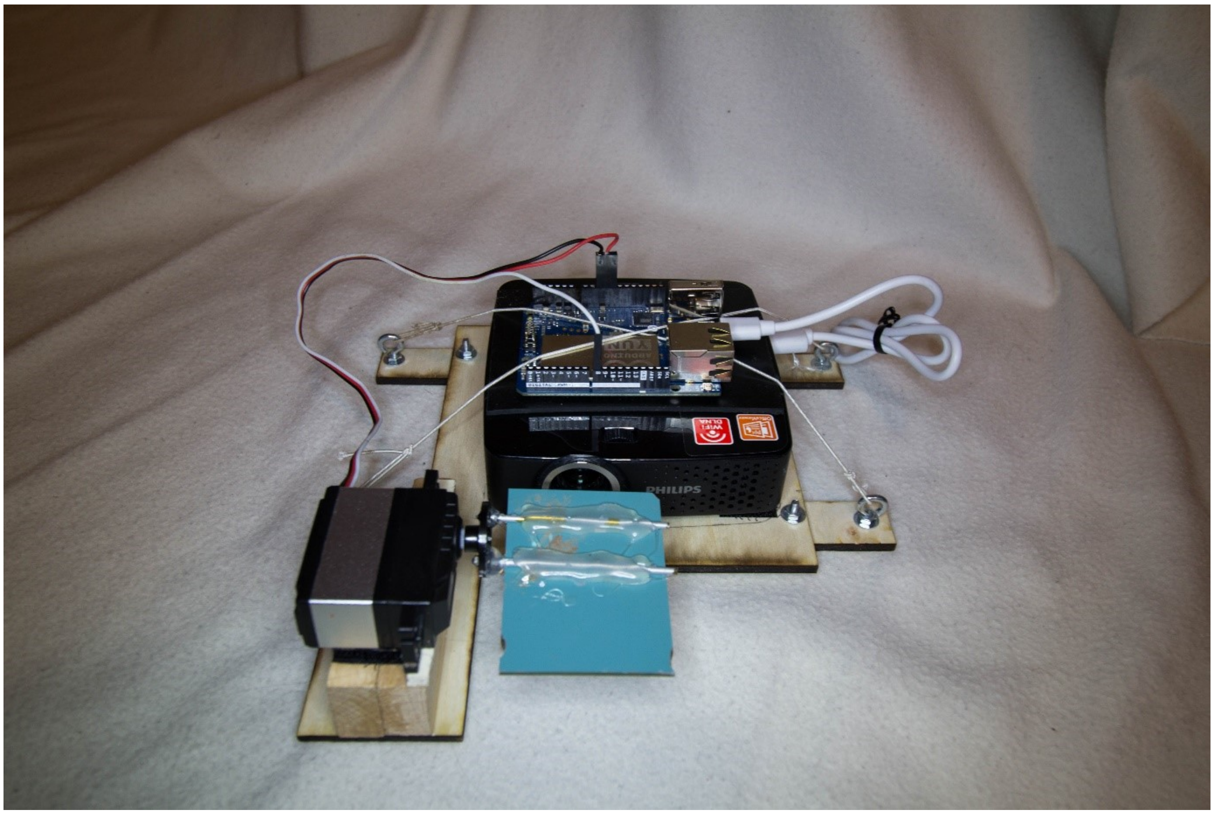

Figure 3: The mirror and servo mounted at the front of the baseplate

5 Arduino

On top of the projector an Arduino Yun is mounted. To prevent scratch marks from the soldered connections on the bottom side a thin rubber plate was simply placed onto the projector, being held in place by the pressure of the Arduino. The Arduino itself is held in place by two rubber bands going crosswise from left to right (see figure 4). The Yun on the one hand is used to control the servo motor and on the other side to create a wireless network. The servo control is done with a simple program written in C++ (see figure 5). This program connects to the “bridge” of the Arduino Yun to establish a connection between the program and the integrated webserver of the Arduino Yun. This makes it possible to send simple commands from external devices by simply opening a specific URL on the Yun. The servo is connected to pin 8 of the Yun (cf. line 14) and the rotation is controlled with the command “servo.write<Angle>”, with <Angle> denoting the desired rotation angle. Whenever a client connects to the webserver the connection is passed to the Arduino program, waiting for a command to be transferred. To keep things simple, the command passed is the plain number of degrees the servo should rotate (cf. lines 23-25). As this program is not openly accessible outside of purposes for this study, checking the incoming data with respect to being well formatted and type conform is not necessary.

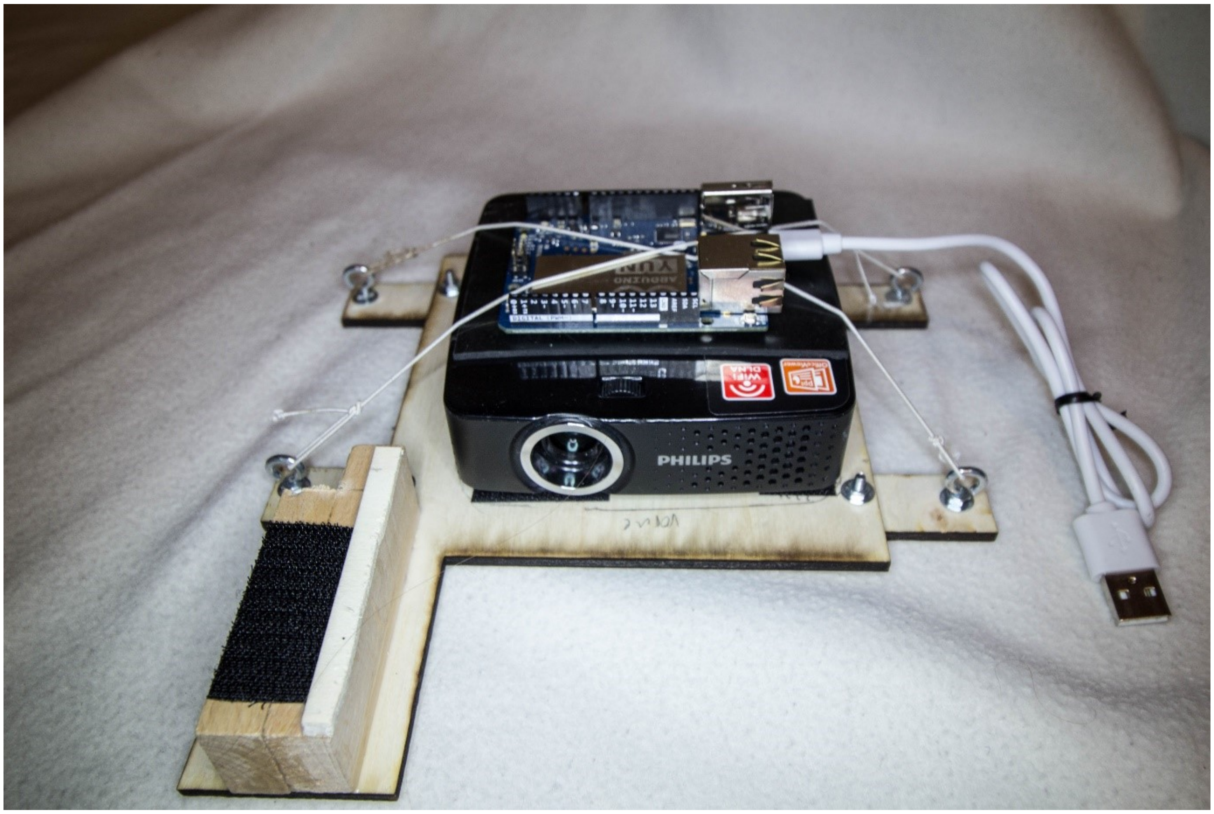

Figure 4: The Arduino Yun being held in place by two rubber bands

The Yun is creating a wireless network, as already said. All relevant devices needed for this prototype and the user study connect to this network. The Yun is assigning each device a fixed IP-Address to make inter-device communication as simple as possible in the means of programming. The Arduino is being powered by the USB port of the projector. As the user study requires the network to exist an increased amount of time it is also possible to power the Arduino with an external power source (visible in figure 1) to not decrease the battery time of the projector.

Features of the Prototype

With the prototype consisting of the parts described above it has gained several features. It can y freely around, being controlled by the 2.4 GHz remote control, with a small decrease in flight time, due to the weight of the projector, mirror and Arduino. The prototype can project images de ned in the projector's Android application in front of it, for example onto a wall. With the help of the mirror the projection can be redirected at any time onto the ground. Due to the possibility of freely choosing the angle the mirror is rotated to, the projection can be deflected in several directions. The default direction not straight ahead would be directly downwards, right underneath the drone. By turning the mirror, a bit less down, the projection would be on the ground, too, but ahead of the quadcopter allowing it to be further away from the user – under the assumption of the quadcopter flying in front of or above the user. Turning the mirror more than 45° downwards the projection wanders behind the drone. This is only possible until a certain angle, due to the wooden platform blocking the projection at too high angles. The projection can be rotated easily, too by simply rotating the drone. Complex interactions where the projection plane switches seamlessly between the ground and a horizontal surface are therefore possible, as well as rotating projections, for example an arrow adapting to the direction of the pathway.