

OPENAR-M DOCUMENTATION

Ville Päivinen & Elisa Mehtonen

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Department of Physics and Mathematics

University of Eastern Finland

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1 Introduction

The goal of this documentation is to explain the inner workings of OpenAR-M -augmented reality glasses: the latest AR-device in the OpenAR lineup. We begin by looking at the OpenAR-M optical setup and the theory behind the augmented reality effect. Then, we will look at the electronics and the code that run the OpenAR-M system, and finally, we will be going over the 3D-printed parts that hold the optical setup and electronics together. List of required components, items and tools can be found in the appendices.

What makes OpenAR-M unique from the rest of the OpenAR builds is the compact size of it. Previous models were “headset” -type glasses while OpenAR-M glasses are more like regular eyeglasses. At least in the sense that they are worn just like regular glasses, although the AR-glasses are a few times heavier.

While the actual use of the OpenAR-M glasses can be easily changed, this document focuses on a AM2320 temperature and humidity sensor attachment. The sensor reads the temperature and humidity of the surrounding air every few seconds and displays this information on an OLED display. The image created by this display is optically guided to reflect into the user’s right eye. The reflected image is sharp, clear and most importantly: theoretically focused at infinity. This ensures that the user experiences minimal eyestrain from the AR-effect, which is a problem even major augmented reality companies continue to address.

Welcome to the world of OpenAR-M!



2 Optics and Theory

While the theory can get complex the deeper you go, the optical setup is surprisingly simple. Even simpler than the previous iterations of OpenAR. This time we want to reflect light only to a single eye rather than both. The method to do so is the following:

1. Reflect the light emitted by the OLED display by 90° with a first surface mirror
2. Collimate the reflected light with a specialized lens
3. Reflect the collimated light again by 90° by using a small rectangular piece of glass
4. The reflected collimated light now reaches the user's right eye

Figure 2.1 visualizes the optical setup. Note that the lens could be right between the OLED display and the surface mirror as long as the OLED display is located at the focal point of the lens. The setup above, however, is the most compact.

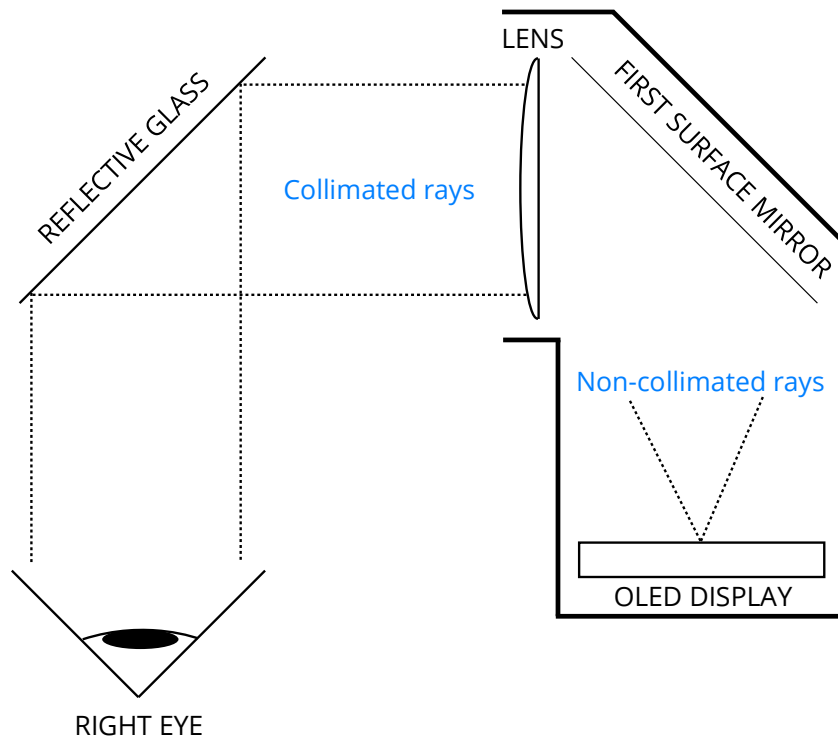


Figure 2.1. OpenAR-M optical diagram (top view).

The light emitted by the OLED display is uncollimated, meaning the light rays spread out in a conical shape. This type of light is not ideal for pleasant viewing, so we need to collimate the light rays (make them parallel to each other) using the lens. Additionally, because the display is positioned very close to the eye, the eye cannot focus on it. The lens creates a virtual image that appears farther away, allowing the eye focus more comfortably.

Before lens, however, the light is reflected using a first surface mirror. Why not a regular mirror? That is a good question! Regular mirrors can cause double reflections due to light reflecting from both the glass surface and the reflective coating behind it, which can degrade the image quality. Front surface

mirrors avoid this issue by reflecting the light from directly from the first surface of the mirror. We modified a makeup mirror by removing its reflective coating to create a first surface mirror, but true first surface mirrors are also available for purchase.

Let's go through each component of the optical system for better understanding. The relevant dimensions of the components are also mentioned below.

OLED DISPLAY	The display used in this version of OpenAR-M is an 128x64 pixels wide I2C protocol OLED display. Even though the display is large, the nature of the lens we used limits the viewable area by a noteworthy amount. Only the very centre of the display is viewable. The width and height of the display screen is 25x15 mm.
FIRST SURFACE MIRROR	The mirror is placed at a 45-degree angle to reflect the light 90-degrees to the left and towards the lens. The size of the mirror is determined by the size of the display. Because the mirror is placed at a 45-degree angle, the size of it should be larger than the display size. We can easily find this size by dividing the width/height of the display with $\sin(45)$. $\frac{25 \text{ mm}}{\sin(45)} = 35.35 \text{ mm}$ $\frac{15 \text{ mm}}{\sin(45)} = 21.21 \text{ mm}$ This, however, is not the minimum size. Due to some magnification effects of the lens, the actual viewable area of the display is much smaller.
LENS	The lens is a ~50 mm focal length lens bought from a photonics equipment company. The distance between the lens and the screen should correspond to the focal length of the lens (see Figure 2.2). This is why the short focal length makes the lens perfectly suited for a compact optical setup. The lens itself is not perfect, however. The short focal length causes a magnification effect. This itself is not a problem, but the lens also causes distortion effects close to the edges of the lens, so only the very centre of it is sharp and clear. The diameter of the lens is 25 mm.

REFLECTIVE GLASS

The purpose of this glass is simple: reflect the collimated light towards the user's right eye. This is achieved by placing the glass in front of the collimated light at a 45-degree angle. Due to the nature of the propagation of light, most of the incoming light passes right through the glass. We have not done the calculations, but around 7 % of the light is reflected towards the right eye. This seems like a very small amount, but luckily the human eye is incredibly sensitive to light, so the image emitted by the OLED display can be easily seen in indoor setting. The image reflects off both surfaces of the glass, resulting in two slightly different images. This causes a double image effect, which should not significantly affect the viewing experience.

The dimensions of the glass are 33x22x1.6 mm (width, height, thickness), but a smaller glass would work too since it is so close to the eye.

THE EYE

Not much to say about the eye. The location of the glass cannot be perfect for every individual due to the difference in eye spacing and head size. As a result, the sharpness of the reflected image varies from person to person. Even small adjustments to the viewing angle can significantly affect the image clarity due to distortion effects of the lens. Therefore, it is important to find the best position and angle of the reflective glass yourself!

It is noteworthy to mention that the virtual image is located at a few meters distance from the eye. Your eye is way happier to focus on longer distances rather than shorter distances. This is visualized in Figures 2.3 and 2.4.

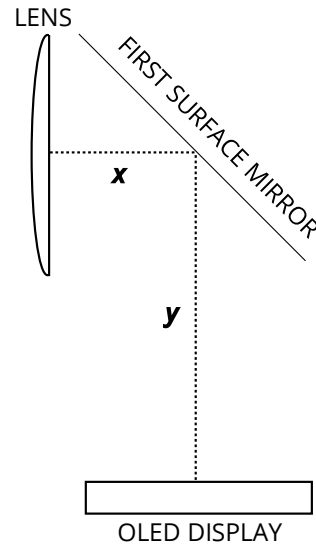


Figure 2.2. Calculating the lens-display distance. Because the lens is after the first surface mirror, the OLED display distance must be calculated in two parts. Note that x is the distance between the lens and the centre of the surface mirror while y is the distance between the display and the centre surface mirror. The distances are arbitrary as long as $x + y = f$, where f is the focal length of the lens (in this case ~ 50 mm).

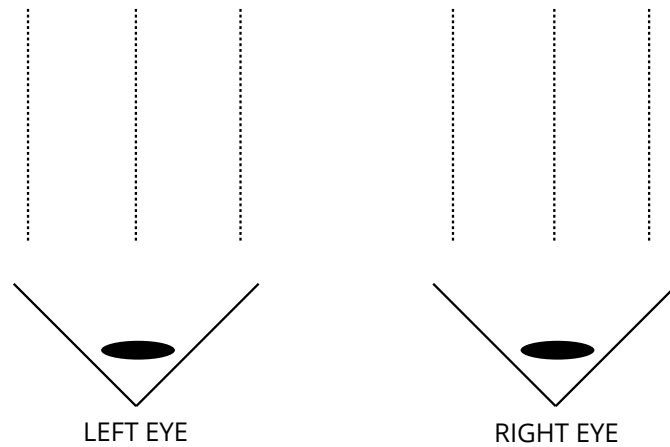


Figure 2.3. How eyes focus to far objects.

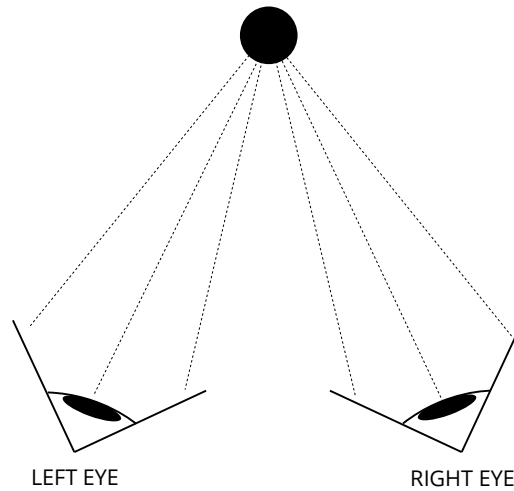


Figure 2.4. How eyes focus on near objects. Much more straining on the eyes.

When viewed through the OpenAR-glasses, the AR effect appears as a floating image in front of the user's eyes. The image is semi-transparent and blends naturally with the surrounding environment. This way user sees both the image and the real world simultaneously. Thanks to the collimated light and the first surface mirror, the image appears sharp, without noticeable double reflections or ghost images. Compared to the previous models (OpenAR 2.0 – OpenAR 2.2), the current optical setup preserves more light resulting in a brighter image. This time, the image can be even seen in the outdoors (Figure 2.5), although visibility in direct sunlight is still limited.

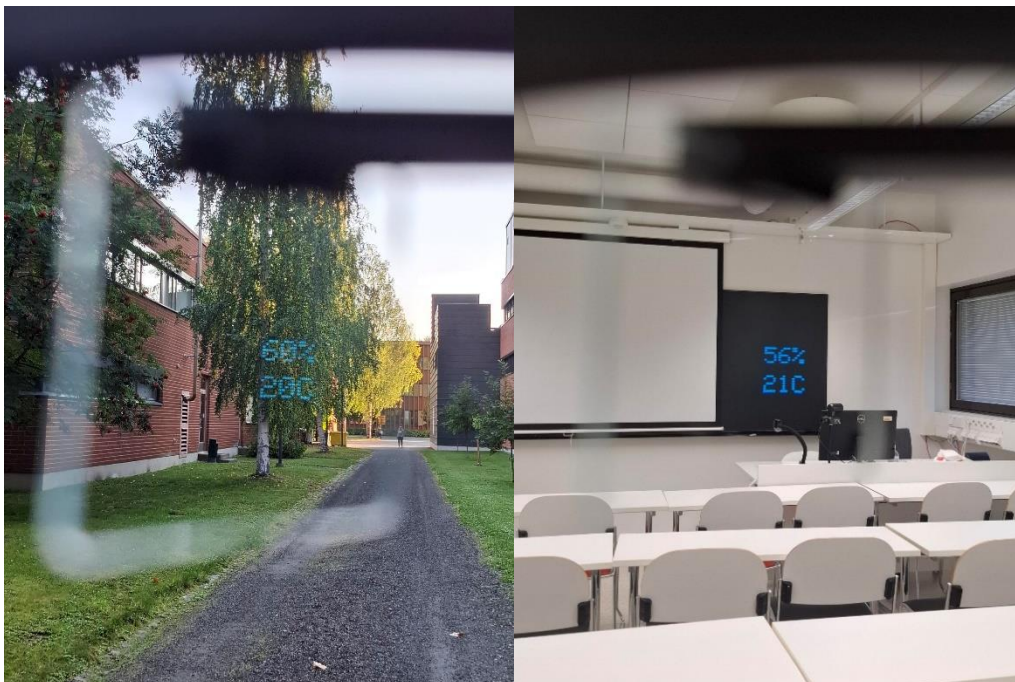


Figure 2.5. The image displayed in the user's field of view is surprisingly bright and can even be seen outdoors under moderate lighting conditions.

3 Electronics and Arduino Programming

Even though the programming part of OpenAR has never been too difficult, we still decided to make it even easier! OpenAR-M is built upon an Arduino Pro Mini 3V3 development board. This board is small, but powerful enough for this simple design. It is powered by a 3.7 volt 500 mAh LiPo battery which the board regulates to a stable 3.3 volts. We also included an USB charger circuit, so that the battery can be charged at any time. Below is a circuit diagram for OpenAR-M (Figure 3.1).

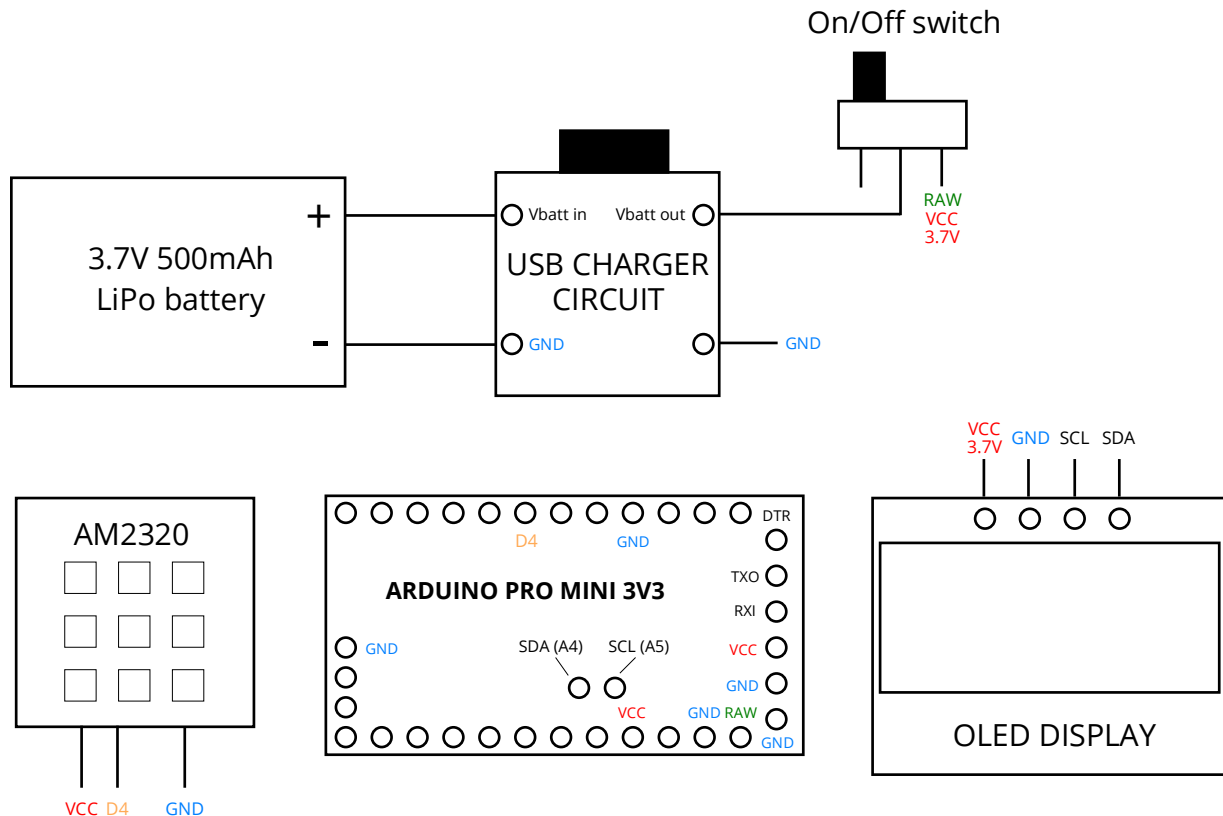


Figure 3.1. Circuit diagram for OpenAR-M (zoom to enlarge).

As you can see, the circuit diagram is relatively simple. We found a datasheet for the AM2320 humidity and temperature sensor we used, so if you are using the same one, we suggest getting familiar with it. This sensor is like popular DHT11 and DHT22 sensors. The connections can vary between the sensor versions, but not too drastically. [You can find the sensor and the datasheet here.](#) To improve mounting and connectivity, we added a soldering perfboard to the back of the AM2320 sensor (Figure 3.2). The perfboard has a hole that allows it to be securely attached to the electronics case using an M2 bolt and nut. Additionally, we added a 220 Ω resistor between Serial Clock Line (SCL) and ground to pull down the SCL and prevent accidental use.

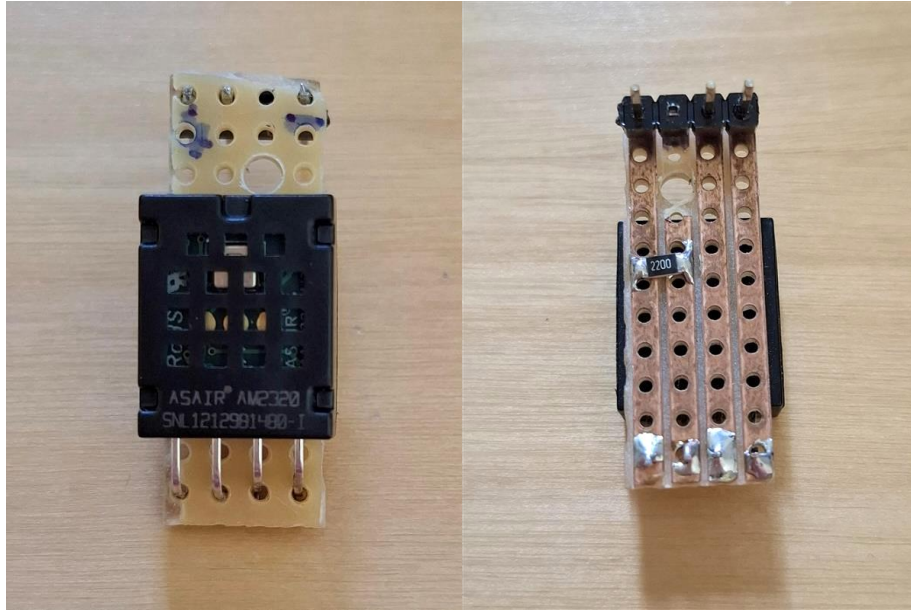


Figure 3.2. We modified the AM2320 sensor by adding a soldering perfboard to improve mounting and connectivity of the sensor.

To program the Arduino Pro Mini, you need an FTDI USB to Serial converter that is suitable for a 3.3 V development board. A quick Google search brings up plenty of options for these converters. We have used a CRIUS FT232RL and a SparkFun FTDI Basic Breakout converter. We naturally used Arduino IDE to program the Pro Mini. [More info about the Arduino Pro Mini can be found here](#). You can find the Arduino IDE program code in the “Arduino IDE code” text file included in the OpenAR-M folder. Just copy and paste it into Arduino IDE and upload the code once you have connected your Arduino Pro Mini (or equivalent Arduino board) to your computer.

4 3D-printed Parts and Assembly

The 3D models we designed for OpenAR-M are meant to bring a sleek and compact look to the AR-glasses. OpenAR-M glasses are meant to be worn like regular eyeglasses for ease-of-use, and the 3D-printed parts support this design choice. The 3D-printed parts consist of three main parts: the frame of the glasses, the optical case, and the electronics case. Let us go through each one and get familiar with them. To get a more detailed description of the 3D-printed files refer to Guide for 3D printed files included in the OpenAr-M folder.



Figure 4.1. OpenAR-M frame and temples. The frame has a tunnel for hiding electrical wires.

The frame of the OpenAR-M glasses resembles the frames of regular eyeglasses (Figure 4.1). Since human heads vary in shape and size, the frame cannot be made perfect for everyone, but the glasses should not easily slide off when worn. However, you can customize the 3D models yourself to ensure the glasses fit your own head comfortably. In addition to ergonomic considerations, the frame also includes an internal tunnel that houses the electrical cables powering the OLED display, keeping the wiring discreet and protected.

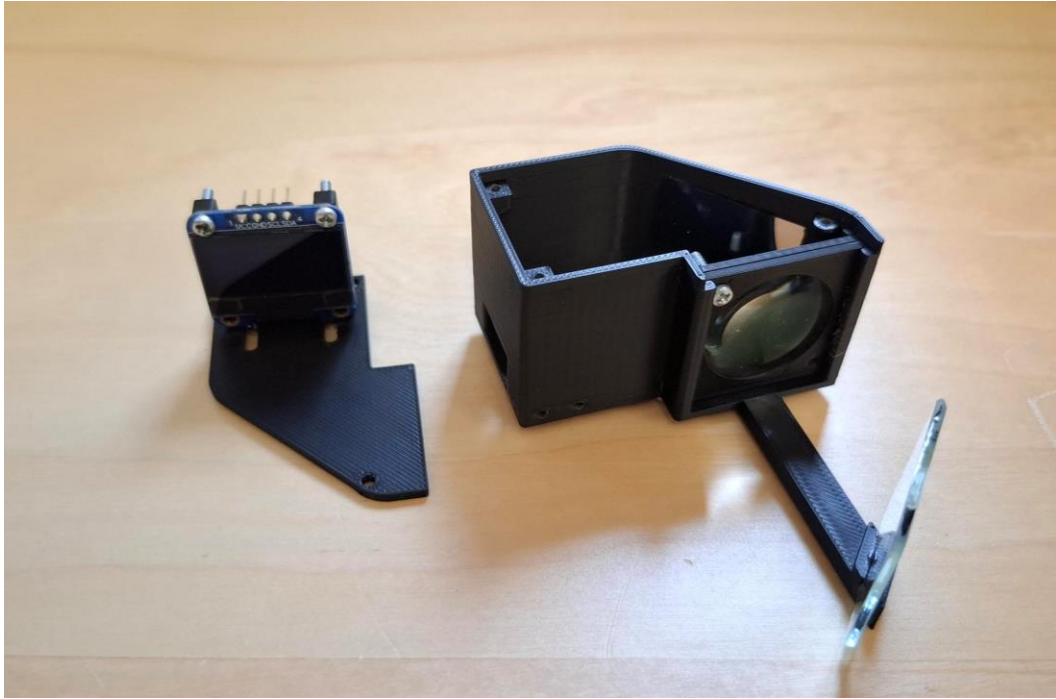


Figure 4.2. OpenAR-M optics case.

The optics case houses the OLED display, the first surface mirror, the lens, and the reflecting glass (Figure 4.2). The OLED display is connected using an adapter that we made. It is possible to move the display closer and further away from the first surface mirror. This ensures you can find the point where the image is the clearest i.e. the focal point of the lens. If you are using a lens with a different focal length, make sure to adjust the length of the optics case to match the new focal length.

The first surface mirror is attached to the angled part of the optics case using strong double-sided tape. The lens is easily slid in place when it is housed in its own holder. The reflecting glass is glued with epoxy glue to the holder that is attached to the top of the optics case. The angle and orientation of the reflecting glass determines where the reflected image appears on the user's field of view. Adjust the length and angle of the glass holder to find a position that suits you.



Figure 4.3. OpenAR-M electronics case.

The electronics case (Figure 4.3) holds all the electronics except for the OLED display inside the optics case. The case is close to the most minimum size it could be, so attaching the electrical components together is kind of a hassle (Figure 4.4). But the result is worth it, as the whole case is nice and compact. The LiPo battery is attached with double-sided tape while the USB charger, switch, and the AM2320 sensor are attached using bolts with 3D-printed nuts to tighten them (regular bolt nuts can also be used). The Arduino Pro Mini board sits freely inside the electronics case, suspended by all the wires connected to it.

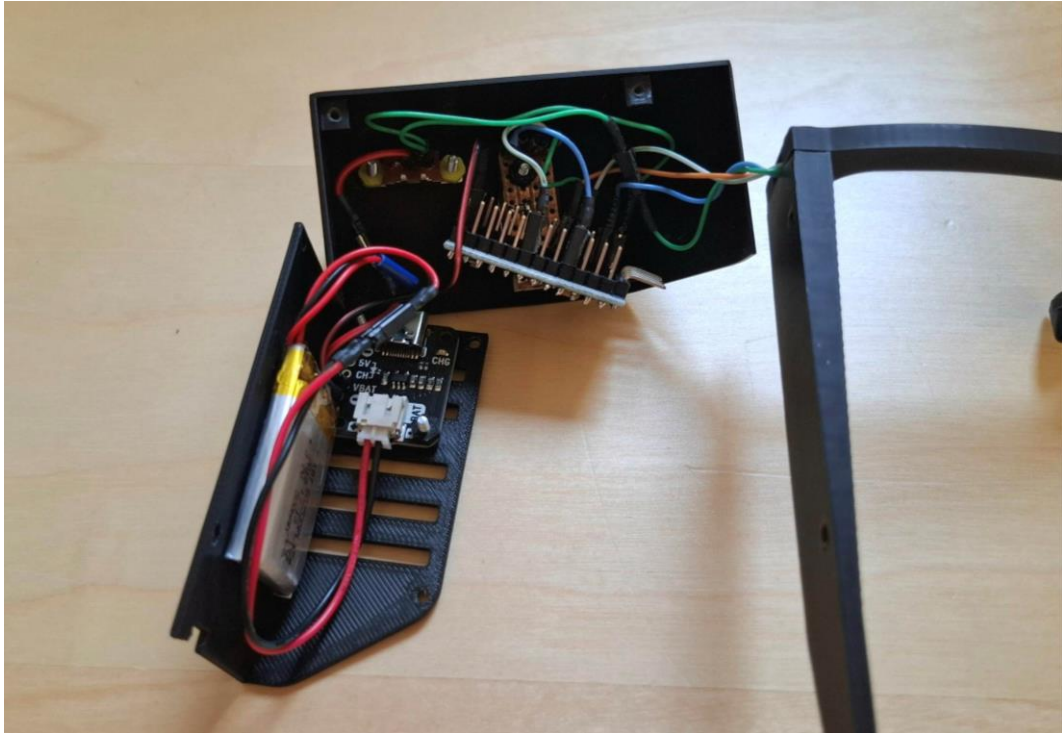


Figure 4.4. Inside the OpenAR-M electronic case.

It is worth to mention that all the 3D-printed parts are designed to be assembled using only M2 bolts and nuts. The assembly of the OpenAR-M glasses is straightforward. Refer to the f3d file and Guide for 3D-printed parts -folder included in the OpenAR-M documentation folder to get an understanding of how all pieces fit together and where threads need to be made.



Figure 4.5. OpenAR-M assembled.

5 Closing Words

OpenAR-M started a small spin-off of the mainline OpenAR systems, but it quickly came apparent how much more compact and easier-to-use OpenAR-M glasses ended up being. The design is much simpler than in previous iterations (although we lost the stereovision effect of OpenAR 2.0, 2.1, and 2.2), but the single eye augmented reality effect is still cool and even a little bit useful in this case. Replacing the humidity and temperature sensor with other sensors would be an easy task, now that the platform is already designed and built. For example, you could attach atmospheric pressure sensors, air quality sensors, photoresistors, heartbeat sensors or almost any kind of sensors if they are compact enough.

This project is not the end of OpenAR-Mini though! We have more upcoming versions notably with different lenses we can create here at University of Eastern Finland. All will be shared in time on our website: <https://sites.uef.fi/openar/>. This first version will be the most hobbyist-friendly as the lens can be bought from the internet.

Appendices

Appendix A. List of the components used in OpenAR-M.

Optical system	Electronics
OLED display 128x64 First surface mirror Lens (25 mm diameter, ~50 mm focal length) Reflective glass	Arduino Pro mini LiPo Battery (3.7 V 500 mAh) USB battery charger LiPo Amigo AM2320 humidity and temperature sensor

Appendix B. List of the items and tools that are needed/were used to build OpenAR-M.

- M2 bolts x 23 (10 mm)
- M2 nuts x 5 (we printed these ourselves)
- A screwdriver compatible with the M2 bolts used
- Threading drill heads for M2 bolts
- Epoxy glue
- Double sided tape
- Drill
- Glass cutting tool
- A 3D printer
- PLA filament
- A whetstone or some other grinding tool
- Soldering iron and tin
- Electrical wire
- Pin headers and socket headers
- Soldering perfboard
- FTDI USB to Serial converter