inno.light - Sunscreen Check

iPDP – International Product Development Project

2024

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Abstract - Sunscreen Check – Year 2024 (Juliane)

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This project focuses on the design and development of a hyperspectral imaging (HSI) scanner, aimed at improving the application of sunscreen. Hyperspectral imaging technology captures detailed spectral information across a wide range of wavelengths, enabling the identification of areas on the skin where sunscreen has been applied sparingly or missed entirely. The scanner is designed to move vertically along wall mounted rails, providing comprehensive coverage of a user's body.

The captured data is processed and displayed on an additional screen, offering near instant feedback on the adequacy of sunscreen application. This immediate visual feedback allows users to identify and correct ineffectively protected areas, ensuring a more uniform application of sunscreen. By facilitating precise application, the system significantly enhances protection against harmful ultraviolet (UV) radiation, thereby reducing the risk of skin damage and skin cancer.

This innovative approach leverages cutting-edge hyperspectral imaging technology to address a common yet critical aspect of personal health. The project not only aims to improve individual sun protection practices but also serves as a preventive health measure. The system's potential to minimize the incidence of sunburn and long-term skin damage marks a significant advancement in personal health technology.

Keywords: HSI, Sunscreen, Scanner

Pages: 48 pages and appendices 4 pages

Declaration

inno.light's team declares that its team members used AI technologies to support the content and development, but it has not been used to produce content into the final form of the report.

All content received from AI has been revised, reviewed, and edited. Based on the AI feedback the final product has been formed by the team members.

Used AI models/services:

- Microsoft Copilot (Free version): for the purpose of producing images of the imagined prototype as in figure 10.
- Chat-GPT 3.5 (Free version): for the purpose of producing chapter naming suggestions, sentences reformatting.
- DaVinci AI Art Generator: for the purpose of producing images of the imagined prototype.

We – inno.light – are aware that we are totally responsible for the entire content of this report, including the parts generated by AI, and accept the responsibility for any violations of the ethical standards of publications.

Table of contents

Appendices

1 Introduction (Juliane)

Over the past 20 years, the number of skin cancer diagnoses has increased rapidly. In Germany, there has been a 75% increase in cases between 2001 and 2021 (ZDF, 2024). One of the main causes is unprotected exposure to the sun. Additionally, many people tend to underestimate the harmfulness of the sun's UV rays.
Within this project, an innovative solution to prevent people from getting sunburn was developed.

The purpose of this paper is to give the reader an overview of everything that was done and learned during the iPDP course. The team inno.light focused first on finding a new area of application for hyperspectral imaging. Therefore, various ideas were brainstormed about different kinds of problems in the world and about how to solve them with hyperspectral imaging.
Finally, the decision was made for one project: The Sunscreen Check.
The goal of this project is to build a mid-fidelity prototype using the design thinking process. Due to its wide user group, this report addresses every single person.

1.1 Team inno.light – skills and contributions to the project (Vero)

inno.light is a diverse and dynamic team of six students – three from HAMK University Hämeenlinna, Finland and three from Hochschule Mannheim, Germany.
Concerning the German side, the team includes Juliane Dörner, Veronique Dill and Mia Markelic.
Juliane is a Biomedical Engineering student, and she is an expert in research and coding. Her experience in working in a lab became very useful for understanding the sponsors workflow and helped immensely during the research phase.
Veronique studies Communication Design and she specializes in human-centered design. Due to her knowledge in that field, she was able to understand the main target group to create a pleasant user experience with a user-friendly interface.

Mia, a Chemical Engineering student, is a specialist in chemical processes. With her expertise, she guided the technological development to fit the chemical challenges of the project.

From the Finnish side, Titus Mwendwa Muoki, Yusuf Mohammad Naeem and Ujjwal Shrestha are a part of the team.

Muoki is a Computer Applications student and a coding specialist. Because of his help the group was able to program the required software.

Yusuf, a Construction Engineering student, focuses on system construction. He managed to find and build a DIY hyperspectral camera which captures detailed spectral information.

Ujjwal, a Mechanical Engineering student is the teams' specialist in mechanical processes. He committed his skills to improving the technology and construction.

All of them come from various academic backgrounds and have united their strengths to work true to the motto "divide and conquer". This collaboration supported their diverse skills individually to innovate and achieve inno.lights' goals effectively.

1.2 Project sponsor background (Juliane)

The sponsor of this project is 'Hylight' (HYLIGHT, 2024). Hylight is part of the ATTRACT Project, which sponsors more than 180 different research and development projects. The project manager and the person corresponding with the team is Anna Ferrer. The research team behind Hylight is located at IBEC (Institute for Bioengineering of Catalonia) in Barcelona. Therefore, it is a group of scientists located in a university.

Hylight's goal is to select the most promising artificially fertilized embryo to increase survival rates after transplantation. For this selection, it is important to scan the different embryos without harming them or causing stress. This is why they use hyperspectral imaging. The first step for this technology is to illuminate the sample (the embryo) with a laser. To achieve the right level of illumination, they shoot two photons in a short period of time in the near-infrared range. Afterwards, the reflected light is detected and processed. This data is then

input into a trained AI algorithm to obtain the necessary information and determine which embryo has the highest potential survival rate. Overall, the information obtained from this hyperspectral imaging can be compared to a specific ‘fingerprint’; therefore, it looks different for each embryo (ATTRACT, 2023). While the team inno.light visited Hylight, this technology and the different steps were explained by either Anna Ferrer or Miguel Ares. Miguel is an optical engineer who is also working on the Hylight project (HYLIGHT, 2024).

This technology will help clinicians choose the most promising embryo and thus make it easier for parents with an unfulfilled desire to have children to start a family.

Until now, Hylight was just a project of ATTRACT. They are now launching a start-up under a different name to further develop the technology and hopefully obtain approval for public sale.

For further information regarding the sponsor Hylight, please follow the link: https://hylightproject.eu

1.3 Problem background (Yusuf)

The challenge was about using the technology of hyperspectral imaging in solving a problem that is not within the medical field. Employing the technology of hyperspectral imaging allows for a non-invasive checking on the many different fields, this ranges from the field of quality checking to the fields of surveying, chemicals checking and much more.

Our team took on the challenge by going through a series of brainstorming sessions in which the approach of eliminating inadequate ideas was followed, after that comes the step of checking whether the solution already exists in the targeted industry, it was at this step our team had to eliminate a bright idea, that idea was about using the imaging technology as a safety measure and a possible efficiency increasing measure in waste sorting plants.

2 Theoretical background (Mia)

The idea behind the inno.light prototype is to create a device which scans the skin for substances called endogenous fluorophores, which are found in human skin. These compounds include fluorescent chemicals, such as collagen, elastin, melanin, NADH (Nicotinamide adenine dinucleotide), FAD (Flavin adenine dinucleotide), and others (Palmer, 2016). Since the sponsor of the group focuses on the autofluorescencence of embryos, which contain NADH and FADH, the group decided to choose a similar approach to tackle the problem of scanning human skin for these compounds (Seidenari, 2012).

Fluorescence is the ability of a chemical to emit light upon excitation. When a chemical absorbs UV-light, its atoms change position to a higher energy state, also called the excited state. The excited state exists only for a finite time and the atoms leave this state due to it being hard to sustain for a longer period. When the atoms leave the excited state, a part of them go back to their ground energy level. Most chemicals go back to their original state without emitting light. However, fluorescent chemicals, which are characterized by their stiff and complex molecular structure, re-emit visible light on their way back to their original energy state. This light has a smaller frequency and a longer wavelength and is visible, meaning it can be detected by the human eye. (ThermoFisher Scientific, 2024)

Sunscreens are formulated with chemicals that work as UV-filters, which can be physical (inorganic) or chemical (organic). The difference between inorganic and organic chemicals is that inorganic chemicals do not contain carbon, and organic chemicals contain carbon-carbon and carbon-hydrogen bonds as their “base”. Most sunscreen formulations nowadays combine both types of ingredients to ensure that all types of UV-rays (UVA and UVB) are effectively blocked. Physical UV-filters, which consist of zinc oxide and titanium dioxide, work by mostly reflecting harmful UV-rays from the skin and absorbing a smaller part of it. On the other hand, chemical UV-filters, also known as organic UV-filters, work by absorbing the different types of UV-rays and dissipating them into heat, before they can reach the skin and cause cell damage. Some of these chemicals include avobenzone, octisalate, octocrylene, homosalate, oxybenzone, octinoxate and a few others. (Menzie, 2022)

Theoretically, if a person applies sunscreen on their skin and misses a part of skin while applying, the endogenous fluorophores would be detected by a hyperspectral camera due to these chemicals being reached by UV-light. Other parts of the skin that have absorbed the sunscreen would not be detected, since the UV-filters in the sunscreen would prevent this.

Inno.light has used these facts to create the core idea behind the sunscreen check device and to lay the groundwork for making the prototype which was presented during the final gala. The other important technology the team used, hyperspectral imaging, will be described in the paragraphs down below.

It must be noted that due to a lack of time and contrary to the sponsor Hylight, inno.light has not used AI to process the images, but rather a code in "GNU Octave" (Eaton., 2024), which was an effective way for the group to process the images that were taken with a hyperspectral camera.

2.1 Design Thinking process (Juliane)

The design thinking process is a step-by-step method to help you develop an idea from the beginning. There are five different steps that need to be repeated many times. During each iteration, the project improves, adjusts, and gains more information about the users and the problem. Therefore, it is a non-linear process, and it is important to understand that the different stages are just a guide. It is very likely that two stages could be fulfilled simultaneously or that stages can be repeated. However, at the center of every iteration and step is the human being. (Dam, 2024)

The following part is explained according to the information and the knowledge the team gathered during the iPDP course as well as information from the ‘Interaction Design Foundation’ (Dam, 2024).

The different stages are: Empathize, Define, Ideate, Prototype, and Test.

Starting with empathizing, you really get to know your user. It is very important for the success of the project to empathize with the user group and to deeply understand the problem you are trying to solve. For this project, the sunscreen check, the information was gathered during interviews and questionnaires. The results of the user research are presented in chapter 3.1.

The next step of the design thinking process is ‘define’. This step is based on the empathizing stage. The goal is to analyze all the data that was gathered and define the core problems. It is important to keep in mind that the problems must be defined in a human-centered manner.

Building on this, the next stage is all about generating ideas. Therefore, the problem must be looked at from different perspectives in order to ideate innovative solutions to the previously defined problem.

After all this theoretical work and data, the next step is to start creating a solution. This is done by building a first prototype to conduct some initial tests. The aim is to identify the best solution to the problem. These prototypes increase in fidelity with every iteration of the process, beginning with a low-fidelity prototype.

In addition to that, the last step is to finally test the prototype. This will help to understand how people will feel and behave towards the product. With all the feedback and new findings, the next iteration of the whole process can start, and the idea/product can be developed further.

Having this process as a basement, the team achieved to come up with a valuable solution that fits to the user's needs. Moreover, low-fidelity prototypes were built and tested. Based on the results, the prototypes were improved and reached a mid-fidelity level at the end.

2.2 Hyperspectral Imaging (Mia)

Hyperspectral imaging is a noninvasive reflectance technology that combines imaging and spectroscopy. By using a hyperspectral camera to generate an image of an object, important information across the electromagnetic spectrum is collected and processed. The aim is to provide the spectrum for each pixel in an image. (Specim, 2024)

Since every object has its unique spectral "fingerprint", this technique can be utilized to identify different objects and materials.

Figure 1 shows the entirety of the electromagnetic spectrum. This term encompasses all types of light, beginning with very long radio waves, which have very low energy, through microwaves and UV/VIS, and ending with X-rays and γ-rays, which have very low wavelengths and therefore very high energy.

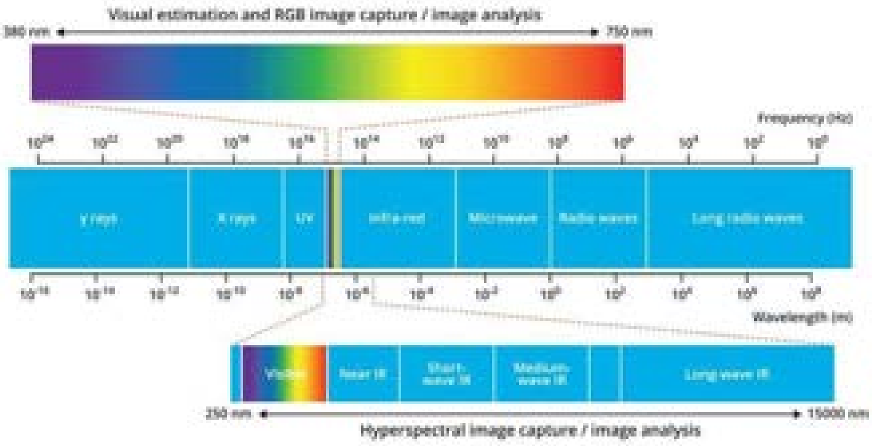

Figure 1: Different wavelengths used in HSI (Specim, 2024)

Though the wavelength range that can be used in hyperspectral imaging is broad, users mostly focus on visible, near-infrared and medium-infrared wavelengths (MathWorks, 2024).

In addition to RGB cameras, hyperspectral cameras are used to test how objects correspond to more wavelengths, anywhere from 250 nm to 15000 nm, going beyond the light that human eyes can see. The processed spectral data results in a color-coded image for the observed object, from which more information about the physical and chemical properties of the object within the image can be provided.

One of the main advantages of hyperspectral imaging is its high spectral resolution which can help characterize materials in detail. However, it must be said that processing hyperspectral images can be a time-consuming task, since these cameras measure thousands or even up to hundreds of thousands of spectra in a short period of time to generate a large hyperspectral data cube, as seen in figure 2. Such a hyperspectral data cube comprises position, wavelength, and time-related information. (Specim, 2024)

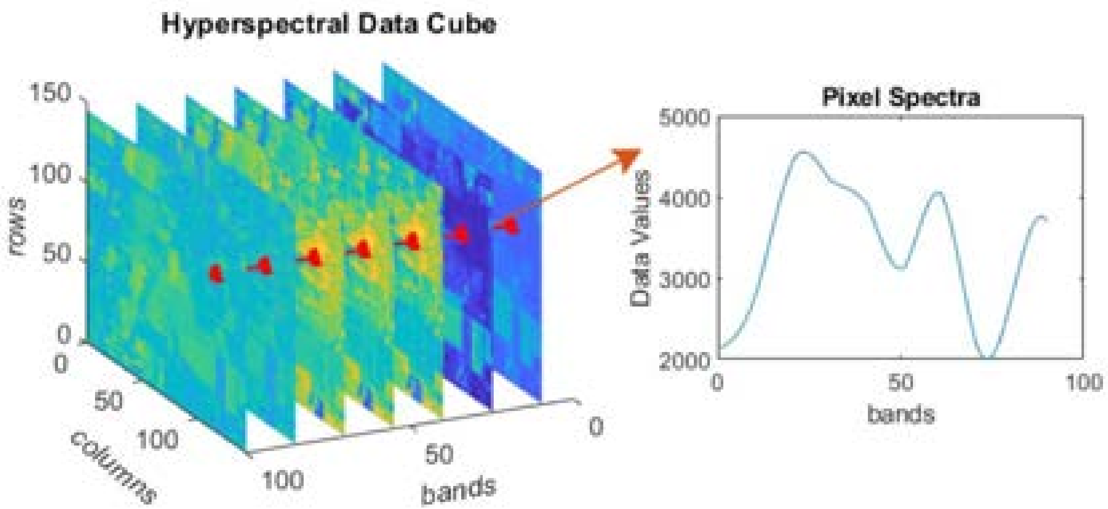

Figure 2: The data from a hyperspectral data cube translated into pixel spectra (MathWorks, 2024)

HSI cameras work by capturing the light that the observed object reflects, separated into individual wavelengths. This way, 2D images are produced, with each pixel containing important and distinctive spectral information. Figure 3 shows the difference between an image that is created by an RGB camera, which uses three different wavelengths, and a hyperspectral image that uses the reflectance at 220 different wavelengths. The latter image contains more comprehensive information which can be used to identify the captured object in an easier way. (Specim, 2024)

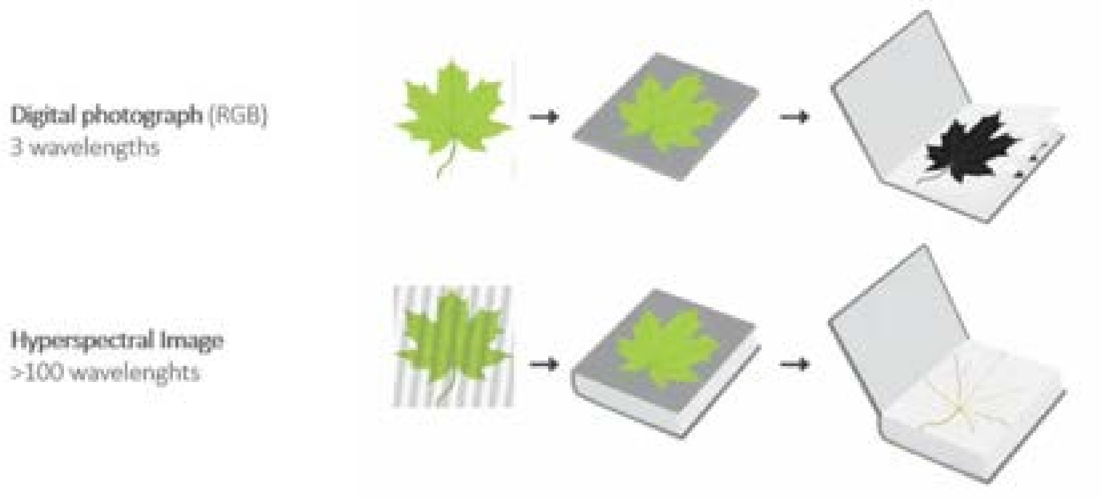

Figure 3: Top image created using RGB bands and bottom image (HSI image) created using 220 different wavelengths (Specim, 2024)

Hyperspectral imaging is mostly used in environmental monitoring, mineral exploration, quality control of food and pharmaceuticals, waste separation, agriculture and many others. (Specim, 2024).

To sum up, it can be said that hyperspectral imaging is a revolutionary technology that has already found use in many different industries, despite its costly implementation, since it represents a reliable way to analyze, identify, and separate different materials and substances. It can be used in place of other spectroscopy techniques, which are slower and not es effective. Its application can lead to enhanced productivity in food production, since it helps select e.g. rotten fruits and vegetables from healthy fruits and vegetables. It also improves quality control in pharmaceutical production by detecting the right distribution of the active substance in a capsule or a pill. These are just a few of the examples on how HSI offers innovative solutions to everyday problems.

3 Project Research (Ujjwal)

The main idea for the research was to find a new application for Hylight's hyperspectral technology. In the first week in the bootcamp the team also talked with the sponsor discussing their expectation and priority of field for the applications.

The project was based on hyperspectral technology which was quite new for all the team members. At the beginning of the project, we studied and gathered information about hyperspectral technology and how it worked. The group also talked with the sponsor to understand their technology and how it is different than other HSI (Hyperspectral imaging) technology.

After that the team started to search for information for the application of HSI technology. The primary resource to collect data about the application of HSI was scientific and research articles and academic journals. Each member tried to find different applications. Then it was discussed how each idea can be unique and useful. Various aspects to the application like usability, reliability and whether the application is already in commercial use were debated.

The research was based on qualitative data analysis using interviews, user testing, research articles and discussions. No specific type of qualitative data analysis method was used.

The next step was to shortlist a few ideas from all the ideas presented by the members. Those ideas were divided among each other for further research. Each member conducted interviews with professionals and experts related to the applicable field. Interviews helped a lot to get deeper understanding to consider while finding applications.

1. Material Age Determination: Distinguishing between old and new versions of plastics based on spectral changes due to weathering and degradation. The ideas shortlisted for further research and result of research are mentioned below.

2. Small device to check if you need to reapply sunscreen: Two interviews were conducted for this idea. One with a normal person who regularly used sunscreen. And other with a person who has allergies when exposed to sun. Both interviewees had positive response to the idea and described it as a unique and helpful idea for all people.

3. Microplastic Detection in water treatment plants: Identifying and characterizing microplastics in environmental samples based on their unique spectral fingerprint: There are already other method to check microplastics in lab condition. The idea was to use HSI image in real time, but HSI camera doesn't work properly in an environment with moving water and vibration as told by our sponsors.

4. To check the ocean if we can see which organisms are dangerous and which are responsible for the extinction of species: There is some research going on this sector. But an interview with marine biologist couldn’t be managed on time. An interview with a marine biologist was held later but our team had already moved on with this idea.

5. Using the imaging technology to inspect airplane engine blades: An interview was conducted with a professional person working in similar industry and he suggested it would be good idea if we could make product that can inspect engines blades without disassembling it.

6. Scanning for allergy-causing substances for companies with bed linen for allergy sufferers: Bed linen in hotels is regularly changed. And a personal device just to check for personal use would be too expensive to use this technology.

7. Detecting or scanning for certain proteins that are known for causing fungus on your skin: A dermatologist was consulted for this idea. According to the dermatologist this could be

useful to diagnose some simple fungus quickly but was unsure about hard to diagnose fugus that need various test for diagnosis.

Later all the findings were discussed, and each member shared their opinions on each idea.

Each member conducted interviews with professionals and experts related to the applicable field. Interviews helped a lot to get deeper understanding to consider while finding applications. Later all the findings were discussed, and each member shared their opinions on each idea.

Then the top 3 application ideas were divided into 3 groups consisting of 2 members. Then the same process was repeated. Also, user testing was incorporated for this step.

1. Using the HSI technology to inspect the airplane engine blades for cracks
It is a light weight, handheld HSI Camera that check a piece of airplane blades for the growth of cracks / hard to detect mechanical damages.

Information from user testing: There are already more reliable methods for crack inspection in blade. There were concerns about how it would work in presence of sunlight and if it would be possible to inspect the crack properly without dissembling the blades.

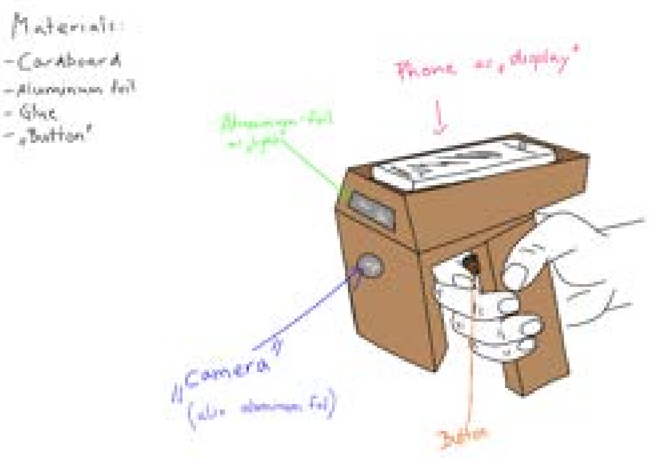

Figure 4: Drawing of the low-fidelity prototype for inspection of engine blades

Figure 5: Low-fidelity prototype for inspection of engine blades

2. Use a hyperspectral camera to differentiate between different kind of skin fungus

It is a relatively small device that could scan any part of the body. A doctor uses a handhold device to scan your skin and he can see on a computer what kind of fungus.

Information from user testing: Uncertainty about the accuracy about the of fungus detection was the major problem. With this uncertainty in accuracy prescribing medicine can be a tricky part and need recheck up from doctor. Misdiagnosis may have higher risk of administrating wrong medicine.

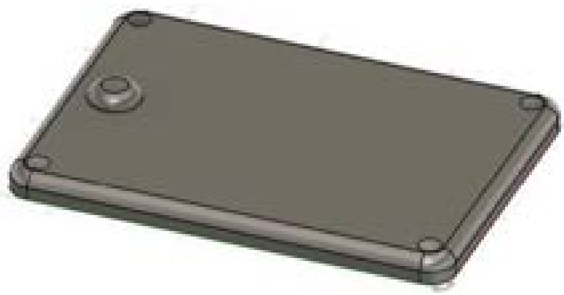

Figure 6: Model of the low-fidelity prototype for checking skin fungus (1)

Figure 7: Model of the low-fidelity prototype for checking skin fungus (2)

3. Use a hyperspectral camera to check sunscreen on people's skin.

The device could be installed on beaches, where people would stand in front of a HSI camera which would scan their bodies and users would be able to see if they have missed some spots on their body or if their sunscreen has worn off so they could see if and where they need to apply/reapply sunscreen.

Information from user testing: There was concern that sunlight will negatively affect the result from HSI camera. The product could not check skin from face to legs and needed multiple cameras to solve the problem. But using more cameras would significantly increase the price of the device. There was a major question about how the product will withstand natural variables like sun, storm, rain and dust etc.

Figure 8: 3D-model for the sunscreen check device

Figure 9: Low-fidelity prototype for the sunscreen check device

The team presented these 3 ideas in the halfway gala with an initial physical prototype.

Each members took multiple interviews using the physical prototype and used all the data collected to discuss and debate on clarifying each idea and used case scenarios. Finally, one idea was picked for the final approach i.e. Use a hyperspectral camera to check sunscreen on people's skin.

A digital image of the prototype was created using the AI-imaging app DAVINCI, as seen in figure 10.

Figure 10: AI-image for a device for sunscreen check

3.1 Previous "How might we…?" (Juliane)

Starting with this project, an initial 'How might we ...?' question was defined:

How might we use Hylight's technology to improve the environment?

With this question, brainstorming for different ideas began. Because of it being a widely open question, the first things that came to mind were ideas regarding waste separation, investigating food or detecting fertile plant seeds. The winner of these ideas was the waste separation area because this field seemed to be the most promising one due to all the different kinds of plastic and materials that could be separated by a hyperspectral imaging camera. Therefore, the ‘How might we ...?’ question was adjusted:

How might we improve the waste separation process with the help of a hyperspectral camera?

Moving forward with this, there were ideas about e.g. separating plastic more specifically or using HSI technology to detect hazardous materials. There was also the idea of improving the life cycle of reselling waste to different companies that could need e.g. paper waste.

Unfortunately, a few weeks into the project, it was discovered that something like this is already done. A company named ‘Inno-Spec’ already uses hyperspectral imaging to enhance plastic and paper recycling, as well as recycling building materials (Spec, 2024). Therefore, this idea couldn’t be continued, even though there is proof that the idea was pretty good and a need for this is already there.

Starting from the beginning again, brainstorming sessions were repeated, and new ideas needed to be produced. In the end, the team came up with our final ‘How might we ...?’ question:

How might we use hyperspectral imaging to prevent people from getting a sunburn?

The basis of this question was the common problem of getting a sun burn as well as the rising number of skin cancer (ZDF, 2024).

3.2 User Research (Juliane)

The user group for this device is not limited, everybody could use it as well as benefit from it. This is because almost every single person is exposed to sunlight in their daily life. More importantly, during holidays, many people tend to underestimate the power of the sun.

Therefore, this device can help many different people or at least raise the awareness of the harmful effects from sunlight.

To really get to know some possible users, 3 interviews and 4 questionnaires were conducted. The interview partners were a female student, a young mother and a middle-aged man. The questionnaires were filled in by a fellow student, a 30-year-old female working as a nurse and two mid-aged workers.

The main findings are that the health of the skin is already very important to the interviewees, and they are aware of the harmful effects of sunlight. However, most of them use sunscreen inefficiently and not often enough. One surprising finding is that some of them tend to get sunburned more often during their daily life and not especially during holidays. This is probably because they remember to use sunscreen more frequently during holidays.

Contradictory is that while their skin health is very important to them, most of them would only use the scan if it took 3–5 minutes. Some are okay with it taking up to ten minutes, but it is important to note that time consumption is a very important factor.

All in all, the feedback for the sunscreen scanner was very positive! Most of the interviewees really liked the idea and thought it would be helpful for themselves as well as for children.

3.3 Stakeholders (Mia and Muoki)

Regarding the stakeholders for this project, the team has discussed the core target group, the direct stakeholders and the indirect stakeholders. When it comes to the core target group, five different groups of people were defined using Mural, as seen in figure 6. These groups of people consist of people sensitive to sunlight, people with a sun allergy, people with a history of skin cancer, people who are conscious of their skin health, and beach goers in general. The core target can be described as a group of people that would use the given product and benefit from it through personal use. These people would be most suited for using a hyperspectral camera on a beach.

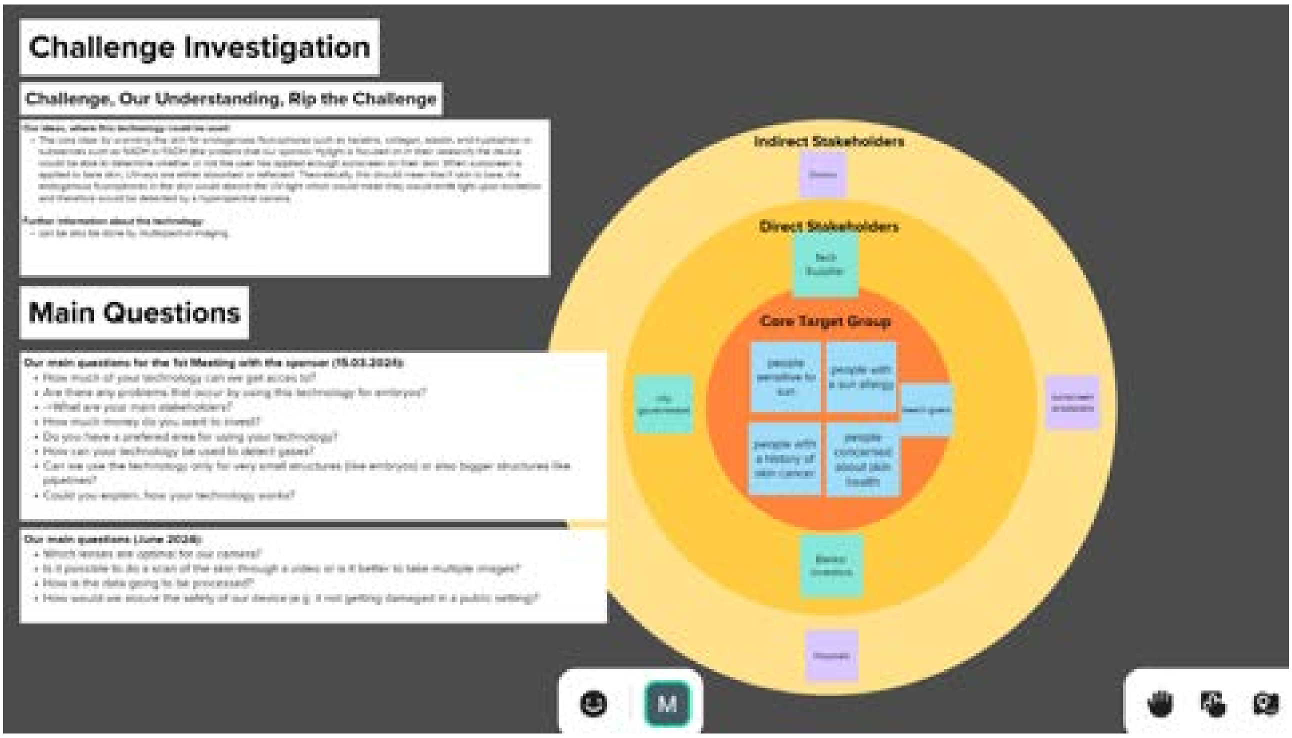

Figure 11: Mural board of inno.light's core target group, direct stakeholders and indirect stakeholders

Furthermore, three direct stakeholders were defined. These would be technology suppliers, the city government, banks and investors, the tourism and hospitality industry, environmental and outdoor recreation organizations advocate for sustainable practices and minimal environmental impact, and public health organizations aiming to reduce skin cancer rates.

The technology suppliers can sell the parts for a hyperspectral camera, the city government would have direct contact to the builder of the technology and the place the device would be installed, e.g. a café bar on a beach. They would also have to ensure that all regulations for installing such a device were followed and that it was safe for the user. Banks and investors would play a part in helping the creators of the device with the loans they would need to take out to finance the project.

Retailers and distributors of sunscreen products play a crucial role in advancing sun protection technologies. Their involvement ensures the availability and accessibility of effective sunscreens detectable by hyperspectral cameras. Collaborating with them integrates specific sunscreen formulations into detection algorithms, enhancing accuracy and user confidence. Additionally, obtaining CE qualifications for the hyperspectral prototype is essential for regulatory compliance and market acceptance within the European Economic Area. CE marking confirms that the device meets stringent health, safety, and environmental protection standards, ensuring its reliability and efficacy. This certification not only bolsters consumer trust but also facilitates partnerships with retailers and distributors, as it signifies adherence to high-quality standards.

The tourism and hospitality industry, encompassing hotels, resorts, and travel agencies, is pivotal in promoting guest sun safety. Integrating hyperspectral cameras into venues provides real-time sunscreen feedback, enhancing guest safety during outdoor activities. This proactive approach reinforces the industry's commitment to enhancing guest experiences and fostering a culture of sun safety among travelers.

Environmental and outdoor recreation organizations advocate for sustainable practices and minimal environmental impact. Collaborating with them tailors a technology to meet stringent environmental standards for deployment in natural habitats and recreational areas. Their involvement ensures responsible technology use, supporting broader sun safety initiatives and reducing skin cancer risks.

The final group, the indirect stakeholders were doctors, sunscreen producers, and hospitals. Potential stakeholders also include public health organizations aiming to reduce skin cancer rates. Ultimately, the goal of the project is to help people avoid sunburn and therefore lower their risk of developing skin cancer. This would ideally result in less melanomas being diagnosed in the future.

3.4 Methods of Analysis (Yusuf and Muoki)

The team has done a fair amount of interviews, and got to collect a fair amount of data in the form of opinions, suggestions related to the technical and user experience side of the project, the team could not consider all the received feedback and include them in the report as some of the given feedback contradict other more valuable received feedback, thus the team resorted to the method of brain storming, where the team would consider a couple of ideas and discuss it´s positive and negative effects on the end user and the progress of the development cycle.

(Titus)

Alongside our brainstorming sessions, we employed affinity diagramming to better organize and prioritize the feedback we collected. By grouping similar ideas and suggestions into categories, we were able to identify key themes and insights. We then assessed each category based on its potential impact on user experience. To deepen our understanding, we conducted scenario-based testing, where we created hypothetical user scenarios to mimic real-world use of the hyperspectral camera. This allowed us to evaluate the practicality and effectiveness of proposed features and adjustments. The insights from these methods played a crucial role in guiding our iterative design process, ensuring that the prototype developed in line with user needs and expectations.

3.5 Existing Solutions (Mia)

The team has found a descriptive study in which UV photography cameras were used to assess if these cameras can be used as visualization tools to illuminate sunscreen on the skin. The study was conducted in three parts. Firstly, different UV cameras were tested, then it was tested if these cameras work on different products with a sun protective factor. Lastly, a web camera was developed and was used by the public in a beach setting. (Caitlin Horsham, 2021)

It was found that the three different UV cameras had a good sensitivity to sun protection lotions, meaning they could detect the UV-filters even if the participants applied a smaller amount and with a lower sun protective factor. 83 % of the participants have said they were satisfied with the UV photography images and that they would use this technology in future. When it comes to the web camera on the beach, 233 participants used it. (Caitlin Horsham, 2021)

To conclude, the participants of this study were satisfied with the UV photography results and are likely to use it in the future if they get the chance. (Caitlin Horsham, 2021)

Compared to Horsham's idea the images that inno.light has created using HSI were not of a very high resolution, however, hyperspectral imaging has a lot more potential, since it can be used in combination with AI and it can scan the skin at a wider range of wavelengths. Also, in this study the reflectance of the sun lotion was detected, whereas inno.light focuses on endogenous fluorophores, which are found in the skin.

There is also a small UV-camera by iOS called "Pavise" which can be used as an extension for iPhones 14 and below to help users check when to reapply sunscreen. The difference between this product and inno.light's idea is that more people could use the sunscreen check on a beach for free, contrary to the iOS product.

3.6 Selected Solution (Yusuf)

After a few discussions, inno.light decided to use the sunscreen check idea as the final idea to work on. Through exploring the internet, the team managed to find an already existing solution, in a research paper called "A plug-and-play Hyperspectral Imaging Sensor using low-cost equipment" (Jairo Salazar-Vazquez, 2024). This article explains in detail the process of assembling a hyperspectral imaging camera, the body of this camera was 3D-printed and the processing unit was mainly a raspberry pi that ran a program which helped produce the images out of the camera, the article has a step by step explanation on how would one prepare every printed part and assemble it into a functioning hyperspectral imaging camera.

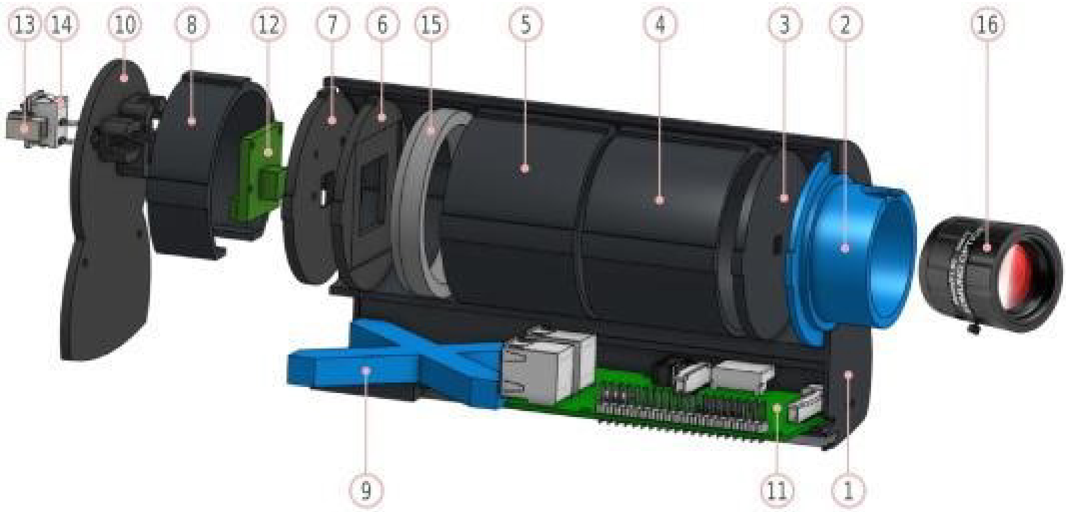

Figure 12: The HSI-components components (Jairo Salazar-Vazquez, 2024)

The team decided to follow the instructions in the research paper and use the result as a proof of concept in the final prototyping sessions.

Even though the research paper (Jairo Salazar-Vazquez, 2024) was comprehensive and detailed, many aspects of the camera had to be modified, but none of the modifications altered the distance between the first point where light enters the lens to the other components as that would alter the point at which the picture concentrates on and thus reduce the quality of the picture.

4 Concept of inno.light's prototype (Vero and Juliane)

Scenario:

In the following paragraph, a typical user experience of the sunscreen check is described.

A user is on vacation and visits the beach on a hot day. As the day grows longer and hotter, the user becomes increasingly unsure whether to reapply sunscreen or if they can wait a bit longer. After all, they have already applied sunscreen several times that day. On the way to the beach restroom, the user notices a small booth situated right next to the restrooms. Outside, they see a sign that reads "Sunscreen Check." Curious, the user decides to take a closer look.

The booth turns out to be a cabin that one can enter. Inside, there is a display, a camera mounted on a rail, and a sunscreen dispenser with a sign indicating that users are welcome to use it. Unfortunately, there are no windows, because it is supposed to be as dark I'm there as possible. The display is on, and the title screen reads, "Scan your body for any spots that are lacking sunscreen." This information catches the user's interest, but they are still a bit skeptical. They decide to learn more by pressing the information button. Here, they find out that the scanner uses hyperspectral imaging to detect sunscreen on the skin and identify areas where no or insufficient sunscreen has been applied. The user is reassured when they learn that no personal data is collected and decides to give it a try.

The user interface guides the user through the process step by step. The user reads that they should press the scan button and then position themselves correctly in front of the camera like the picture of a person on the display. Therefore, the user stands centered, in front of the camera with legs and arms apart so that the body is as visible for the camera as possible. The scan starts a few seconds later automatically, similar to the self-timer function of a camera. For scanning the whole body, the camera moves up and down on a rail. Signal tones alert the user when the scan begins and ends. After the front side is scanned, the display gives instructions that it is time to turn around now, so that the backside of the body can be scanned. The process is the same.

After the scan, all the information that was gathered by the camera is processed and analyzed. The user can then view the results on the display and could be advised to reapply sunscreen to specific areas, if there is a lack of sunscreen. The result could even be, that the user should move out of the sun entirely if necessary. The user can now directly use the sunscreen dispenser located in the cabin. Once the scanning process is completed, the user exits the cabin and can continue to enjoy their day at the beach with a sense of security.

A small 3D prototype of this booth is placed inside the Stand-Alone booth. The dimensions in there are not exactly like they should be in real life, it is just to get an idea of how it could look like. In real life it is supposed to be a small cabin that is big enough for 1 person to enter without feeling constricted, like public toilets.

5 Solution (Ujjwal)

In this chapter, an overview of the solution will be presented. Furthermore, all prototypes regarding the sunscreen check idea will be introduced. Our team developed the idea we picked from project research into a working solution. The solution can be divided into different phases.

5.1 Overview of the solution

The solution focuses on helping everybody with their skin health. The science and the key facts about this idea are explained in the theoretical background chapter of this report. All in all, it is a scanner that can be placed at a beach. It must be in a small room, to cover the technology from sunlight to get good results. It could be placed next to beach toilets or even next to or inside a beach cafe.

The scanner checks whether there is enough sunscreen on the skin of the user and tells them where to apply more.

5.2 Early phases

A simple, low-level physical prototype was then built using cardboard for the user to have better visualization of the idea during testing. This low-fidelity prototype is shown in figure 13.

Figure 13: Low-fidelity prototype front view

Figure 14: Low-fidelity prototype display

This is just a scanner that could be placed anywhere. It has a display on the one side and a camera on the other side. This needed to be changed. It wouldn't be easy to use, if you had to walk around the scanner all the time.

Testing result: During user testing, users mentioned that this device can't scan faces which is the most important part people want to protect from sun.

Second low-fidelity prototype:

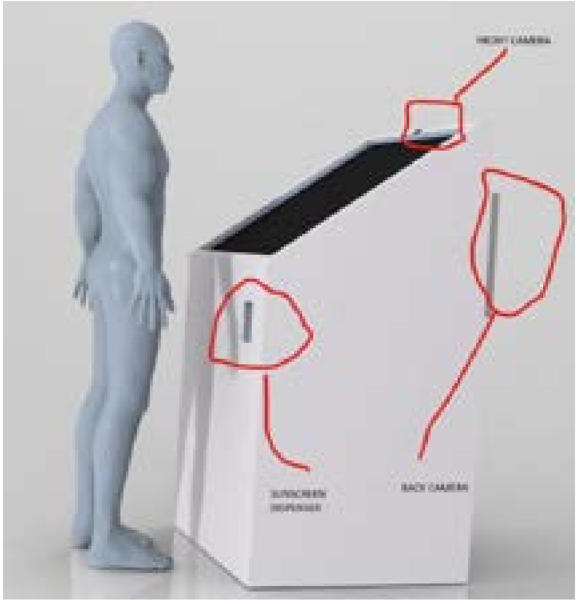

Figure 15: Second low-fidelity prototype

As seen in figure 9, the team added a front camera above the screen so that the user can easily scan their face without having to go towards the back camera. The back camera is still there to scan the body of the user.

Testing result: During testing users complained that going back of the screen to scan body is not user-friendly process and users cannot see the screen to check if the scan is going on properly.

Third low-fidelity prototype:

Figure 16: Third low-fidelity prototype

In this prototype, the group tried to remove the problem of going back to the scanner booth to use the back camera. Therefore, the camera was placed on the side so the user can use and interact with the screen at the same time.

Testing result: The problem in these last two prototypes is the need of two hyperspectral cameras to scan the face and body. But hyperspectral camera systems are very expensive and using several makes the product too expensive. Another point that needed to improve is where to put the scanner. It should be in a covered area to prevent the sunlight from damaging the quality of the picture. Thus, another prototype was developed. The user also suggested enclosing the product inside a structure to give a sense of protection and privacy while trying to scan different body parts.

During testing, an interviewee recommended putting a sunscreen dispenser with the product in case the users don't have sunscreen with them.

Mid-fidelity prototype:

Figure 17: Middle-fidelity prototype

In this mid-fidelity prototyping session, a closed structure was added around the previous prototype. The closed structure helps to eliminate unwanted sunlight which may negatively interfere with the scan result. Moreover, the sensitive technology needed to be protected from harsh weather conditions, such as rain. Also, a vertical sliding mechanism was used, so that a single camera can be used to scan the whole body by moving it up and down. Simultaneously, a special need of the user was covered. The need for privacy. Scanning the whole body is a daring step for a user which requires trust to the inno.light device and hence keeping the user's privacy to make them feel as comfortable as possible is essential. This information was shared with inno.light by the interviewees that were a part of the interviews the team conducted after the first prototyping phase.

Testing result: After user testing, we found some new problems with the prototype. Firstly, the screen took up a lot of space. Secondly, the screen and the camera weren't on the same side, which led to an 90° angle between the user and the hyperspectral camera, which made it hard to see the screen and stand in front of the camera at the same time. The user must've turned several times between the scanning and interacting with the display, which just complicated the process and user experience immensely.

Finally, this prototype was still lacking one item – a sunscreen suspenser. This idea came up during an interview. Inno.light decided to incorporate this idea in our final prototype.

6 Final Prototype for Final Gala (Ujjwal)

In the final prototype, the screen and camera were placed on same wall. A sunscreen suspenser was also added to make a perfect user experience. Sunscreen suspenser may also help the new user encourage to apply enough sunscreen.

The final prototype of the solution is shown in the following figure.

Figure 18: The final prototype

In the middle of the wall, there is the display, on which the user interface is shown. This display can be controlled by touch and guides the user through the scan. Next to the display on left, is the hyperspectral imaging camera. This one is placed on a motorized sliding system so that it can move up and down to scan the whole body from one side. For scanning the backside of the body, the user must turn around.

On the right-hand side is the added sunscreen dispenser. This comes in handy if the result of the scan tells the user to put some more sunscreen on the skin.

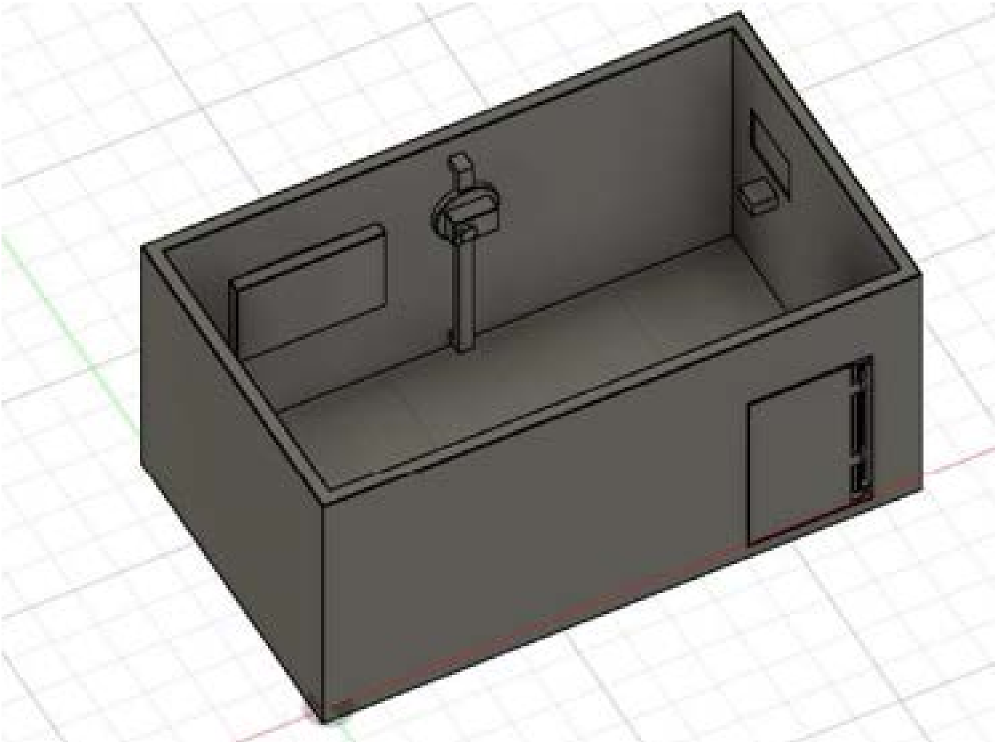

Figure 19: Miniature version of the final prototype solution

In figure 19, a miniature version of the final prototype is shown. This version differs slightly from the prototype the team has built in the HAMK Design factory. For example, the soap dispenser that was built in real life is not a real dispenser but a holder for the sunscreen and it was placed on the same wall as the camera. Furthermore, there was a marking on the floor in HAMK Design Factory during the final week gala, which was meant to signal to the user where they need to stand. In the 3D-model this was not incorporated. This 3D-model was done via Autodesk Fusion and printed at inno.space in Mannheim. At the moment, the printed version is placed in the Stand-alone booth, which you can find at HAMK university in Finland.

Figure 20: Stand-alone booth with prototype

6.1 About the User Experience and User Interface (Vero)

One of the highest goals was to create a user-friendly experience which is easy to understand and fun to use. It is common knowledge that nothing is more frustrating to a user than trying out something new and not understanding it.

In this case, the users find themselves in a rather hot environment at the beach. Their focus here is to quickly check their body for potential sunburn risk, most likely without any knowledge about hyperspectral imaging technology. Because of the weather conditions the user aims to be done fast and to be better protected to enjoy the rest of the stay at the beach without a worry.

Due to inno.light's user research it was discovered that the users would be willing to spend some minutes but would not be happy about the device taking more than 10 minutes in total. On top of that, privacy is a must for the user to feel comfortable. Data transparency was also wished for.

To ensure a quick, safe and easy process, inno.light installed a guide through user interface that is shown on the display next to the camera which lets the user handle the technical procedure on their own.

Figure 21: User Interface first slide

To explore the user interface in greater detail, click on this link:

https://xd.adobe.com/view/f472ff89-509c-4533-be54-fb6dda4872fc-a121/?fullscreen&hints=off

All in all, the UI gives the user some general information and leads the user through the whole scanning process, to scan the front and the back of the body. It also gives advice on how to proceed with the stay at the beach, including a suggestion to reapply sunscreen or in a worse case, sunburn, to get out of the sunlight and into a shaded area.

Figure 22: User Interface slide result

Regarding the visual design elements, the UI is mainly in light blue tones to create a calm and trusting effect on the user to prevent deterrence because of the not very well-known technology. However, signal red highlights important aspects. Based on the experience and knowledge of the team's designer, the chosen contrast between the red content and the blue content proved to be understood correctly while being the most effective design solution during user testing. In addition, gender neutrality is also very important and shown through the unisex figure.

To support the concept of an easily understandable UI, rounded edges, shaded buttons that are not too small and reasonable font sizes form the basic framework of the display application.

Figure 23: User Interface scanning process

In conclusion, inno.light's device is designed to be easy, clear, and enjoyable to use. Recognizing the frustration users face when confronted with new and complex technologies, the team has developed a system that is rather simple and straightforward. At the beach, users can quickly and efficiently check their risk of sunburn, even if they are not familiar with hyperspectral imaging technology due to the user-friendly interface.

6.2 The hyperspectral imaging camera prototype (Yusuf)

The camera prototype was an essential part to prove the assumption the team had relied on, which was the ability to detect a difference in sufficiently sunscreen covered skin and the non-covered skin. This part of the report explores the details of the prototype.

6.3 Physical prototype printing (Yusuf)

The outer shell and many internal component holding parts were printed using 3D-printers at HAMK Design Factory. Some modifications had to be made which are going to be mentioned further in the report.

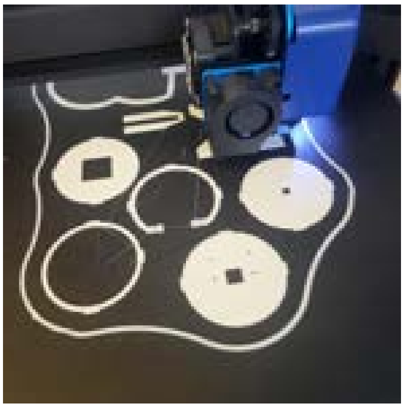

Figure 24: Prototype parts printing

In this picture above the internal components while being 3D-printed are shown.

Figure 25: Prototype printing almost finished

Here, most of the 3D-printed components are finished.

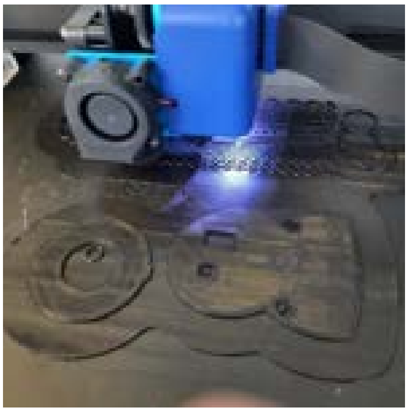

Figure 26: Outer parts of prototype

In this picture, the outer parts of the camera being 3D-printed can be seen. The color black is used for the outer shell of the camera.

Figure 27: Outer part of the prototype (1)

Figure 28: Outer part of prototype (2)

The outer shell of the camera is shown in these photos, with the unchanged design structure. The tree like form is a support meant to help print the upper parts of the construction, that could have been avoided if the print were to be printed with a rotation of 90 degrees along its longest axis.

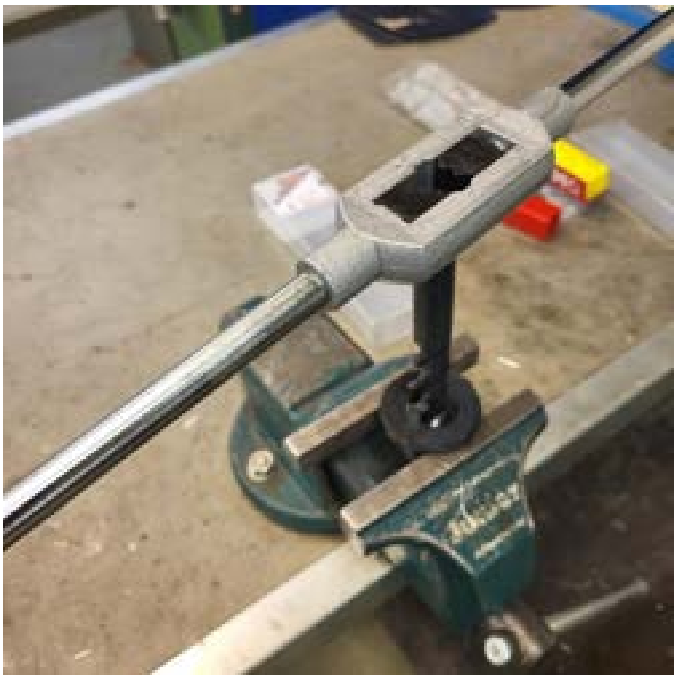

Figure 29: Threading process of a 12mm hole for the lens holding part of the camera

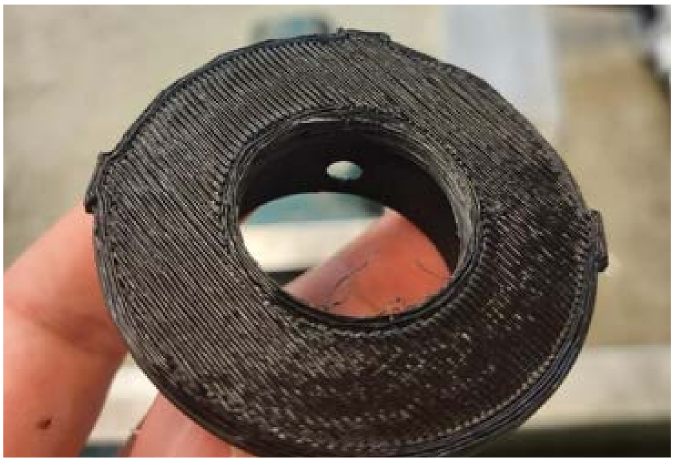
Figure 30: Threading process end results

The process of threading is shown in the previous pictures. The threading process was necessary as the lens did not fit into place until threading was used.

6.4 Changes applied (Yusuf)

At first, the outer shell of the camera was not printed thick enough to allow drilling through it and connecting the camera to the stand holding it. The changes applied made the camera use more plastic as printing material, but it was indeed necessary.

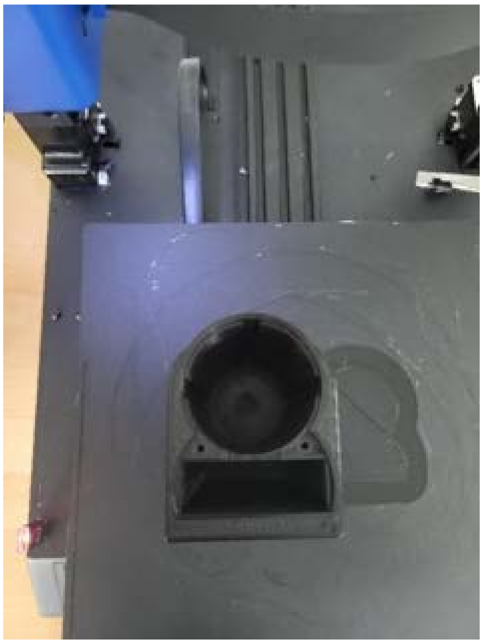

Figure 31: Changes in prototype (1)

Another change was made to one of the internal components which helps to hold the diffraction grating in place. A main challenge was to keep the diffraction paper in place without tilting it, as any slight tilt would distort the resulting images and make it hard to process. In the end, the following pictures shows what the last version looks like:

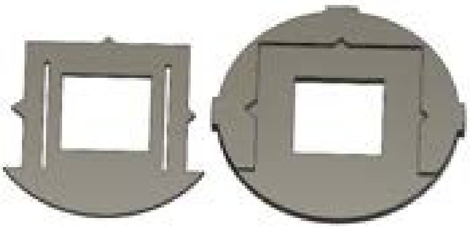

Figure 33: Changes in prototype (2)

Figure 32: Diffraction paper example

6.5 Methods of Analysis (Yusuf and Muoki)

Data gathered by the DIY hyperspectral imaging camera was analyzed by a code that runs on a program similar to MATLAB called Octave, the code was initially coded by researchers called Jairo Salazar-Vazquez and Andres Mendez-Vazquez, the adjustments to the code were minimal as the code itself was functioning and capable of producing results in the wished format.

The method to analyze the final results of imaging sessions was just comparing two areas where one area has sunscreen applied over it and another where sunscreen was not applied, this method allowed for a straightforward results interpretation and is efficient on the level of complexity the camera offers, one must keep in mind that the camera is a DIY camera and the error margin is not 0 % thus the methods of analysis must take that into account.

Therefore, the team's analysis is designed to factor in for this variability caused by a merging of error, ensuring the reliability and accuracy of the results.

Refinement of the algorithm and validation of its performance across different scenarios will also be important to the success and reliability of inno.light's prototype technology utilizing a DIY hyperspectral camera for sunscreen detection. Firstly, ensuring the algorithm's accuracy and reliability is paramount to effectively distinguish between areas where sunscreen has been adequately applied versus inadequately or not at all. This validation process is crucial in minimizing false positives and negatives, thereby enhancing the overall effectiveness of our sun safety solution. Secondly, variability in sunscreen application among individuals necessitates algorithmic refinement to accommodate diverse skin types, tones, and application habits. Thirdly, environmental conditions such as varying light intensities, humidity levels, and temperatures can influence sunscreen's spectral signatures, underscoring the need to validate the chosen algorithm across diverse environmental settings. Moreover, the algorithm must cater to the diversity of users, from fair-skinned individuals to those with darker skin tones, to provide accurate assessments universally. Additionally, iterative refinement based on stakeholder feedback, including dermatologists and sunscreen manufacturers, will drive continuous improvement in algorithmic performance. Lastly, meeting regulatory standards and ensuring user safety are paramount, requiring rigorous validation to operate within acceptable error margins and safety guidelines. By addressing these factors comprehensively, the team aims to enhance the algorithm's robustness and applicability, ultimately advancing sun safety efforts and reducing the incidence of skin cancer.

Moving forward, continued collaboration with dermatologists, sunscreen manufacturers, and healthcare providers will be essential to further refine the algorithm and validate its performance across various practical settings. This collaborative effort aims to leverage the expertise and insights of each stakeholder group, thereby enhancing the applicability of our technology in promoting sun safety and reducing the risk of skin cancer in real-world applications.

6.6 Results acquired from the prototype (Yusuf)

Results were extracted from the camera operating application and several tests were made. The test with the most obvious results was a test where the skin of two arms was tested.

The picture is at the wavelength of 531 nm. The testing person applied sunscreen on one inner side of the forearm and none on the other inner side of the other forearm. Then they held their arms together, with the creamed and not creamed side faced upward, so that the camera could capture both sides clearly.

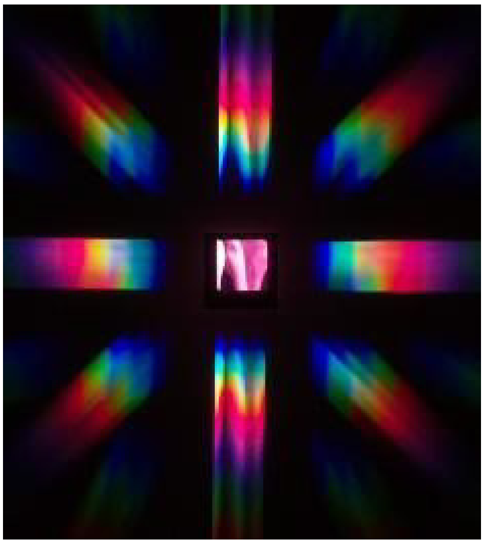

Figure 34: Pre-processed picture

The following settings were used to get the final result picture, shutter speed 5000 Ms, square shutter speed 2000 Ms, ISO 152, AWB mode Auto, Exposure mode Auto, camera resolution 8Mp, In the picture above one could see the pre-processed picture.

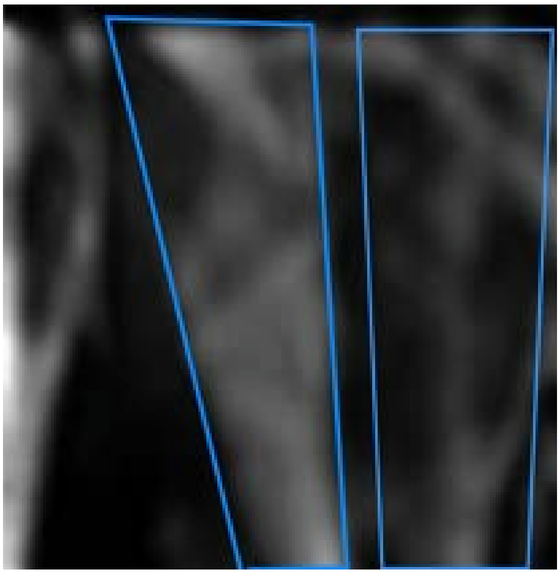

Figure 35: Processed picture

In this picture the arms of one of the team members can be seen, the left side is where no sunscreen was applied, the right side is where sunscreen was applied, that is why the left side is brighter than the right side.

This proves the assumption made by the team which was about the possibility of detecting the absense of sunscreen using a hyper-spectral camera under adequate lighting combination of UV lights and high-power flood LED lights.

Which makes further development into this concept reasonable.

7 Finance (Yusuf)

The spending in inno.light could be summarized in two main categories – travel expenses and prototype related purchases.

7.1 Travel expenses

Traveling expenses happened in the following order, HAMK Design Factory traveling to Mannheim Design Factory.

Afterwards, the entire team traveled to Spain, Barcelona to meet the sponsor where the team got to meet and interview Anna Ferrer (HYLIGHT Project Manager) and Miguel Ares (HYLIGHT Scientific Coordinator).

Finally comes the expenses of travel for the team members from Germany Mannheim to Finland Hämeenlinna and participate in the preparations for the Final gala.

The cost goes as follows:

Trip name	Cost in €
Travel from HAMK to Mannheim design factory	2464,62
Travel to meet the sponsor in Spain	2620.69 (Finland side) + 3265.69 (German side) = 5886.36
Travel from Mannheim to Hämeenlinna to participate in the Final Gala	3225.5

Table 1: Financing for inno.light's trips

7.2 Cost of the prototype

In order to build the prototype and prove the concept of the team objective the team had to purchase the components required to make the camera.

The total cost of the items reached 2853.436 €.

In total the spent amount of the team is 14429.94 €.

8 Business plan for inno.light's Sunscreen Check (Yusuf)

The product was intentionally designed in a way to help people to prevent skin damage and skin cancer caused by sun exposure. For that reason, the final prototype may not contain all the elements for a business setup.

The initial idea was to keep the device around the beach where people are exposed to the sun. The team could collaborate with the local hotels and restaurants operated near the beach areas so that their customers could also benefit from a Sunscreen Check.

The second option is the possibility to collaborate with the local government to place the sunscreen check booths on different public areas near paths many people walk by, playgrounds, or hiking trails. The booths could play a big role in decreasing skin cancer and other skin diseases and create awareness.

Future plans could also include a premium subscription-based feature. There could be a mobile application which shows the different locations of sunscreen checks, transfers all the data collected by the device to your mobile application and provides much more refined data using weather data, information about UV radiation in your environment and the health of your skin.

9 Future development (everyone)

For future development a better and more reliable hyperspectral imaging camera must be acquired, in addition to that a more consistent testing environment should be created, as in having more control over the lighting of the testing room and create a repeatable testing process, different types of commercially sunscreen products should be tested.

A process that would help identify the results would be a necessity before releasing the product to the market, training an AI to identify the common patterns displayed by skin when no sunscreen in applied would be beneficial, especially when dealing with people from who have different amounts of melanin in their skin.

All what was mentioned above could be achieved through time and financial investments, but pushing the product into the market would require dealing with regulations and acquiring the trust of the public.

10 Learning outcome (everyone)

Working with people from different backgrounds, both ethnic and professional backgrounds is more than possible, but it would not go as smooth as one would expect it to be, working with people who come from different work ethics does require a different way of handling tasks and supervision, the way that worked with our team was that every person selects the task they feel confident with and have no deadline, most of the time the task gets checked up by the team on the next team meeting.

As for the technology, acquiring the parts for the DIY-prototype of the HSI camera was the most challenging, as many different suppliers offer similar products but finding the adequate product with a reasonable delivery time took a little bit more time than estimated at the beginning of the task.

Our team succeeded in dividing tasks and producing deliverables in good quality over the given time, all the team members had their own schedules, but everyone got to produce a deliverable of a quality the team would be proud of.

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12 Figures directory

Appendix 1: guide on operating the HSI camera prototype

How to operate the prototype of HIS camera:

One should have an operating system that operates on Linux, in my case a Ubuntu running on Power shell worked fine, I suggest you find a VIM which allows you to have a interactable graphical user interface.

Once that is done one should follow the following instructions https://osf.io/4z5s6

The camera is calibrated, one must apply the calibration file by extracting the zipped file and replacing the already existing files with the calibrated ones.

The mode of 8MP must be selected, the pictures are acquirable through the following button.

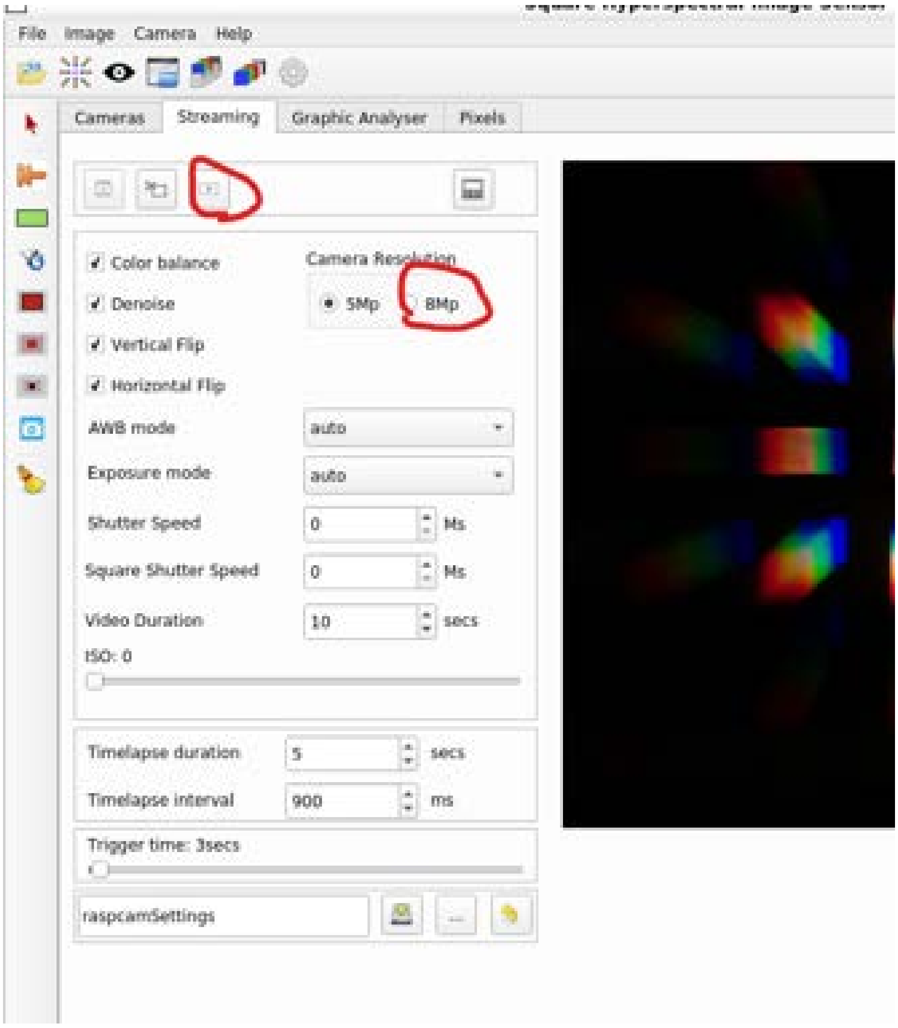

Figure 36: Operating HSI prototype (1)

Then one should select the wavelengths through the following button.

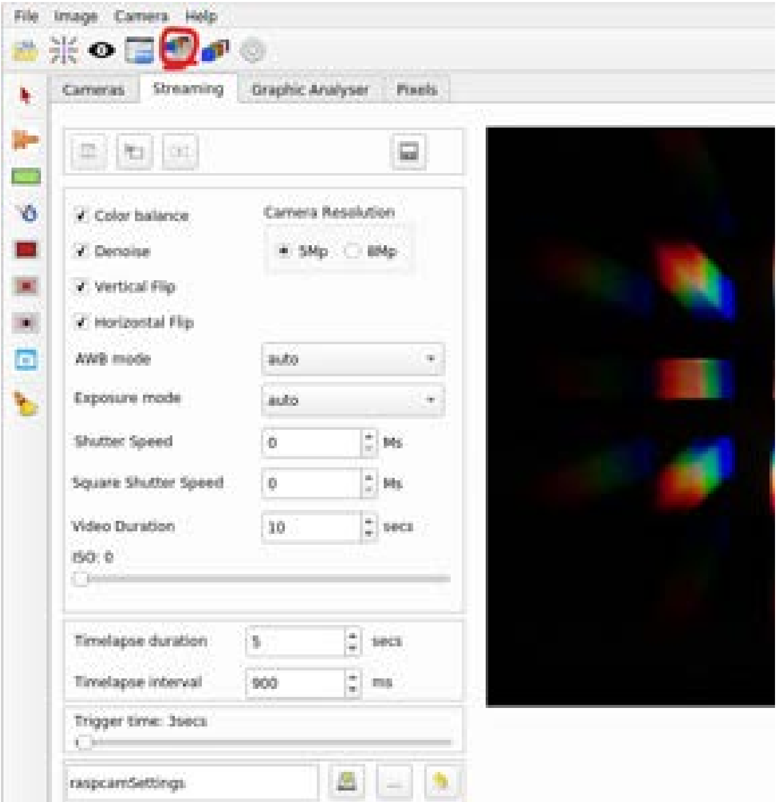

Figure 37: Operating HSI prototype (2)

The result should look like this.

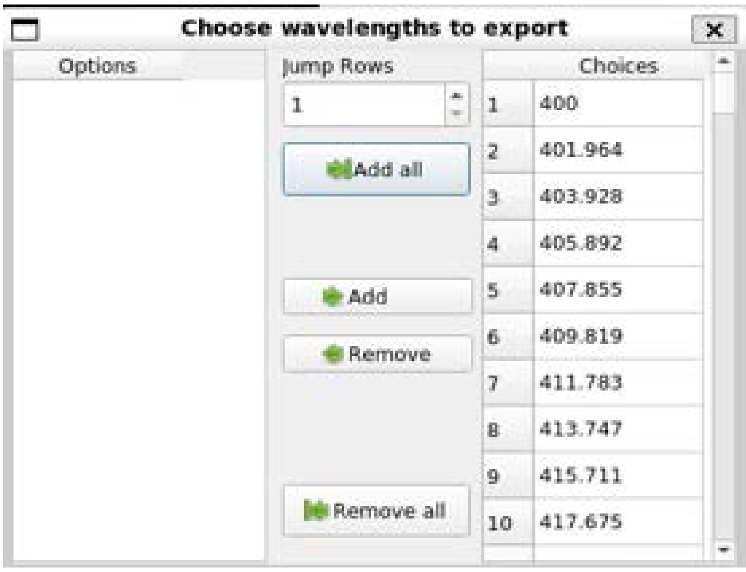

Figure 38: Operating HSI prototype (3)

Lastly the following button should be pressed.

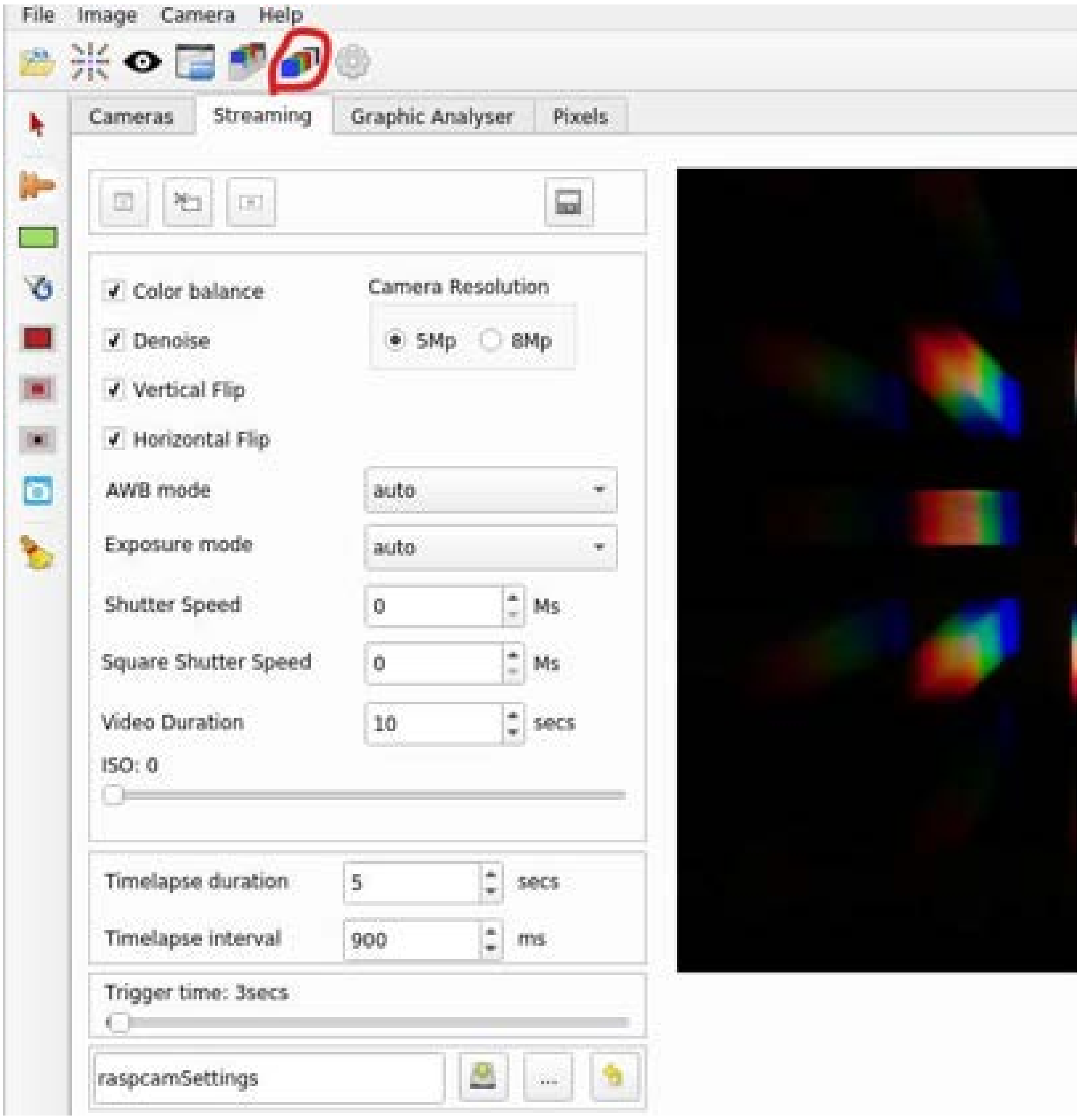

Figure 39: Operating HSI prototype (4)

With that the user would end up with results under the tab of pixels, the user is advised to experiment with the amplify scalar value which could result in a clearer contrast in the results. In order to connect to the camera, one should connect to the Wi-Fi broadcasted by the camera, it is called (the camera), its password is 200200200.