SPECTR³

TEAM SPECTRE

Forestry Applications of Hyperspectral Imaging

ATTRACT SP-1 BASE – International Product Development Project

Year 2024

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Forestry Applications of Hyperspectral Imaging | Abstract
Year 2024

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In today’s forestry industry, timber inspection often relies on visual assessments, which can vary in effectiveness due to different levels of expertise. To advance this process, we need a solution that offers reliability, certainty, and efficiency. This project, in collaboration with H-cube, a research organization, focuses on developing a Terahertz (THz) Hyperspectral camera. This device captures images using the terahertz radiation range of the electromagnetic spectrum, providing detailed information not visible with regular cameras.

The objective of this project was to identify an innovative, suitable, and feasible application for this technology in the market. Utilizing a design thinking process, we developed prototypes and eventually created a forestry scanner tool as the final product. The device is designed to attach to forestry harvesters and scan each tree, collect data and sort harvested material within different qualities.

Limited testing showed promising results which indicates a potential for this technology to revolutionize timber management. By ensuring only the highest quality timber moves forward, we can enhance productivity and support sustainable forestry. This approach combines precision with ecological responsibility. It also promotes a healthier forest ecosystem, improves the wood industry’s efficiency, and maximizes the use of our precious resources.

Keywords H-Cube, Attract project, Terahertz Hyperspectral imaging, Forestry Harvester, Log Scanner.
Pages 40

inno.space DESIGN FACTORY MANNHEIM
HAMK Design Factory
h-cube

Use of Artificial Intelligence

Artificial Intelligence (AI) was utilized in this report as a writing aid. Specifically, the AI tool ChatGPT by OpenAI was employed to assist in gathering information and drafting initial text. All AI-generated content underwent thorough review and editing to ensure accuracy and alignment with the projects data and findings.

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1 Introduction

Forest depletion is an ongoing issue that results in a loss of 10 million hectares of forest each year. (FAO, 2020, p. 4). Finding sustainable ways to meet demands can be attained by improving on the methods and techniques used in forestry, which can ultimately reduce the impact deforestation has in relation to forest depletion. The team came up with a product solution, that can classify wood quality, enhance both industry processes and the ecosystem of the deforested areas. By collecting and analysing data from each individual tree, our products can determine optimal locations for planting specific species of trees and for their purposes.

This study was part of an ATTRACT-project, which is an European initiative aimed at boosting innovation and incentivizing research into new technologies. The project was organized by two institutions: HAMK-Design Factory in Hämeenlinna, Finland and Innospace Design Factory in Mannheim, Germany. The course consisted of international teams, each comprising of six members from different academic programmes who collaborated to enhance creativity through a blend of knowledge and culture.

Each team was paired with a startup company and the Spectre team was paired to collaborate with H-cube, a research organization developing a Terahertz Hyperspectral camera. This device captures images using the terahertz (THz) radiation range of the electromagnetic spectrum, providing detailed information not visible with regular cameras. H-cube aims to develop a competitive, affordable product with broad applications.

The objective of this project was to identify an innovative, suitable, and feasible market application for the THz Hyperspectral camera, particularly in areas where similar technologies are not yet implemented. To achieve this goal, a design thinking process was undertaken. Several ideas and prototypes were considered, leading to the development of a forestry scanner tool. The solution is designed to be attached to a forestry harvester, scanning each tree, and collecting data to sort the harvested material into different quality categories.

This report is intended for supervisors, clients, and stakeholders, providing a comprehensive overview of the project's development, outcome and possible further developments.

1.1 Team

The International Product Development Project (iPdP) is designed to bring together international students to collaborate on a project provided by ATTRACT. The team comprised members from both Germany and Finland, representing a mix of cultures, disciplines, and perspectives.

1.1.1 Formation and Early Challenges

The initial phase of our project was marked by significant challenges. During the first two weeks, the German team members had to leave for various reasons, causing confusion and delays as the team tried to understand its tasks and the technology provided. To fill the gap, an additional student was enrolled, but ultimately, the team was left with only the Finnish side.

After two restless weeks, the official team was finally formed, consisting of three members from HAMK University of Applied Sciences in Finland. This period of adjustment and reformation was difficult, but it set a foundation for the team dynamics.

1.1.2 Team Composition

Our team, though composed solely of students from Finland, brought together diverse backgrounds and mindsets. All three members are part of international degree programs, contributing to a rich blend of cultural perspectives that enhanced creativity, particularly during the ideation process.

Claudio is from Italy and is completing his Mechanical Engineering degree at HAMK in Riihimäki. His technical expertise and problem-solving skills were invaluable assets to the team.

Hammadi is from Tunisia and is studying Construction Engineering at HAMK in Hämeenlinna. His background in business management and innovative thinking brought a unique perspective to the project.

Shima is from Iran and is also pursuing a degree in Construction Engineering at HAMK in Hämeenlinna. Her software design skills and attention to detail significantly contributed to our project's development.

Despite their similar academic backgrounds, Claudio, Hammadi, and Shima have distinct mindsets, skills, and values, shaped by their different nationalities and personal experiences. This diversity within the team fostered a collaborative environment where various ideas and approaches were considered and respected.

Figure 1. Team Spectre - from the left: Claudio, Hammadi, Shima

1.1.3 Overcoming Challenges

Team members availability posed significant challenges throughout the project, which occasionally slowed down the progress. Discussions around team-building skills and a commitment to effective teamwork paved the way to resolve some of these issues. Maintaining regular meetings and an open line of communication was crucial in overcoming obstacles and ensuring smooth project development.

1.1.4 Conclusion

The composition of the team and its diverse expertise and commitment to collaboration, laid the foundation for a successful iPdP experience. Despite the challenges, the effective communication and mutual respect enabled us to achieve solid outcomes and leave a lasting impact in the realm of international product development projects.

1.2 Project sponsor

The team had the opportunity to collaborate with H-Cube, a research organization formed by several institutions across Europe, which is developing a hyperspectral camera.

1.2.1 Introduction to H-Cube Technology

H-Cube provides low-cost, portable solution for hyperspectral imaging in the terahertz (THz) range of the electromagnetic spectrum. Their technology broadens the use of THz imaging from expensive, specialized applications like airport body scanners, in-line production quality control, and advanced research tools to more common uses such as crop monitoring, building control, and weapon identification in crowded environments.

Unique Characteristics:

- Cost and Portability: H-Cube's system is more economical than current options and doesn’t require cooling or complicated setups.
- Technical Specs: It uses plasmonic filtering for spectral sensitivity and has no large moving parts. The final prototype will be lightweight, around 150 grams.

- Manufacturing: The production process is simple and cost-effective, allowing for mass production and broader use.

1.2.2 Project Challenges and Team Dynamics

This project experienced some challenges mainly pertaining to team dynamics. The team was tasked with finding a suitable, feasible application without having a clear initial understanding of what the technology could achieve. The technology was very sophisticated and so gaining a full understanding of its nature posed a challenge.

During the brainstorming and ideation phase, various potential applications were discussed, including:

- Medical applications as body scanners
- Agricultural applications for monitoring disease, pests, and treatment effectiveness
- Air quality control
- Food packaging inspection
- Structural inspection
- Waste sorting

Filtering these ideas to select the most viable solution was challenging due to the lack of experience in hyperspectral imaging.

1.2.3 Sponsor Interaction and Field Visit

To better understand the technology and refine the project, a few meetings were held with the sponsor, H-Cube. These meetings provided valuable feedback and helped clarify the team's understanding. A pivotal moment in the project was a visit to the Research Center for Non-Destructive Testing in Linz, Austria. Here the team met with Elisabeth, a specialist who provided comprehensive lectures, tips, and facilitated some testing with wood samples. This visit significantly enhanced the development process, offering practical insights and solidifying the project's direction, ultimately leading to a successful outcome.

1.2.4 Conclusion

Despite initial hurdles, the team was able to overcome challenges and along with the help of the H-Cube developers, the team was able to navigate the complexities of hyperspectral imaging technology. The diverse perspectives and relentless drive to understand technology allowed the development of a meaningful solution. The subsequent sections of this report will delve into the ideation process, the evolution of the product concept, and the strategic decisions that brought the vision to life.

2 Theoretical background

In this chapter, the key aspects of the report will be defined, and the approaches will be explained. The goal is to provide a comprehensive understanding of the topics discussed in the report.

2.1 Design Thinking Process

Design thinking is a human-cantered approach to innovation. It uses methods from design to meet people's needs with the possibilities of technology and business requirements. The process involves five stages:

1. Empathize**:** Understand the users' needs through observation and interaction.
2. Define**:** Clearly state the problem that needs solving.
3. Ideate**:** Generate a variety of ideas and solutions.
4. Prototype**:** Create simple models of a few ideas.
5. Test**:** Try out the prototypes to improve the solutions.

(Rikke Friis Dam, 2024)

In the Define stage, “How might we” (HMW) process was implemented to pinpoint the core issues within the project scope. This technique involved framing problems as questions that start with "How might we," which opened up possibilities for innovative solutions and encouraged a positive, solution-oriented mindset.

The design thinking process was crucial in the team's project. It helped to move through cycles of coming up with ideas, creating prototypes, and testing them to develop a workable product concept.

2.2 Hyperspectral Imaging

Hyperspectral Imaging (HSI): HSI involves capturing and processing information from across the electromagnetic spectrum. Unlike regular cameras that capture images in three colour bands (red, green, and blue), HSI captures images in many more bands, often extending beyond the visible spectrum. This technology allows for the capture of a complete spectrum at each pixel, providing detailed information about the composition of the observed material.

Modes of Operation:

- Reflection Imaging: Captures light reflected from the surface of an object. It is used for analysing surface properties and identifying materials.
- Transmittal Imaging: Captures light that passes through a material. It is useful for examining the internal structure or composition.

Some key applications already present on the market include:

- Agriculture: Monitoring crop health, detecting diseases, and assessing soil composition.
- Medical Diagnostics: Non-invasive analysis of tissues and early disease detection.
- Environmental Monitoring: Checking water quality and detecting pollutants.
- Security: Identifying hidden objects or substances through their spectral signatures.

(Y. Mao, 2022, pp. 1-3, 10-12)

2.3 Conclusion

The theoretical background provided in this chapter lays the foundation for understanding the design thinking process and hyperspectral imaging technology.

3 Project Development Journey

This chapter delves into the main stages of the project and the steps involved in the design thinking process. It covers the recruitment process, key events such as the Bootcamp and the Final Gala, and the application of the Double Diamond structure, which guided the team through several iteration of the phases Empathize, Define, Ideate, Prototype, and Testing.

3.1 Recruitment Process

In January and February 2024, the recruitment process for the project took place. The course, separate from the main degree programs offered by HAMK, was open to students from all disciplines. Its aim was to foster an interdisciplinary, intercultural, and international atmosphere where each team member could contribute its unique skills and perspectives, thus maximizing the potential for ideation and innovation.

The course was advertised through social media and flyers distributed across the various campuses of the institution. Prospective participants expressed their interest via email, submitting their CVs, and attended interviews with the course lecturers. The selected students were then informed of their acceptance into the program.

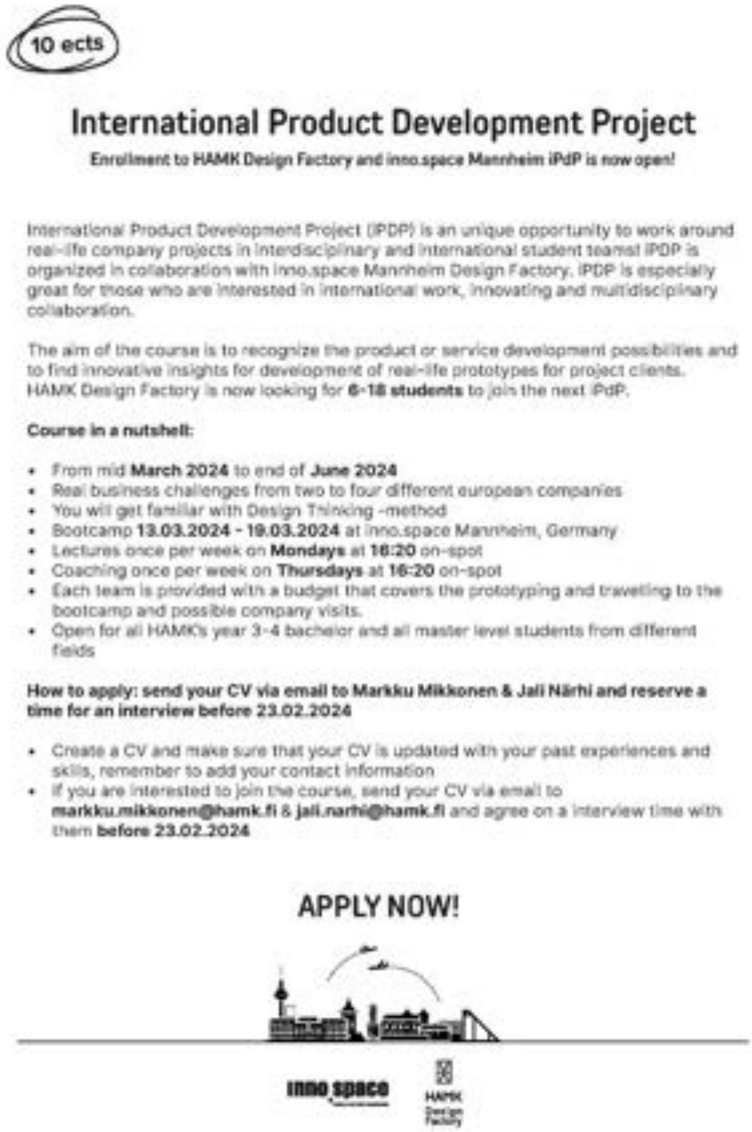

Figure 2. Recruiting Flyer

3.2 Key Events

Two main events were central to the project: the Bootcamp and the Final Gala. These events marked the beginning and the end of the project, respectively. For these occasions, all Finnish and German students met at a single location. At the start, the Finnish students travelled to Mannheim, Germany, to work at the Innospace Design Factory. At the end of the project, the German students travelled to Hämeenlinna, Finland, to the HAMK Design Factory.

In between these events, online lectures and coaching sessions were held weekly on Mondays and Thursdays. Additionally, midway through the project, there was an event called the Half-way Gala, where developing ideas were presented, and a Sponsor Visit trip, during which teams got to know the startup and its technology firsthand.

3.3 Double Diamond Structure

The project followed the Double Diamond structure, encompassing the iterations of the design thinking process: Empathize, Define, Ideate, Prototype, and Test.

The first diamond defined the initial phase from the Bootcamp to the Halfway Gala, where the team engaged in research, brainstorming, ideation, and prototyping. The second diamond represents the subsequent phase, where the team focused on a single idea, developing it into a final solution and prototype to present at the Final Gala.

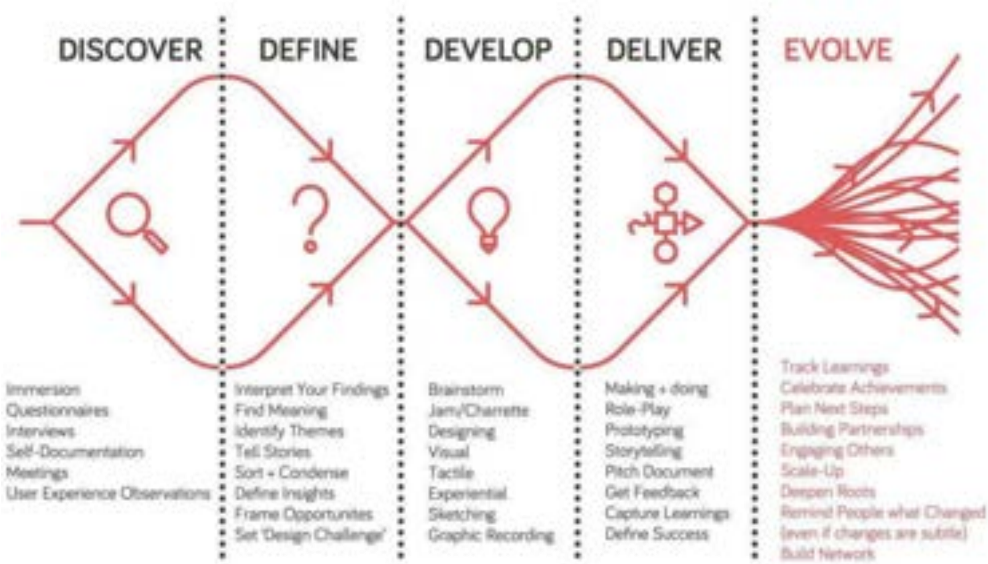

Figure 3. Double Diamond – Design Thinking Process

3.4 Bootcamp

The project kicked off with a Bootcamp in Mannheim at the Innospace Design Factory. Here, the teams were formed and paired with the start-up companies (sponsors) and their developing technologies. The lecturers emphasized diversity in team formation, assigning students based on their preferences. The team documented in this report was paired with H-Cube, a start-up developing a hyperspectral camera. Each team comprised six members: three Finnish students and three German students. The challenge was to explore the applicability of H-Cube's technology in different fields and application beyond its current scope.

During the one-week Bootcamp, the team began their collaborative efforts. Tasks included researching the technology, defining a team name, brainstorming ideas, and developing initial low-fidelity prototypes to present their concepts. An initial online meeting with the sponsor, H-Cube, introduced the team to the technology and provided answers to their questions. The Bootcamp was crucial for team bonding and establishing a strong team structure, laying a clear foundation and motivation for the project.

Games and social activities, such as building a Rube Goldberg machine, were organized to enhance team cohesion. Additionally, dinners featuring pizza and Chinese food were offered, further fostering a collaborative and enjoyable atmosphere.

During the Bootcamp, the team experienced some changes when one member had to be replaced due to personal reasons. This adjustment was challenging and slightly disrupted the team's dynamics. In the following weeks, the team faced more sudden changes that further disrupted the dynamic, making the development process even more challenging. These unexpected shifts required the team to adapt quickly and find new ways to maintain cohesion and productivity.

Figure 5. Team Spectre - Group Picture 1

Figure 4. Team Spectre - Group Picture 2

3.4.1 Team name and logo

The team chose the name "Spectre," inspired by the terms "Spectral," "Hyperspectral camera," and "Electromagnetic Spectrum." The number "3" in the logo references the cube in "H-Cube". A logo was developed with the expertise of an artistic designer team member, adding a professional touch to the design. Figure 6 illustrates the different logo designs considered, while Figure 7 shows the final chosen team logo. Team T-shirts were also created, featuring the laser-cut logo and other design elements glued onto black T-shirts, as shown in Figures 4 and 5.

Figure 6. Designing of team logo

Figure 7. Team logo

3.4.2 Researching, Ideating and Prototyping

During the Bootcamp, the team delved into the basics of the sponsor's technology, drawing information from various sources, including online resources, sponsor meeting, and provided materials. The technology, recognized as having high potential, presented several key features:

- Enhanced Vision: The technology can reveal details invisible to the naked eye and regular cameras.
- Safety: Operating in the terahertz range, it is similar to X-ray technology but safer, as it is not harmful to bio-organisms.
- Versatile Imaging: The hyperspectral camera can function in both reflection and transmission modes, allowing it to scan either the surface or the interior of an object. The mode used depends mainly on the source.
  - In Reflection Mode, the source can be unnecessary because terahertz radiation reflects off surfaces before being captured by a sensor, similarly to visible light.
  - In transmission Mode, a source sends terahertz radiation from the opposite side of the material to be scanned, and the unfiltered radiation is then captured by the sensor.
- Market-Ready: H-Cube is developing a reliable, affordable, portable product tailored to market needs, focusing primarily on implementing the product in transmission mode.

Armed with this foundational knowledge about hyperspectral imaging and its current main applications, the team began brainstorming potential ideas. Given the limited knowledge available, any idea was good considering and anything could have a potential. Here is a list of the brainstorming ideas:

- Drug Testing
- Cancer Detection/Blood Inspection (Medical Sector)
- Pipeline Inspection
- Timber Quality Assessment (Detection of Rot, Cracks, Bugs)
- Insulation Inspection
- Gear Inspection (Fractured Tooth Detection)
- Water Contaminant Inspection
- Historical Monument Inspection (e.g., 3D Scan of Notre Dame)
- Recycling (Material Separation)
- Caloric Content in Food
- Air Quality Monitoring

- Mold/Moisture Detection

To further explore these ideas, the team created several low-fidelity prototypes to illustrate their concepts. Figure 8 shows two prototypes: on the left is a wall scanner for historical buildings to detect potential damages, and on the right is a body scanner designed for cancer detection. Figure 9 depicts a common smartwatch equipped with hyperspectral technology to provide detailed and accurate information about blood composition and quality.

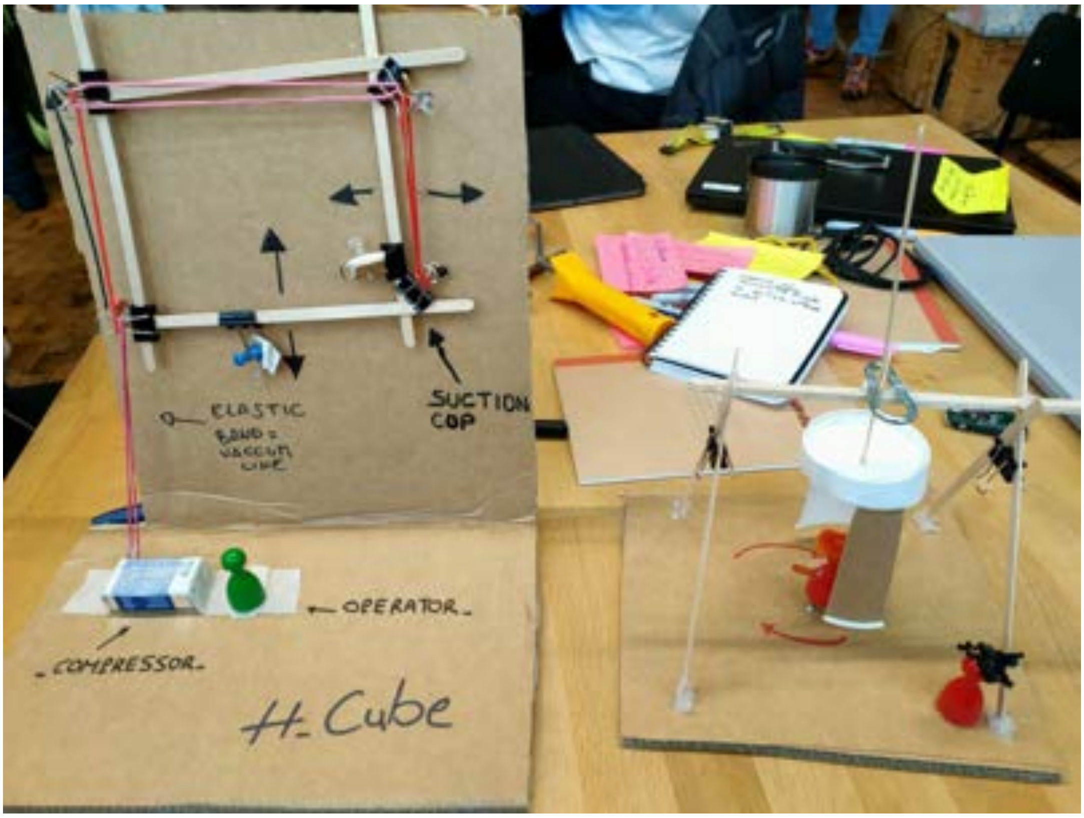

Figure 8. Low-fidelity prototypes

Figure 9. Low-fidelity prototypes (Hyperspectral smartwatch - Glucose Measuring)

3.5 First Diamond: Problem Space

During the first half of the project, the team concentrated on the Discover and Define phases. They brainstormed potential applications and conducted interviews to gather valuable insights. Iterating through the design thinking process multiple times, they discussed and filtered various ideas and prototypes. This phase saw the team composition solidify, now consisting solely of Finnish students as the German students were no longer part of the team. Although unexpected and challenging, this change provided a fresh start for the project.

The remaining small team, composed of three engineering students, decided to focus on fields where each member had experience and passion, aiming to enhance the project's outcome. Several interviews were conducted across different fields, including agriculture, medicine, and fitness, to explore various applications of the technology. Personas were created based on the collected data and interview results to identify and prioritize user needs.

Three prototypes emerged from the ideas developed in this first phase and were presented at the Halfway Gala: a medical/body scanner, a structure scanner, and a forestry scanner.

3.5.1 Interview Summary: Agostino "Farmer"

Interviewee: Agostino, a farmer from Trento, Italy.

Current Method of Examining Grape Quality: Agostino tests grape quality close to the harvest time by randomly sampling grapes, smashing them to extract juice, and using a hydrometer to measure sugar content, which indicates grape maturity. The cooperative society sets acceptable sugar content ranges.

Frequency of Grape Testing: Typically, testing starts three weeks before harvest, initially weekly, increasing to every two days closer to the harvest date.

Feasibility of the Proposed Product: Agostino believes the product is feasible if reasonably priced and ease of field use is emphasized as a crucial feature. It could particularly benefit larger farms by allowing faster and easier examination of larger vineyard areas.

Additional Potential Applications: The product could inspect vine and apple tree leaves for diseases and pests, as well as monitor beneficial insects. While late-stage disease detection might be less useful, end-of-season checks for intervention effectiveness and general insect monitoring could be valuable.

Additional Comments:

- Agostino highlighted the importance of ease of field use for any new tool.
- He mentioned the existence of an optical hydrometer for direct sugar content readings from a single drop of must.

3.5.2 Interview Summary: Perttu "Forestry student"

Interviewee: Perttu, a Forestry degree student from Hamk Evo.

Context and Current Practices: Perttu noted that Finnish forestry relies on visual tree inspections due to the ease of identifying local species. In contrast, the diverse species and complex forestry methods in Central Europe make visual inspections more challenging.

Potential Benefits and Limitations: Perttu expressed doubt about the application's immediate need in Finland since post-harvest inspections already occur at sawmills. Nevertheless, he acknowledged that selecting different tree qualities before transport has significant potential. He agreed that leaving low-quality trees in the forest would enhance the ecosystem and improve transport efficiency.

Quality and Ecosystem Considerations: Perttu mentioned that up to 20% of trees in areas affected by root rot or bark beetles might be of poor quality. He supported leaving these suboptimal trees in the forest to boost ecosystem health.

Final Thoughts: Perttu found the ideas discussed valuable and relevant. While the application may not meet all current needs in Finland, it shows promise for broader use in various forestry environments.

3.6 Half-Way Gala

The Half-Way Gala served as a checkpoint for sponsors, lecturers, and teams. The team presented three developed ideas and their corresponding prototypes, receiving valuable feedback to guide further development.

Figure 10. Half-Way Gala Presentation

3.6.1 Prototype 1: Body scanner

The first prototype resembles a body scanner. Similar to the prototype developed during the boot camp, this device is designed to scan the human body to detect diseases, such as identifying tumours.

However, it was deemed unfeasible by the sponsor experts during the presentation event. They noted that the high-water content in the human body would obstruct the terahertz (THz) radiation required for effective scanning.

Figure 11. Body scanner

3.6.2 Prototype 2: Structures scanner

The second prototype was designed to inspect structures like bridges, detecting internal rot, cracks, and corrosion in various components. The device was planned as an attachment for cranes or robotic arms. In addition to providing internal information on different elements, this solution aimed to replace humans in hazardous tasks, such as working at heights. However, this idea did not gain full approval from the experts. Although the reasoning was not entirely clear at the time, the feedback suggested that the technology was not well-suited for this purpose since fractures and moisture penetration are typically visible from the outside.

3.6.3 Prototype 3: Forestry scanner

The third prototype was a handheld tree scanner designed for use in the forestry and wood industry. It is user-friendly, requiring neither heavy machinery nor extensive expertise. The scanner effectively identifies defects such as rot, cracks, and insect damage, and categorizes wood by quality. This would enhance inspections, streamline harvesting operations, and improve efficiency in the transportation and processing of harvested material. The idea was well-received by H-Cube experts, who engaged in an extensive discussion about its potential. However, some limitations were also noted: being handheld, the device can only scan up to a certain height and is obstructed by branches. Additionally, moisture content was identified as a significant issue, as terahertz (THz) radiation is highly absorbed by moisture.

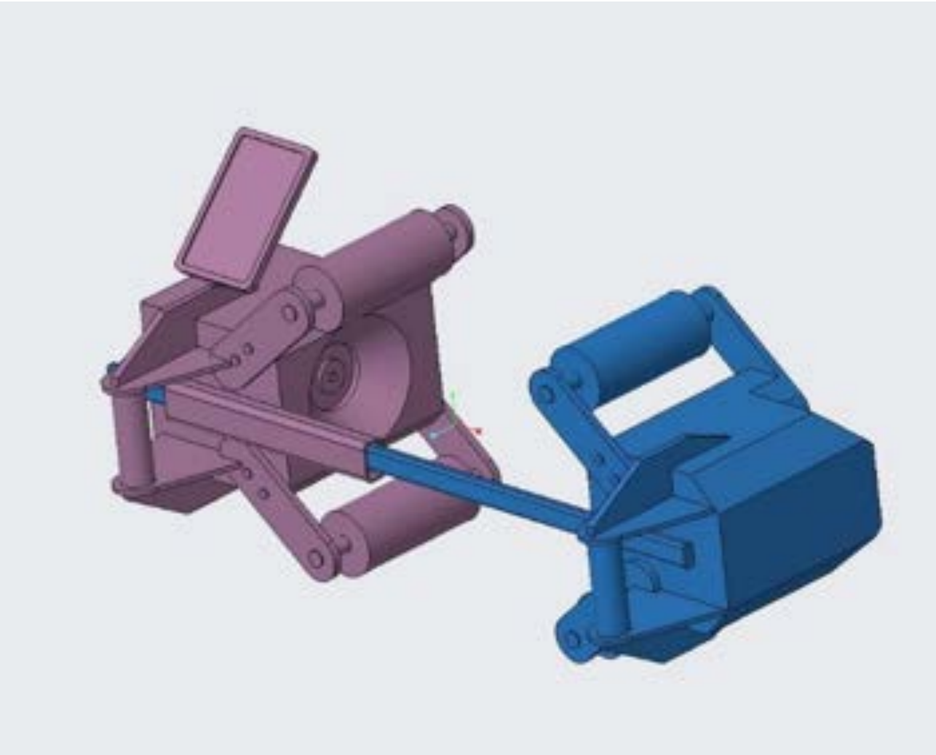

Figure 12. Tree scanner

3.7 Second Diamond: Solution Space

In the second half of the project, the team focused on developing and delivering the final solution. They selected the most suitable idea from the initial three and refined it. It was decided to proceed with the timber scanner which seemed the idea with highest potential. Another interview was held for this idea. A sawmill worker was interview and he gave good insight sawmills operations. He explained the processes in short. Many steps and inspections need to be done and he proposed that the technology could maybe do all inspections in one reducing the steps required. The team also had the opportunity to visit the sponsor's location, gaining valuable information and feedback.

3.7.1 Sponsor visit

During the last weekend of May, the team visited the Research Centre for Non-Destructive Testing in Linz, Austria. Elisabeth warmly welcomed the team and provided an in-depth overview of hyperspectral technology and the various testing methods undertaken in the Research Centre. Following, she gave a tour of the different labs, where are involved also numerous other projects and startups.

On the second day, after discussing the team's developing idea, Elisabeth proposed conducting some tests. The team collected wood samples from a nearby forest and set up a terahertz source and hyperspectral camera to evaluate the technology's effectiveness. The results were challenging to interpret, reflecting the early stage of the technology development. Despite the difficulties, some results were collected, and the tests provided valuable insights into the impact of moisture content and material thickness on hyperspectral imaging.

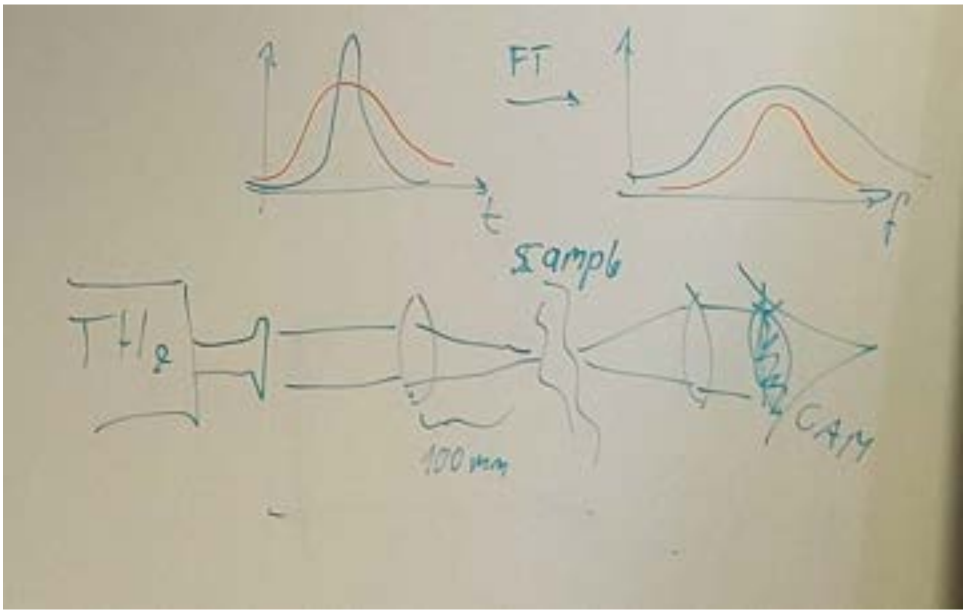

Figure 13. Witheboard skecht of the set up

Elisabeth demonstrated the correct setup installation. In figure 13, on the left, the radiation is emitted by the source. A lens is positioned to focus the radiations on the desired location on the sample. A second lens directs the radiation towards the sensor/camera.

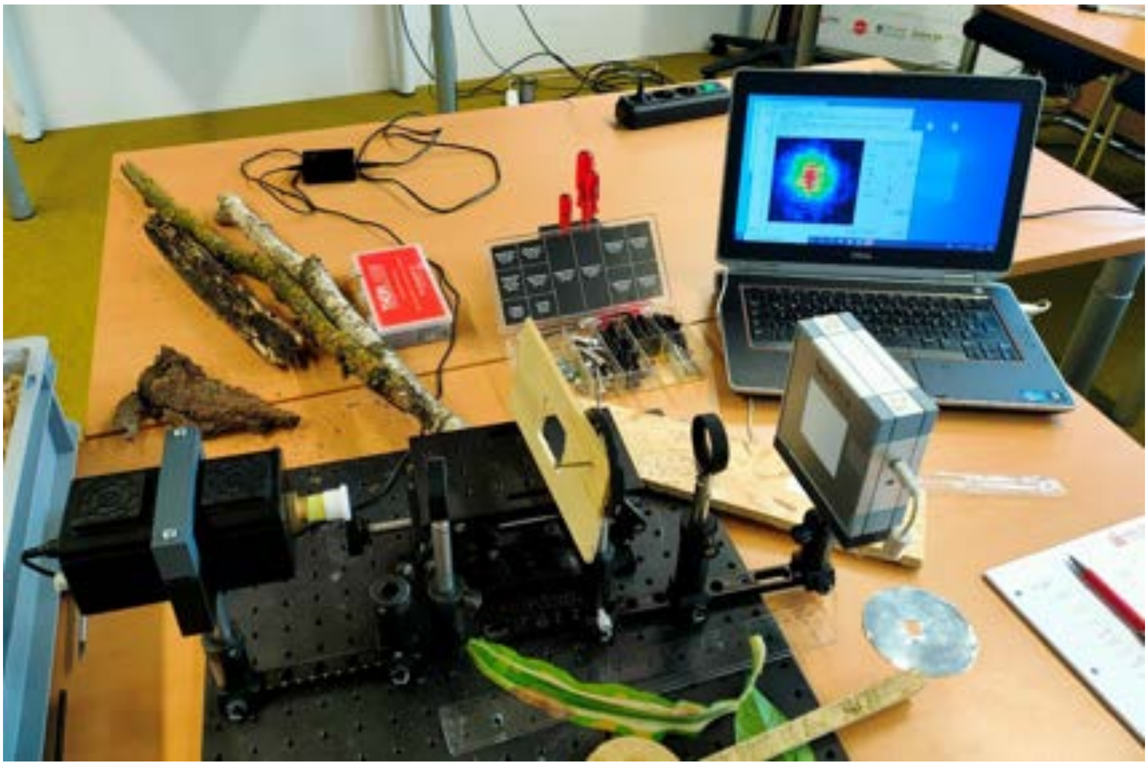

Figure 14. Hyperspectral camera set up

Figure 15. Group picture with Elisabeth

3.8 Final Gala

The final week of the project brought together all students from Finland and Germany in Hämeenlinna, Finland. This week focused on preparing for the Final Gala, where each team showcased their solution at a presentation booth, allowing visitors to interact with the teams and explore their innovations.

During this time, the team built its booth and designed and assembled a prototype for display. The Gala aimed to welcome sponsors, lecturers, participants, and outsiders attracted through flyers, social media, and other communication channels.

Additionally, the team created two posters and a short teaser video to complement their presentation. Below are a few images from the final week and the event.

Figure 16. iPdP Gala Poster

Figure 18. Team picture by the Final Gala Booth

Figure 17. Final Gala Booth - Final Prototype, Team and Product Posters, additional gadgets

4 Solution

This chapter discusses the final solution and the development of the final prototype. Following multiple iterations of the International Product Development Project, the team presented its final solution at the "Final Gala" event.

The final solution is a device designed to scan timber during the forest harvesting process, offering several benefits to the wood industry without disrupting the harvesting workflow. This innovative approach promises to enhance efficiency, improve quality control, and support sustainable forestry practices.

4.1 Overview of the solution - Final Prototype

4.1.1 Problem Statement

Two main issues the team's product addresses are forest depletion and dependency on expertise. Forest depletion is a significant concern, causing the loss of millions of hectares of forest annually. (FAO, 2020, p. 4). To mitigate this, it is crucial to adopt sustainable forestry practices that reduce the impact of deforestation. Traditional visual timber inspections are often inconsistent due to varying expertise levels, resulting in inefficiency and unreliability. Therefore, there is a clear need for a more precise and efficient method to assess and manage timber quality.

4.1.2 Solution Concept

In collaboration with H-Cube, the team developed a Terahertz (THz) Hyperspectral camera. This advanced device captures detailed images using the terahertz range of the electromagnetic spectrum, revealing information not detectable with standard cameras. The team designed this camera to be mounted on the processor head of a forestry harvester.

A harvester is a forestry machine that cuts a tree at its base. Once the tree falls, rollers move it through the processor to remove branches. During this stage, the developed scanner performs a thorough scan of the tree, gathering valuable data without disrupting the harvesting process. The device categorizes the logs into different quality batches, enhancing transportation efficiency and providing the wood industry pre-sorted logs tailored to their needs. Poor-quality trees can be left in the forest to promote ecological health.

This solution also has the potential to collect extensive data for further analysis, helping determine optimal species, soil types, terrain, and moisture conditions for future planting. This supports more informed forest management practices.

Figure 19. Forestry Harvester toy used at the Final Gala for demostation purposes

4.1.3 Final Prototype

The prototype (Figures 20, 21, 22) built for the event resembles a processor head of a forestry harvesting machine. It consists of several components: the main body, arm attachment, debranching knives, feed rollers, and a cutting saw. The prototype integrates the THz technology with an emitter and sensor on each side of the tool. These are positioned at an angle to operate in transflection mode rather than transmission mode. Transflection mode involves directing THz radiation at an angle, allowing it to pass through the material and reflect back to the sensor. This method captures both transmitted and reflected signals, facilitating easier reading and more comprehensive data collection.

The processor head was constructed with plywood cut into different shapes and assembled with screws, while the components resembling the H-Cube Hyperspectral technology were 3D printed. The various parts were then painted with spray paint in different colours.

Figure 20. Final Prototype – Construction phase

Figure 21. Final Prototype – left side

Figure 22. Final Prototype – front side

4.1.4 Key Features/Benefits

- Advanced THz Imaging: Provides detailed, non-visible data to enhance the accuracy of timber quality assessments.
- Quality Categorization: Sorts logs into different quality batches, improving transportation efficiency and meeting the specific needs of wood industries.
- Operational Efficiency: Integrates seamlessly with forestry harvesters, automating the inspection process and reducing time and labour costs.
- Sustainability: Promotes sustainable forestry by minimizing waste and ensuring the best use of harvested timber, with poor-quality trees left to support ecological health.
- Portability and Ease of Use: Lightweight and easily attachable to existing machinery, facilitating practical use in the field.
- Data-Driven Insights: Collects comprehensive data to inform better forest management decisions and improve overall forest health, aiding in planting planning by determining optimal species, soil types, terrain, and moisture conditions.

4.1.5 Conclusion

The team's solution offers a groundbreaking approach to tackling the challenges of timber inspection and forest depletion. Utilizing advanced THz Hyperspectral imaging technology, it provides a precise, efficient, and sustainable method for timber assessment. This innovation enhances productivity, supports environmental sustainability, and contributes significantly to the forestry industry's efforts to manage resources more effectively.

5 Finance

The team received funding from the ATTRACT project, which was allocated for bootcamp travel, sponsor visits, travel expenses and prototype materials. The sponsor visit in Linz proved to be immensely beneficial for the project. The visit gave a clear path for the developing ideas and prototype.

This section discusses the financial aspects of the project, including travel expenses and costs associated with building the booth and prototypes. The following details provide a breakdown of these costs.

5.1 Travel costs

The bootcamp trip from Helsinki to Mannheim, Germany, took place from 13th March 2024 to 19th March 2024, lasting 7 days and involving the 3 member of the team. The cost, including flights and accommodations, was €2,676.04.

The sponsor visit to Linz, Austria, occurred from 30th May 2024 to 2nd June 2024. This trip lasted 4 days, and the cost, including flights and accommodations, was €2,484.21.

5.2 Prototype Development Costs

In addition to travel expenses, the project incurred costs related to developing the prototype for the final gala presentation. The expenses for materials and resources for prototype development totalled €958.37.

These costs were essential for ensuring the project's success and enabling effective presentation.

Summary of cost

Expense category	Total cost €
Bootcamp trip Mannheim	2676.04 (Travel+Accommodation)
Sponsor visit (Linz)	24542.21 (Travel+Accommodation)
Prototype development	958,37
Total	6118.62

6 Future development

Through the final prototyping process, the team explored various potential future directions for the hyperspectral camera technology, especially in the forestry sector. Although some ideas were not realized due to time and financial constraints, there are several promising avenues for further development.

With additional resources, the team envisions expanding the capabilities of the hyperspectral camera to improve the quality and productivity of wood processing. One significant enhancement would be the ability to analyze the moisture content of wood sheets. By integrating this technology into the plywood manufacturing process, real-time monitoring and control of glue application and humidity levels could be achieved, leading to more consistent and high-quality products.

To achieve these advancements, the plan includes developing an automated scanning system that can be easily integrated into existing production lines. Combined with advanced data analytics and machine learning algorithms, these systems could offer practical insights for streamlining processes, reducing waste, and improving overall efficiency.

7 Learning outcome

Throughout the course and project, the team gained valuable insights and skills that significantly contributed to their personal and professional development.

7.1 Design Thinking Process

One of the most crucial aspects learned was the design thinking process, comprising five phases: empathize, define, ideate, prototype, and test. Each phase involved specific tools and techniques essential for guiding the completion of the project.

7.2 Team Dynamics and Problem-Solving

Initially consisting of six members, the team faced a significant challenge when three members left after the first weeks. Despite the difficulty of managing tasks with a reduced team, this experience proved invaluable for learning teamwork and problem-solving skills. The team addressed these challenges by:

- Flexibility: Adapting quickly to the new team size by redistributing tasks and responsibilities.
- Decision-Making: Developing efficient and cooperative decision-making processes, ensuring all voices were heard.
- Teamwork: Emphasizing open communication and mutual support within the smaller team, leveraging each member’s strengths for effective task completion.

7.3 Coaching and Support

The coaching sessions were instrumental in the team's success. They provided essential guidance and deepened their understanding of the design thinking methodology. The support from the lecturers maintained motivation and facilitated collaboration throughout the project.

7.4 Conclusion

The team successfully navigated all phases of the design thinking process. They developed a functional prototype and created a standalone booth for presentation. This experience enhanced each member’s skills in design thinking, teamwork, and project management.

8 References

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