University of Debrecen

Department of Economics and Business

BSc Thesis

Bioversee: A Pioneer Startup to Develop an Innovative Web Application for Industrial Automation

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2024

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Acknowledgements

I would like to thank Adrian Szilard Nagy, PhD, associate professor of University of Debrecen, Institute of Economics, Non-independent Department of Business Development, for the supervision of my work, as well as the encouragement to write my thesis about my independent idea.

I would like to express my sincere gratitude to my cousin Zsofia Szathmary, PhD from Technical University of Denmark, for her unwavering support and encouragement throughout my project. Her expertise in biotechnology and language skills besides her business acumen were invaluable, and her suggestions were always spot on. It was a true pleasure working with you, Sophie, and I look forward to future collaborations.

I am forever grateful for the kindness and generosity of Professor Zoltan Zeman from the Neumann Janos University, which accompanied me throughout my university years.

I'm especially thankful to a special friend who took the time to teach me the building blocks of web development. His support and guidance were instrumental in bringing Bioversee to fruition. Beyond that, he helped me navigate my future, offering a different point of view that challenged my own. I truly couldn't have done it without you.

I am thankful for Sebastian Grassme for programming suggestions and factual supervision.

I am indebted to my previous supervisor Professor Ida Miklos from University of Debrecen, Department of Genetics and Applied Microbiology for her belief in me.

My family has been the bedrock upon which my academic journey has been built. Their love and support have been the guiding stars, illuminating my path and inspiring me to reach for the stars. I am eternally grateful for their sacrifices and unwavering belief in me.

I would like to express my appreciation to my friends Adam Anderko, Daniel Kiss, Peter Varga and Bence Vincze for their emotional support.

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Abstract

I introduce a thesis of a comprehensive software solution for remote industrial automation control web application built to upgrade aging bioprocess machinery such as bioreactors, as well as to create a modern looking and intuitive bioprocess simulation system for educational purposes. The proposed approach addresses limitations faced by many professionals working within the biotechnology sector. Bioversee software enables real-time monitoring and control of bioreactor parameters from anywhere with internet access, enhancing efficiency and convenience of operation. Leveraging off-the-shelf customizable personal computing platforms and electronic components such as the Raspberry Pi, a tool package and the software offers a cost-effective alternative to proprietary automation systems, promoting sustainability and inclusive access to technology in laboratories. Through design and prototyping, I confirmed the system's compatibility with bioreactor actuators and sensors of varying ages, resolving any further wiring challenges that arose during implementation. I also investigated the business aspect of my developments. In the business development section of this thesis, my research identified a market niche: small-scale laboratories and businesses with limited financial resources prioritize the most economically feasible upgrade of their existing equipment versus the purchase of new and expensive, state-of-the-art machinery. In my thesis, I formulated a business plan aimed at facilitating the potential future distribution of my system. Both the technological and business results underscore the practical value of the innovation, positioning it as a cost-effective, inclusive and sustainable solution for improving bioreactor functionality in diverse settings.

1. Introduction

1.1 Problem Statement

While I was previously writing my bioengineering thesis, which focused on examining the fermentation process of specific yeast strains, I concurrently conducted 18 fermentations. To monitor these processes, I manually measured the weight of my reactors every 6^{th} hour throughout the total fermentation period. To do this, I had to be physically present in the laboratory without the possibility of performing these measurements remotely or automatically, even though theoretically this could have been done.

I found out that most modern companies have bioreactors which can be monitored and controlled remotely. These devices cost exorbitant amounts of money. Additionally, upgrade modules for older devices are also rare and expensive.

I identified some other fields of development, where bioreactors can be programmed to make supervised or unsupervised decisions helped by machine learning models.

Most of the bioreactors that I had access to still rely on physical controllers (e.g., buttons and switches) for setting parameters, and even the ones equipped with touchscreens lack internet connectivity, necessitating close physical proximity for control. This limitation introduces inconvenience and in some cases safety concerns for laboratory personnel. Particularly in small laboratory settings, there is a need for real-time monitoring of the fermentations running in bioreactors, at the users' convenience.

This opens the door to further enhancements, paving the way for a more accessible solution to enhance productivity, especially on aging devices. A cost-effective upgrade would allow more inclusive access, enabling a broader range of laboratories to adopt it. Furthermore, the proposed solution would open the possibility of partnerships between bioreactor manufacturers and users.

From an economic perspective, it is much cheaper to upgrade an older bioreactor with an off-the-shelf customizable personal computer such as Raspberry Pi, making it capable of being controlled remotely, rather than buying an all-new piece of equipment. By extending the lifetime of an older device, a laboratory can be more sustainable and more efficient.

1.2 Motivating Questions

Therefore, the following research questions are investigated in the presented Bachelor of Science thesis:

1. Is it possible to completely control a bioreactor remotely via a web application?
2. Is it feasible to implement this solution using an off-the-shelf available and customizable, inexpensive computing platform such as the Raspberry Pi?
3. Is there a need for this kind of invention on the market?

1.3 Thesis Statement

To address the issues I presented above, I designed Bioversee. Bioversee is the proposed name of both my envisioned, future company and the web application that I invented for bioreactor control. The software utilizes an off-the-shelf customizable personal computer and is engineered to seamlessly integrate with a wide variety of bioreactors, enabling control via a user-friendly web application. In this report, I aim to describe the technological framework of innovation while also outlining a prospective startup business model for product distribution.

1.4 Structure of Thesis

- **Chapter 1: Introduction.**
- **Chapter 2: Background.** I give the reader essentials information about bioreactors and their automation control used, when they are deployed, their use and economic design theories.
- **Chapter 3: Technological Aspect.** I dive into the engineering details, providing a step-by-step breakdown of how I built the solution to the problem I outlined in the Introduction section.
- **Chapter 4: Business Aspect**. I examine the expected market for the product. I design a business model to market the product and create the foundation for the proposed startup company, Bioversee.
- **Chapter 5: Discussion.** I describe the outcomes of the Bioversee web application development and deployment, as well as summarize my business associated plans.
- **Chapter 6: Conclusion.** I evaluate the outcomes of both the technological and business parts of my thesis.
- **Chapter 7: Future Work.** I present ideas for further possible development and research.

2. Background

2.1. Technological Background

2.1.1. Introduction of Bioreactors

A bioreactor (also commonly referred to as a fermenter) is a fundamental piece of equipment in the pharmaceutical, food and biotechnological industries as well as in any other sectors where microbial strains are utilized for the production of different biomolecules and target compounds [1]. These machines create a controllable, biologically active environment, in which microbial organisms grow and produce biochemically active substances (like enzymes) [2].

The organisms inside of a bioreactor have special needs, for example a specific temperature or pH, at which they are the most effective to grow and produce the desired compound [3]. To control the pH in the reactor area a base or acid can be added to the microbial broth. Bioreactors commonly use dual layer chambers. Between the layers water can be circulated and with it, the temperature adjusted [4]. Furthermore, oxygen and nutrients must be provided for optimal cell growth, facilitated by the submerged aerators and the agitation system, respectively. The latter consisting of a kind of rotor [5]. There are also examples of fermenters which use the aerator system to create flow inside [6].

Bioreactors commonly have 4-6 actuators for electric motors (for the rotor, the aerator, the fluid circulation and for acid and base intake) and 2-3 measuring instruments (most often temperature, pH and inlet humidity sensors) to gather information about the status of the reactive environment as demonstrated in *Figure 1*. Additional instruments can be implemented as well, for e.g., for measuring the purity of the air that goes into the aerator or measuring the microbial culture weight throughout the fermentation process.

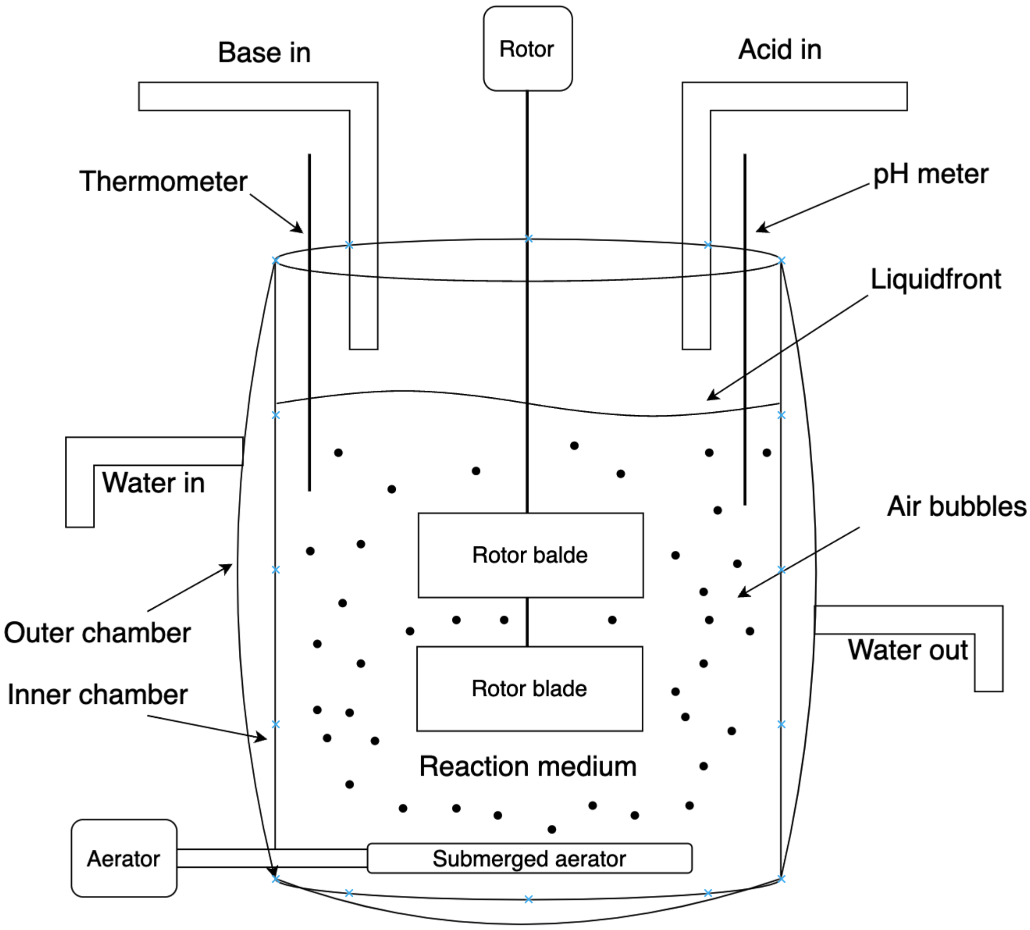

Figure 1: A common bioreactor with the general sensors and actuators

The most common building blocks of a bioreactor are the following:

2.1.1.1. Actuators

Intro sentence:

- Agitation system: The rotor creates a flow in the fluid to provide optimal liquid distribution in the system [7].
- Aerator: The aerator works just like the rotor with a different purpose. The aerator provides oxygen to the organisms. The aerator needs an air pump, it can also be an on/off device or an adjustable setup [8].
- Water pump: This instrument enables to set the necessary temperature. This system circulates water between the 2-wall layer of the reactor. The circulated water is either cold or hot depending on the needs of the microbes. [9]

- Base and acid pipe: To set the required pH of the microbial culture base or acid are added to the system. To do that two pumps are needed, each responsible for adding one liquid [10].

2.1.1.2. Sensors

Intro sentence:

- Thermometer: A thermometer employs a thermistor, which is a temperature-sensitive resistor, that alters its electrical resistance in response to temperature variations, that is then converted into a digital reading. [11].
- pH meter: Digital pH meters measure the voltage generated by the pH probe's electrodes as they interact with hydrogen ions, converting this voltage into a digital pH reading. [12].

2.1.2. Description of Common Ways to Control Bioreactors

Controlling bioreactors encompasses several approaches. While some engineers and scientists still rely on older models featuring manual controllers, the majority opt for more advanced set-ups, however these systems are still frequently unable to connect to the Internet. Below, I provide the most prevalent examples of bioreactor control systems. [13]

2.1.2.1. Programmable Logic Controllers (PLCs)

Programmable Logic Controllers (PLCs) are devices specifically designed to control machines on assembly lines. They are used in conditions where a high level of reliability is needed [14]. In case of an error PLCs provide the possibility for fault process diagnostics. They were designed to replace relays and switches in a wide range of manufacturing processes, giving the user standardized platforms for machine control [15]. PLC hardware is modular, reusable and offers many standardized connection options. PLCs operate on a cyclic and prioritized execution model, offering a stable runtime environment that prevents programming errors from compromising system integrity [15].

In industrial environments, PLCs are frequently utilized for automation and control tasks, such as in bioreactor systems. These tools provide hardware, which is programmed using ladder logic or specialized languages, like Function Block Diagram (FBD) or Structured Text (ST)

[16]. These devices give the user access to real time control and help monitoring features that are crucial for overseeing the processes within bioreactors.

While the core functionality of PLC runtime systems has remained consistent since the 1980s there have been advancements in programming requirements. PLCs now handle a range of control tasks across applications from industrial processing plants to precision motion control systems [15]. They play a role in real time networks within factory environments by linking sensors, actuators, intelligent peripheral devices and other industrial control systems. To adapt to changing demands the PLC community has introduced programming languages specialized to scan cycles and improved hardware capabilities, over time [17].

PLCs offer an organized platform for creating and implementing control logic, focusing on safety, dependability and effectiveness in operations.

The programming approaches for PLCs are regulated by the International Electrotechnical Commission IEC 61131 standard [18]. These programs are typically developed using personal computers. Connectivity options, and integration with PLC programming software are provided by manufacturers [19].

The PLC device software is divided into tasks that are sets of operations carried out in response to certain events. They work on information stored in I/O image tables. PLCs communicate with equipment using this table, handling sensor data inputs and producing outputs for actuators. Data blocks can aid the exchange of information between functions [17].

PLCs communicate with other PLC devices over local networks. These can be categorized by timing patterns such as periodic or sporadic [20]. Achieving synchronization on the device network poses challenges, particularly with fluctuating network delays [21], [22].

2.1.2.2. Supervisory Control and Data Acquisition (SCADA) and Distributed Control Systems (DCS)

Supervisory Control and Data Acquisition (SCADA) systems combine programming languages with ladder logic for PLC programming and scripting languages like VBScript or JavaScript [23]. These are useful for creating user interfaces and implementing custom logics for the actuators [23], [24]. SCADA systems are utilized to oversee and manage processes, working with a variety of manufacturing machines, including bioreactors.

Distributed Control Systems (DCS) systems are like SCADA systems. They are focusing on managing industrial processes with distributed control units. DCS programming languages usually encompass languages for control strategies along with configuration tools to define control loops and system setups [25], [26].

SCADA and DCS systems both have the advantage of giving centralized control and monitoring possibilities for the operators across multiple locations for industrial processes. They use software applications to communicate with PLC or other control devices [27]. These applications run on singular computers or servers.

PLCs often perform better at controlling specific processes, as they are usually more focused on localized control. On the other hand, SCADA and DCS systems are more effective for managing complex and distributed systems. They provide advanced features like real-time data analysis and alarm management, which improve the efficiency of task execution and decision-making in manufacturing operations compared to PLCs. Additionally, both SCADA and DCS can be integrated with enterprise-level systems, facilitating better coordination across different departments. [28].

Despite the advantages of SCADA and DCS systems, they tend to be more complex and costly to design, implement, and maintain compared to PLCs. These systems depend significantly on communication networks for sharing data, which can lead to risks and concerns about system security [29]. This dependence can result in system malfunctions, downtimes and potential crashes in industrial operations.

2.1.2.3. Custom Software Applications

Custom software applications are developed for controlling and monitoring bioreactors. These applications can be developed using a variety of programming languages depending on the requirements, including Python, Java, C#, or C++. These languages offer flexibility and ease of development for implementing complex control algorithms, data analysis, and integration with other systems [30] - [32].

2.2 Business Background

After coming up with the idea of the invention, I started thinking about how to reach the right people with my idea and begin the networking process. It became my goal to establish a company that deals with the development and distribution of the invention. In the business background section of my thesis, I would like to consider the idea of how writing a business plan can benefit my goal as well as prepare a market research to test the validity of my idea, before establishing a company. The market research will be a part of my business plan, however that is planned to happen before the execution of the business plan.

2.1.1. Introduction of the Business Plan

A business plan is a formal document that outlines the goals, strategies, market analysis, financial forecasts, and operational guidelines for a business [33]. For startup companies, it serves as both a roadmap for internal management and a tool for attracting external investment and funding [34]. The importance of a well-crafted business plan is not only to provide a structured approach to realizing the business idea but also to significantly increase the likelihood of success in a highly competitive market [35].

A study by the Harvard Business Review found that companies with a formal business plan are 16% more likely to achieve viability than those without one [36]. Moreover, business plans are essential for securing funding from investors and financial institutions, as they provide a detailed picture of the business's potential and the entrepreneur's preparedness.

2.1.2. Key Components of a Business Plan

In my business plan for Bioversee I would like to include the following topics.

2.1.2.1. Executive Summary

This section provides a concise overview of the business idea, including the mission statement, product or service offering, target market, and financial highlights. It is often considered the most critical part of the business plan as it needs to capture the reader's interest and summarize the entire document effectively [37].

2.1.2.2. Business Description

This section details the nature of the business, its industry, and the market needs to be fulfilled. It includes information about the company's goals, the problem it solves, and its competitive advantages [38].

2.1.2.3. Market Analysis

A thorough market analysis is essential for understanding the industry landscape, target market demographics, and competitive environment. This section should include data on market size, growth trends, and consumer behavior [39].

2.1.2.4. Product Line and Services

This section provides a detailed description of the products or services offered by the business. It should highlight the unique features and benefits that differentiate the offerings from competitors [40].

2.1.2.5. Marketing and Sales Strategy

Here, the plan should articulate the strategies for attracting and retaining customers. This includes the marketing channels, sales tactics, and customer relationship management approaches [41].

2.1.2.6. Organization Structure and Management

This component outlines the business' organizational structure, detailing the roles and responsibilities of the management team. It is crucial for demonstrating the capability and experience of the team driving the business [42].

2.1.2.7. Financial Plan and Projections

Financial projections are critical for assessing the viability of the business. This section includes income statements, cash flow statements, and balance sheets for at least three to five years. It should also address funding requirements and potential return on investment [43].

2.2.1. Market Research

Marketing research is important both for startups and the successful launch of new products. It helps entrepreneurs understand their targeted market, future potential customer preferences, and industry trends, enabling informed decision-making and strategic planning [44]. By conducting thorough market research, startups can identify potential customers, assess market demands, and tailor their offerings to meet specific needs, thus increasing the likelihood of product acceptance and business success[1]. Additionally, competitive analysis through market research allows startups to differentiate themselves by identifying gaps in the market and capitalizing on competitors' weaknesses.

2.2.1.1. Secondary Research

To estimate the success factor of Bioversee we need to examine the current market of bioreactor control programs. These softwares are key tools for optimizing and enhancing the efficiency of biotechnological processes. The aim of this research is to provide a comprehensive overview of the literature related to bioreactor control programs, showcasing current trends, challenges, and innovations in this field. The analysis utilized various scientific sources, including journal articles, books, conference proceedings, and patents.

Literary Sources Possibilities for Market Research:

- Scientific journals such as Journal of Industrial Microbiology and Biotechnology (JIMB)[2], or Processes (MDPI)[3].
- Books and Technical Books like Principles of Fermentation Technology [45] This book discusses in detail the principles of fermentation processes and the design of bioreactors, including control systems.
- International Conference on Bioprocess Engineering is also a great source. The conference presentations and proceedings showcase the latest research results and technological developments in the field of bioreactor control, including new control techniques and software solutions.

[1] https://online.hbs.edu/blog/post/how-to-do-market-research-for-a-startup
[2] https://academic.oup.com/jimb
[3] https://www.mdpi.com/topics/Bioreactor_Control

- Patents and online databases (e.g., Google Patents, PubMed): These sources are useful for learning about new innovations and technological developments in bioreactor control programs.

2.2.1.2. Primary Research

Next to the secondary research I performed the primary research in order to collect first-hand data on bioreactor control application users. This chapter presents the type of planned research, research tools, methodology for selecting respondents, and details of conducting the research.

2.2.1.2.1. Research Type

The research will employ both qualitative and quantitative methods to obtain comprehensive and reliable results on the subject.

1. **Qualitative Research**
    - **Objective:** To provide a deeper understanding of the practical application of bioreactor control software, user experiences, and emerging challenges.
    - **Methods:** Interviews
    - **Sample Size:** 5-10 experts and users
2. **Quantitative Research**
    - **Objective:** To collect statistically valid data on the prevalence, efficiency, and overall satisfaction with control software usage.
    - **Methods:** Survey
    - **Sample Size:** 30-60 respondents

2.2.2.2.2. Research Tools

1. **Interviews**
    - **Format:** Semi-structured interviews, allowing detailed and in-depth responses while ensuring data comparability.
    - **Questions:** Open-ended questions related to the use, advantages, disadvantages, and user experience of the software.
    - **Data Collection Platforms:** Online video conference platforms (e.g., Zoom, Microsoft Teams, Google Meets) and in-person interviews.
2. **Survey**

- **Format:** Structured questionnaire containing closed questions, allowing for simple statistical analyses.
- **Questions:** Likert scales, multiple-choice questions.
- **Data Collection Platforms:** Online survey platforms (e.g., Google Forms).

2.2.2.2.3. Respondent Selection

1. **Interviews**
    - **Selection Criteria:** Experts and users who already use bioreactor control software. Preferably representatives from various industries (e.g., pharmaceuticals, food industry, biotechnology). For Bioversee market research, researchers known personally and working at the University of Debrecen will be preferred.
    - **Methodology:** Snowball method and targeted outreach through professional networks (e.g., LinkedIn, University of Debrecen Biotechnology Institute).
2. **Survey**
    - **Selection Criteria:** Employees of biotechnological companies, researchers, and other relevant professionals.
    - **Methodology:** Random sampling and targeted online advertisements in professional groups.

2.2.2.2.4. Evaluation of Data Collection Methods

1. **Online Data Collection**
    - **Advantages:** Fast and cost-effective, widely accessible, allows for larger sample collection.
    - **Disadvantages:** Less personal, response rates may fluctuate.
2. **In-Person Data Collection**
    - **Advantages:** More in-depth responses, more direct contact with respondents.
    - **Disadvantages:** More time-consuming and costly, limited geographical reach.

2.2.2.2.5. Research Tools

- **Questionnaires:** Structured questionnaires on online platforms to facilitate responses and data collection.
- **Interviews:** Semi-structured interviews that allow deeper insights into user experiences and application practices.

2.2.2.2.6. Data Processing and Analysis

- **Quantitative Data:** Statistical analyses, such as means, standard deviations, and correlations, will be applied to evaluate the responses.
- **Qualitative Data:** Content analysis and thematic analysis will be used to process the information gathered from interviews and focus groups.

2.2.1.3. Analyzing Collected Marketing Data

In the data analysis chapter, I present the methods for analyzing the quantitative data collected during the primary research. The data processing and analysis are conducted using Statistical Package for the Social Sciences (SPSS)[4].SPSS is a widely used statistical software that enables complex data analysis and easy evaluation of results with visual representation.

2.2.1.3.1. Data Preparation

1. **Data Entry:** Inputting data from the online questionnaire into SPSS.
   - **Coding Variables:** For example, if the questionnaire includes respondents' gender, coding 1 for males and 2 for females.
   - **Handling Missing Data:** SPSS provides various methods for handling missing data, such as case deletion or imputation.
2. **Data Cleaning:** Checking data for realism or outliers that could distort the analysis.
   - **Descriptive Statistics:** Summarizing data in the form of means, standard deviations, minimum and maximum values.

2.2.1.3.2. Descriptive Statistical Analysis

1. **Frequency Analysis:** Analyzing respondents demographic characteristics (e.g., age, professional background).
   - **Frequency Tables:** Displaying the distribution of individual variables.
   - **Charts:** Pie charts and bar charts for easier visualization.
2. **Measures of Central Tendency:** Calculating mean, median, and mode for key variables (e.g., user satisfaction, software efficiency).
   - **Mean:** The arithmetic average of the data.
   - **Median:** The middle value of the data.

[4] https://www.ibm.com/products/spss-statistics

- **Mode:** The most frequently occurring value.

2.2.1.3.3. Inferential Statistical Analysis

1. **Correlation Analysis:** Examining the relationship between variables (e.g., the frequency of software use and satisfaction).
    - **Pearson Correlation Coefficient:** Measuring the strength and direction of a linear relationship.
    - **P-value:** Determining statistical significance.
2. **Analysis of Variance (ANOVA):** Investigating if there are significant differences between different groups (e.g., user satisfaction across different industries).
    - **Simple ANOVA:** Examining the effect of one independent variable on a dependent variable.
    - **Post-hoc Tests:** Detailed analysis if ANOVA shows significant differences.
3. **Regression Analysis:** Determining relationships and making predictions (e.g., predicting software efficiency based on user satisfaction).
    - **Linear Regression:** Examining the effect of one variable on another.
    - **Multiple Regression:** Examining the effects of multiple independent variables on a dependent variable.

2.2.1.3.4. Presentation of Results

1. **Tables and Charts:** SPSS provides the capability to visually display results in various graphs and tables.
    - **Boxplots and Histograms:** Visualizing the distribution of variables.
    - **Scatter Plots:** Displaying the results of correlations and regression analyses.
2. **Report Preparation:** Summarizing and interpreting the analyses, including explaining statistical results and answering research questions.

3. Technological Aspect of Project Bioversee

3.1. Software

In the software section I will describe how the software architecture formed over time and how I decided to use the current programming languages. The choice of specific languages was driven by the resources available and the preexisting knowledge of given languages.

3.1.1. Software Architecture Considerations

The original idea was to use Python as the main and only language for software development. By only using one language it would have been easier and faster to create the software. Python has packages for both creating desktop and web applications such as Tkinter or Flask and packages for universal pin control like gpiozero [46]-[48]. Python has serious advantages controlling the GPIO[5] pins on off-the-shelf devices like a Raspberry Pi.

In the past I have used HTML, CSS and JavaScript for web application development. I wanted to them here as well. I hesitated between using Flask or Node server for the web application. After consideration I found out that Flask could potentially hinder further development for several reasons. First it is a synchronous by default and I planned to build async functions. Then another disadvantages of Flask for me is that it's written in python and that way Bioversee web application would have used 2 different languages. An advantage of Node over Flask is that it natively handles JSON, making it easier to work with API calls, science both front- and backend uses JavaScript. In the future I would like to port Bioversee to Android and IOS apps, which is also easier if I decide to use Node.

After examining my choices, I made the decision to combine the two programming languages and approaches. To be able to use JavaScript and Python both where they have their advantages, I separated my software into a web application and a device controller module. The two approaches connect to each other by using the same MongoDB database. There are different methods such as message queue, or web hook, or web socket approach but to ensure process safety and to enable good subsequent inspection possibilities, I decided I create a database

[5] GPIO or general-purpose input output pin is an uncommitted digital signal pin on an integrated circuit.

record about every event on both sides. On the JavaScript-based end, I created event listener functions that control the front-end application. Through REST API[6] calls then I transfer the inputs from the user to the MongoDB database. At the same time, the device controller python codes are listening to the changes in the MongoDB instance and propagates the changes to the actuators. Parallel to this the web application also polls the sensor outputs and shows changes on the frontend.

3.1.2. Software Architecture of Bioversee

3.1.2.1. Web Application Approach

I decided to create Bioversee using a MERN technology stack (not framework). MERN stands for MongoDB, Express.js, React, and Node.js, is a strong approach for web applications due to its full-stack JavaScript usage, promoting a unified development experience [49]. MongoDB provides a flexible NoSQL database that scales easily and handles large volumes of data which will be beneficial later as Bioversee`s customer base grows [50]. Express.js offers a robust and minimalist web framework for backend development. React ensures a highly interactive and efficient front-end experience with its component-based architecture and virtual DOM. Node.js facilitates fast and scalable server-side operations with its event-driven, non-blocking I/O model.

After I created the backend server, and the frontend or client side had to developed at the same time. The backend handles data transition between the client and the database. On *Figure 2* I present the how the independent codes work together and how they communicate with the database. The arrows are showing the way the information between the codes. The “models”, “controllers” and “routes” on *Figure 2* are representing folders, where I create the way for the data to reach the database.

[6] REpresentational State Transfer is an Application Programming Interface, a way for applications to talk to each other using standardized messages over the web.

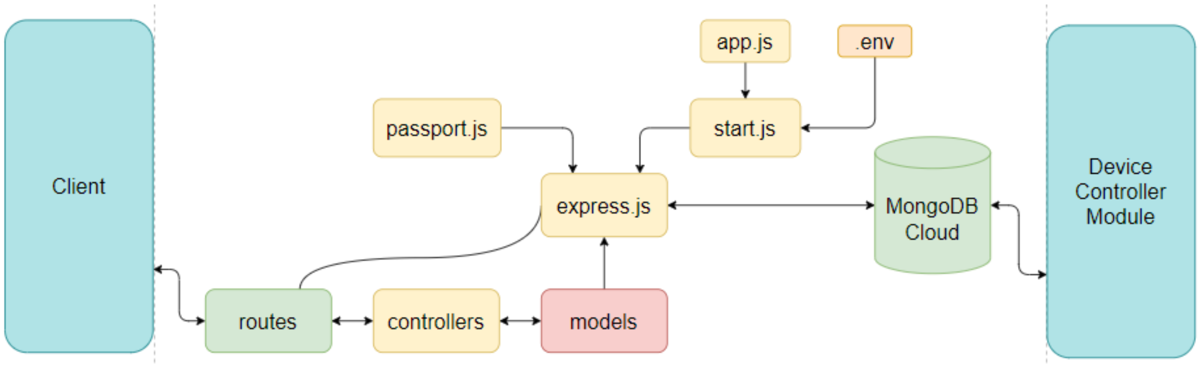

Figure 2: Backend Software Architecture of the Bioversee

For the client side I created a Vite application. Using Vite as a frontend tool in a MERN project brings several advantages. It offers fast development time due to its lean, pre-configured setup and on-demand compilation. It leverages native ES modules in the browser for instant server start and efficient hot module replacement, making development smoother and more responsive. Vite's optimized build process ensures smaller and faster production bundles, enhancing the performance of web applications [51].

The frontend was written in TSX (TypeScript) files. TypeScript adds static typing to JavaScript, enabling developers to catch errors at compile time rather than runtime, leading to more robust and maintainable code. TSX also provides enhanced code readability and documentation through type annotations, which makes it easier to understand and collaborate on large codebases [52].

On the client side I created a multiple page website focusing on OOP[7] principals. Each element of the website is a component stored in the components folder. As presented in *Figure 3* each component contains an index.tsx file and a CSS[8] file. These components are called in on one of the pages in the pages folder. One page also has its own TSX and CSS file. In addition, there is also a utils folder where I store short codes for easy functions. These functions are stored separately for easy import. In the App.tsx file I set up the pages and configure the URL routes for them. Then finally the main.tsx calls the App and runs it. These foundations prepare Bioversee for easy further development and upscale needs.

[7] Object-Oriented Programming
[8] Cascading Style Sheets

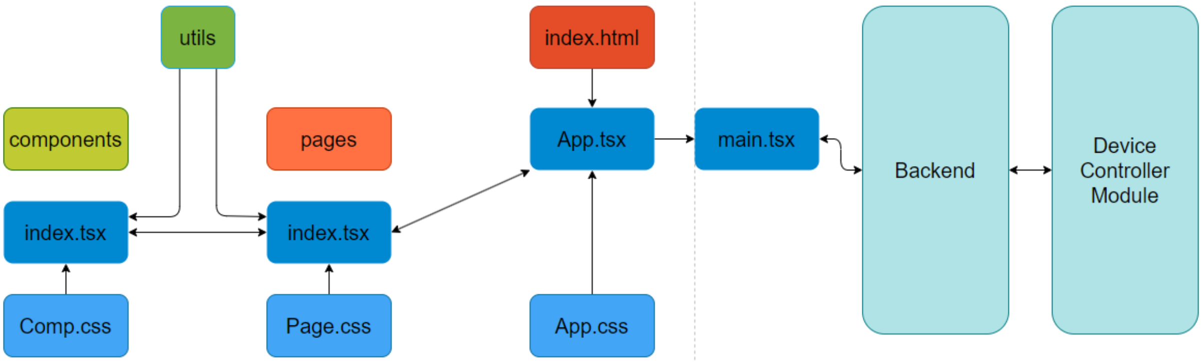

Figure 3: Frontend Software Architecture of Bioversee

The application is hosted on Render[9]. Render is an easy way to host a web application and provides good scaling possibilities. I bought the domain name www.bioversee.com on a separate website called Squarespace[10]. The 2 hosts are connected via DNS nameservers. Bioversee was created in a 3-tier architecture.

3.1.2.1.1. Presentation Layer

In the presentation tier I present a dashboard with sliders and buttons to control the actuators for the reactor. Next to these controls, I also present the sensor outputs with line charts.

3.1.2.1.2. Business Logic Layer

In the business logic tier, I collect the required setting for the bioreactor and load the current state of the actuators I want to save into the database. For this purpose, I use an Express.js server to communicate between the client and the database.

3.1.2.1.3. Database Layer

In the database tier I have a MongoDB cloud-based database where I store the data for the actuators and the data from the sensors as well as data about users. In the bioreactor database I set up 4 collections:

- Actuators have 2 collections. In one I store data for those, which are only capable to be switched ON or OFF. In the other one there are data for those, which are capable for variable speed operations. One record contains the required setting for the actuator, an

[9] https://render.com/
[10] https://www.squarespace.com/

id to specify, which actuator does the user want to operate, the time, when the record was created and the id of the user, who set the new settings.

- In the sensors collection I store the data from the temperature and pH sensor. The records here are like the ones the actuators have, except these have no user id assigned.
- The fourth collection is for storing user data. Currently the controls are only available with google authentication. Every data I store here comes from google and it is publicly available.

3.1.2.2. Device Controller Module Approach

In its current state, the local applications are intended for demonstration purposes only. As shown in *Figure 4*, the connection is established using the db_connect.py code. There are two databases used here for storing actuator and sensor data. A backup local database exists on the device to handle potential internet connection loss. Sensor data generated by the sensor controller Python scripts are typically stored in the cloud database. In the event of a malfunction, the system automatically switches to the local database and operates with the most recent settings. Last commands for the actuators are always saved and updated in the local database and can be used if there is no internet connection. By default, sensor data is stored in the cloud database, with local storage only used during malfunctions. Once the internet connection is restored, the system synchronizes the sensor data from the local database with the cloud.

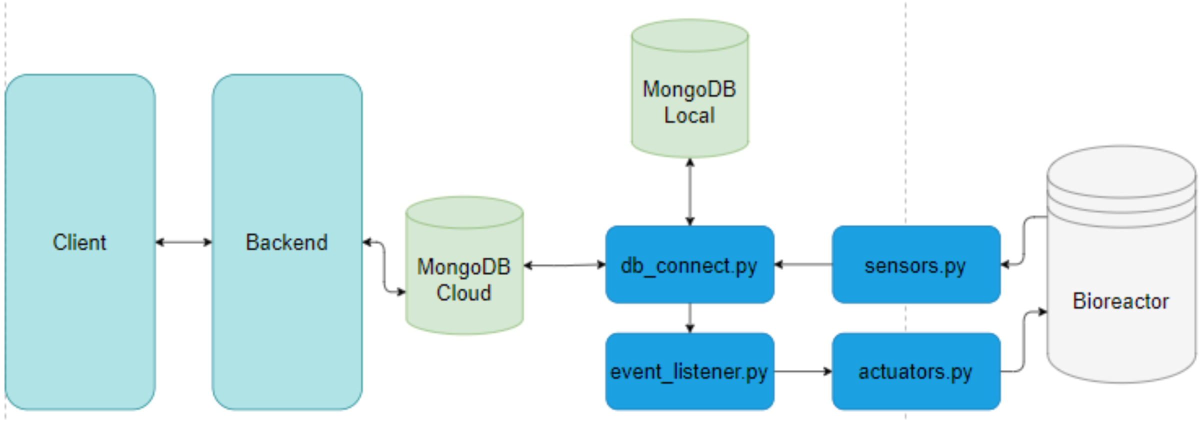

Figure 4: Device Controller Module Architecture of Bioversee

3.2. Hardware

Bioreactors -even if they are older- are expensive equipment. Unfortunately, I did not have the possibility to test my idea on an actual older machine. In this section, I would like to describe the prototypes I built to test my idea.

3.2.1. System Setup Theory

The idea was to have an off-the-shelf customizable personal computer such as a Raspberry PI and through the GPIO pins connect the devices from an existing fermenter and access the device setting on a website. To do that, first I created the web service and when it was ready to be tested, I built the first prototype. As a product I want to give the code and documentation to the customer. They must buy their own devices for their bioreactor control system. I created a guidebook on how to set up the hardware side. On the customer side python codes need to be ran to control the bioreactor. On the server side the website communicates with the database. We can set the current state we want for the controllers in the database. The locally running python codes are monitoring the server for new actuator states as well as sending sensor data to the database. The customer will be able to see the current state and near live sensor data from their device on the website. The website works separately from the local codes, but they relate to using the same database.

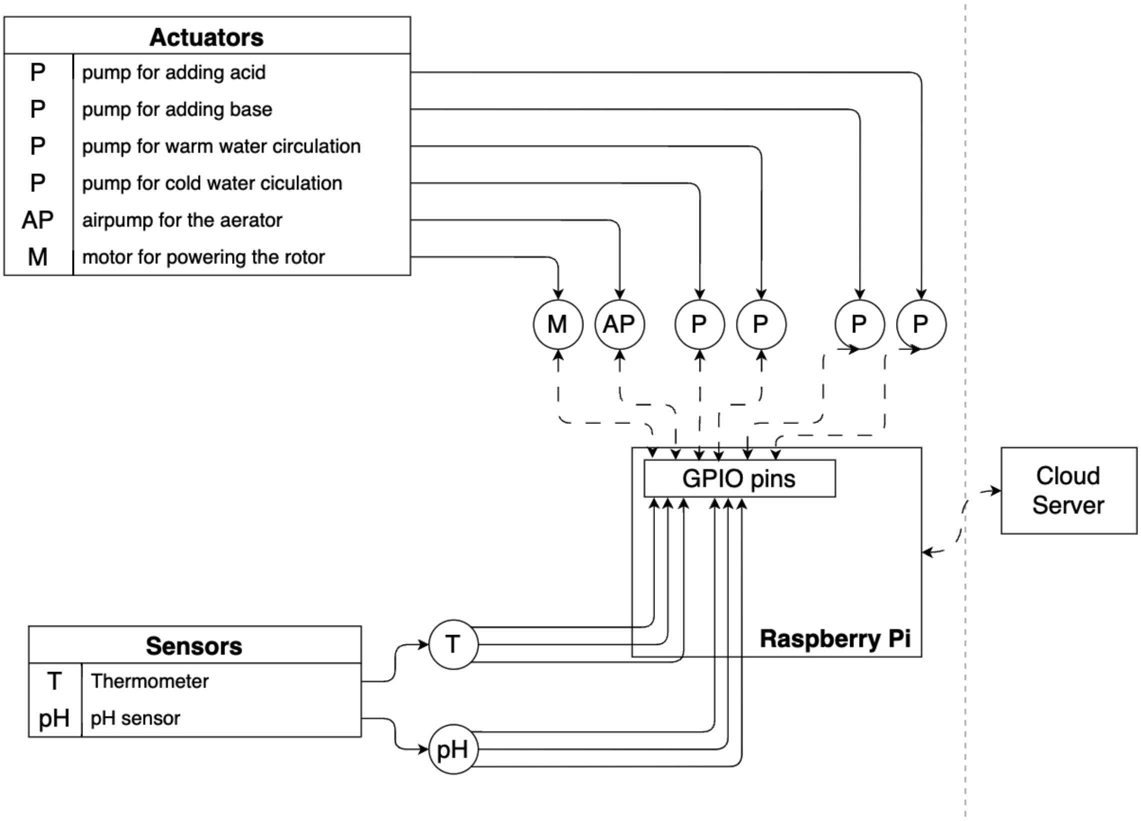

Figure 4: Theoretical blueprint of the hardware wiring system

3.3.2. Prototypes

3.3.2.1. Prototype 1

3.3.2.1.1. Purpose

The goal, what the first prototype had to achieve was that it needed to demonstrate how the software works. It was never intended to be used for the fermentation process. I was focusing on using simple actuators and sensors and simple circuits. Prototype 1 needed to be as small as possible, I wanted to make it fit on a shoebox for better transport possibilities. This prototype as it is can be a product as well. It can be used for teaching how bioreactors work. With the web application students can try it on site if there is internet connection.

3.3.2.1.2. Device Planning

For running the software, I chose to use a Raspberry Pi, specifically a Raspberry Pi 5 8GB. The relay module is a singular circuit board from SONGLE[11] with 4 of the same SRD-5VDC-SL-C relays.

Prototype 1 has two sensors connected to it. One is a DS18B20 thermometer with a one wire design. This device is wired to the Raspberry Pi via a PluggableTerminal connector module. The thermometer uses 3.3V to operate. This comes directly from the computer. The other sensor is a pH electrode which uses an ADS1115 interfacing module to communicate with the Pi. The sensor provides an analog signal via a PH-4502C board for the interfacing module. Raspberry Pi 5 has no analog pins, that is why I need to use the ADS1115. To further improve the understandability of the device I used a breadboard connecting the Raspberry Pi pins. I also used colored wires for better understanding. In *Figure 5* I illustrate the wiring of the instruments on Prototype 1. *Table 1* shows the meaning of the colors in *Figure 5* and *Table 2* lists the pumps in *Figure 5* with their respective purpose.

Color	Meaning
Red	5V power
Orange	3.3V power
Black	Ground
Yellow	Collecting sensor data
Blue	Commands for the relay module

Table 1: Wire coloring code sheet for Prototype 1

[11] SONGLE is a manufacturing company specified for micromagnetic relay modules.

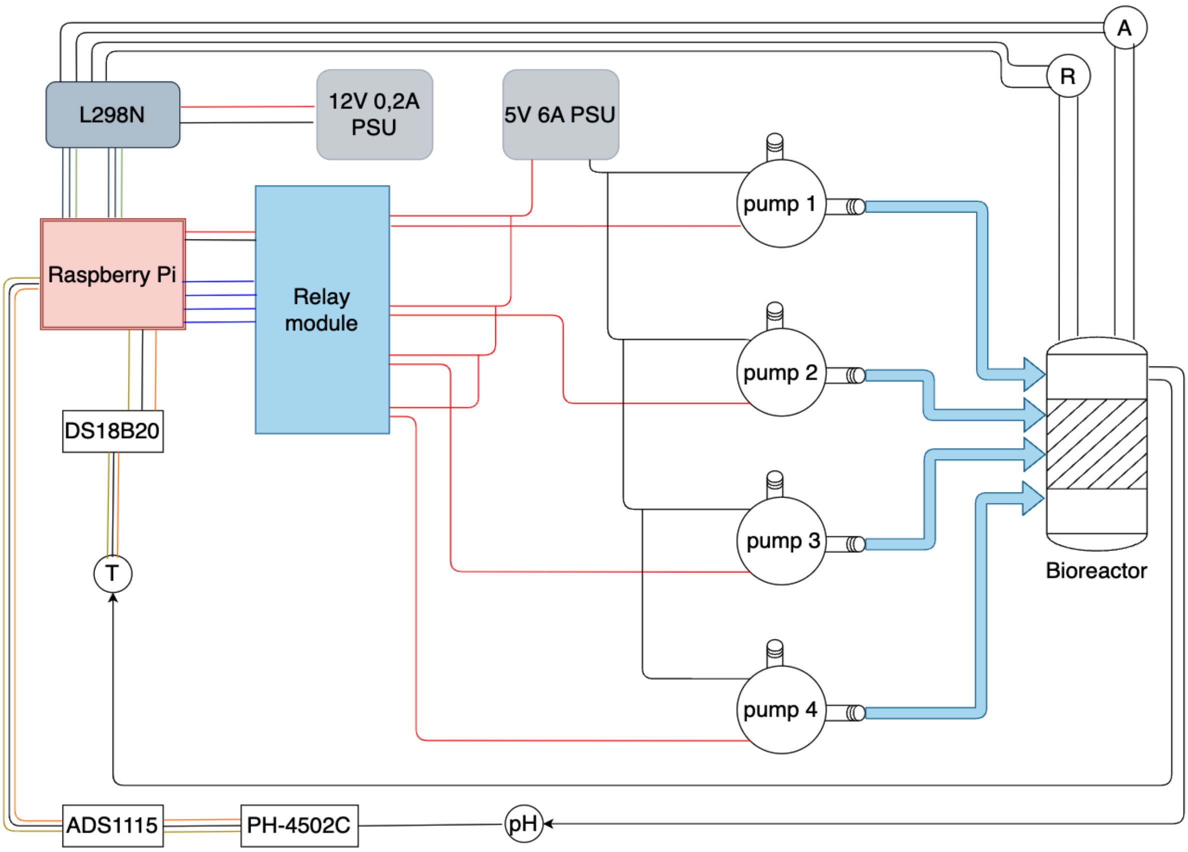

Figure 5: Wiring schemes blueprint for Prototype 1

Pumps	Purpose
pump 1	Warm water circulation
pump 2	Cold water circulation
pump 3	Acid pumping in
pump 4	Base pumping in

Table 2: List of pumps in prototype 1 with their respective purposes

3.3.2.1.3. Modules Used in Prototype 1

To make Prototype 1 as easy to understand as possible, I assembled all the modules side by side on a plastic board. The wiring goes to the back of the plastic board and connected to a Raspberry Pi via a breadboard.

3.3.2.1.3.1. 4 Channel Relay Module from SONGLE

This board uses 5V for control and its relays can use up to 250V AC and 10A. Each relay is wired to a 5V pump through a 5V 6A power supply. This power source has more than enough power to run our 4 water pumps, even all at the same time. The pumps run on alternating current (AC) electricity.

The SRD-5VDC-SL-C (*Figure 6* and *Figure 7)* relays have 3 wire connection points (2, 3, 4 on the figure below). The one (2) in the middle is the ground connection, the other 2 on the sides (3 and 4) are the power outputs. When the relay gets a command signal from the Raspberry Pi via a GPIO pin it can switch between the 2 power outputs. This is a useful function because in case the relay is in default settings one circuit is always open and the other circuit is closed. Using this function Prototype 1's pump control circuits are set to be always open if the relay controller is not under command.

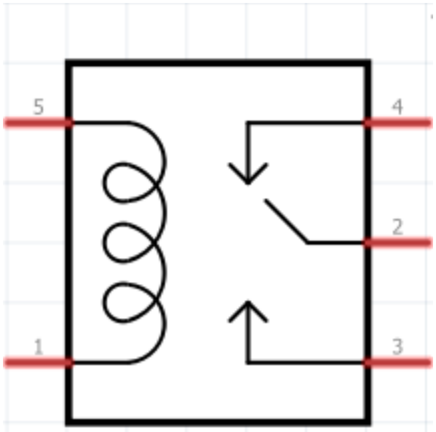

Figure 6: Wiring diagram for SRD-5VDC-SL-C relay

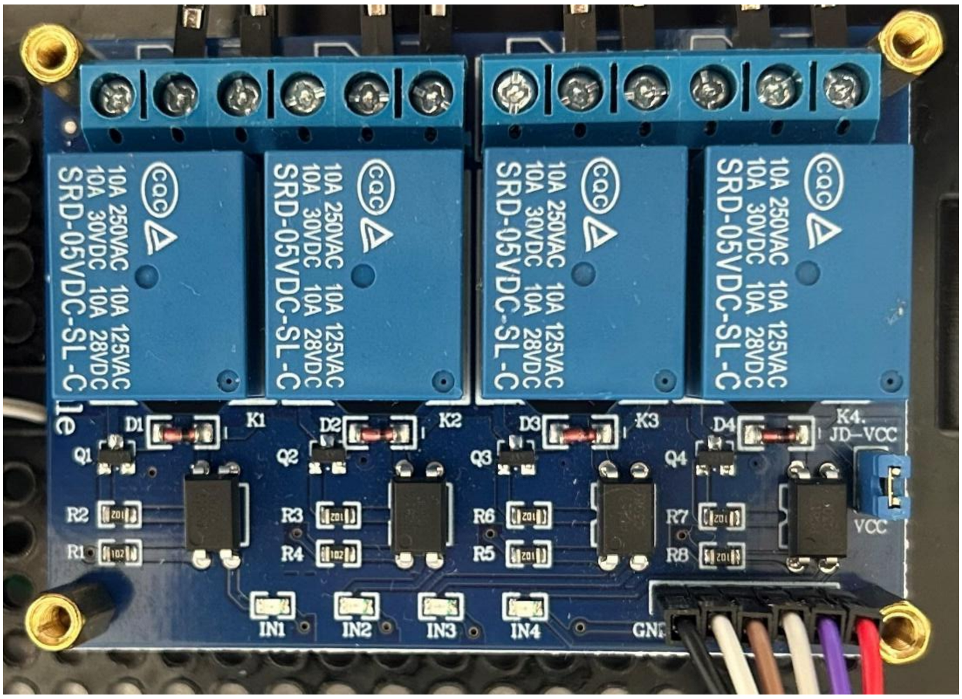

Figure 7: Picture of SONGLE 4 relay module

3.3.2.1.3.2. L298N Motor Driver Module

This module is the controller module for the actuators where adjustable work density is needed. In Prototype 1 these actuators are the rotor and the aerator (demonstrated by 2 CPU fans). The motor driver module uses an H Bridge to connect the power source with the device. The H Bridge gives us the capability to decide the direction of the rotation by changing the way of electricity as presented on *Figure 8*.

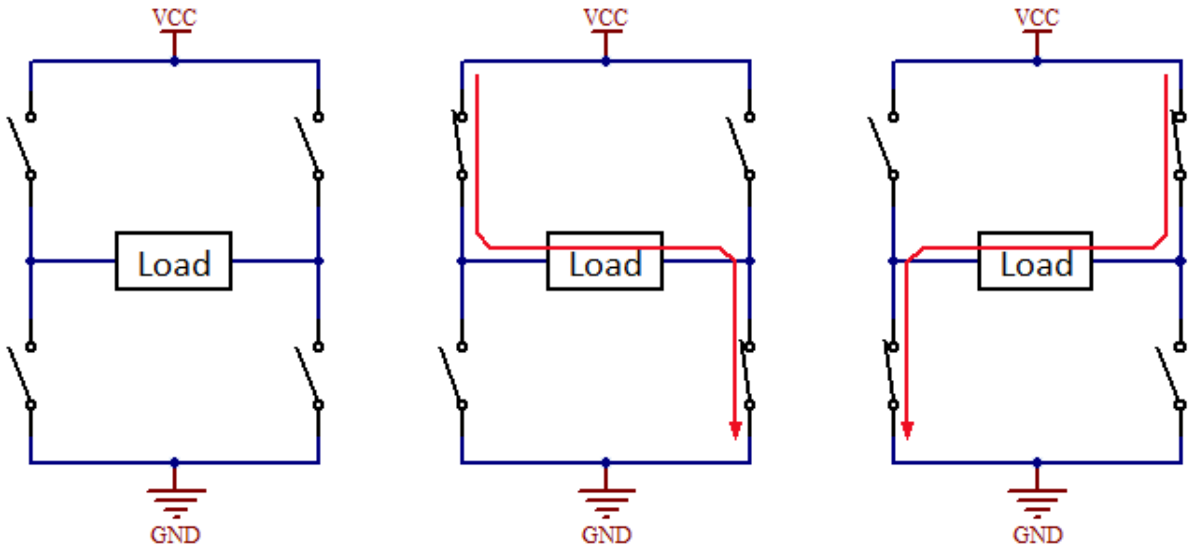

Figure 8: Wiring diagram of L298N motor driver module H Bridge[12]

To decide which circuit is closed we need to give low and high signals to the bridge. The L298N motor driver module has 2 H bridges since this module can control two individual motors. With IN1 and IN2 on the module I control the direction of the first, with IN3 and IN4 the second fan. The signals can be given through GPIO pins form the Raspberry Pi, as well as by a power source. High signal means it has voltage, low mean it does not. To make Prototype 1 easy as possible I simply connected IN1 and IN3 to a 5V output and IN2 and IN4 to a ground pin on the breadboard. To set the speed of the rotation I needed to provide PWN[13] signal. PWN is a method used by many electronics to modulate the output voltage by sending a series of ON-OFF pulses as presented on *Figure 9*. Using this method, the average output voltage can be adjusted to a needed level. The average voltage is proportional to the with of the pulse length,

[12] https://axotron.se/print.php?page=34&lang=en

[13] Pulse With Modulation

which is referred to as duty cycle. The higher the duty cycle, the higher the average voltage output.

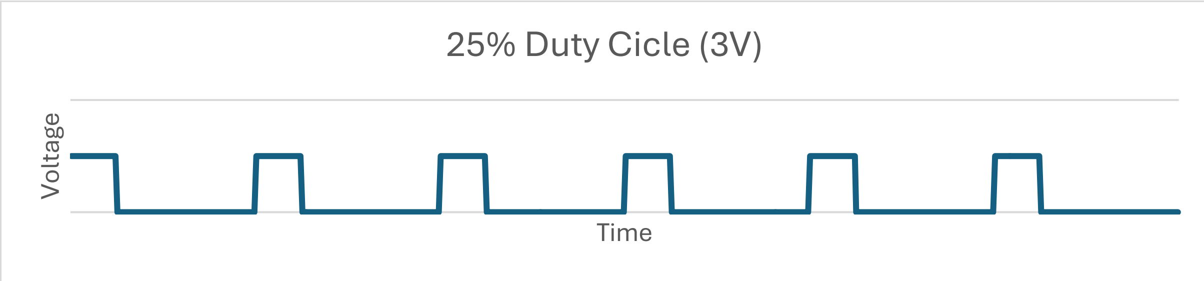

Figure 9: Diagrams of a 3V PWN signals if the max voltage is 12V

In Prototype 1 the L298N (*Figure 10)* motor driver module gets the PWN signal from GPIO23 (connected to ENA on the module) and GPIO24 (connected to ENB on the module). The ENA signal controls the fan (rotor) connected to OUT1 and OUT2. The ENB signal controls the other fan (aerator) on OUT3 and OUT4.

As a power source I use a 12V 0.5A power supply for the fans and a 5V pin form the Raspberry Pi for the switching logic circuitry inside the L298N module. The ground pin is connected to the ground wire of the power supply.

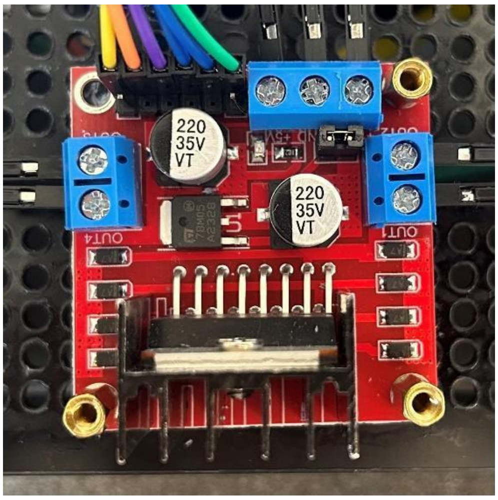

Figure 10: Picture of L298N Motor Diver Module

3.3.2.1.3.3. DS18B20 Temperature Sensor Module Kit

To measure the current temperature inside of a bioreactor, engineers use a temperature sensor hanging into the liquid inside the reaction chamber. For Prototype 1 I used a DS18B20 1 wire temperature sensor. This sensor is made from stainless-steel. It is capable to measure the temperature between -55 and 125 degrees Celsius. The measurement error is ±0.5 degrees between -10 and 85 degrees Celsius. In bioreactors the temperature is between 20 and 80 degrees, this makes the DS18B20 (*Figure 11*) temperature sensor perfect for Prototype 1. In addition to that, the sensor is also acid and corrosion resistant.

In Prototype 1 this sensor gets 5V power from the Raspberry Pi. To provide temperature data for the computer it is connected to a GPIO pin. GPIO4 is the default pin on newer Raspberry Pi models to be the 1 wire interface. Providing an easier way to connect the sensor with the Pi, Prototype 1 has a pluggable terminal adapter (*Figure 12*) connecting these two devices.

Figure 11: DS18B20 temperature sensor

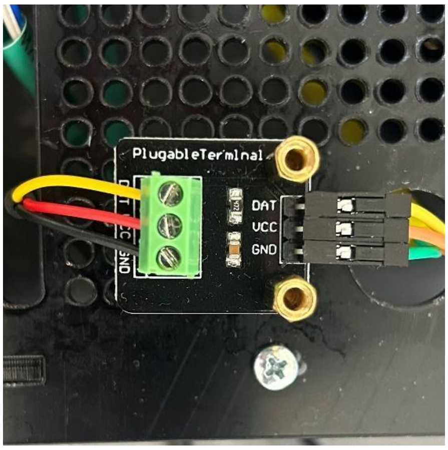

Figure 12: PluggableTerminal connection module

3.3.2.1.3.4. PH-4502C Liquid pH Detection Sensor

Besides the temperature, Prototype 1 can measure the current pH value. For this function, it has a PH-4502C pH detection module connected to the Raspberry Pi. The pH probe works with 5V provided by the computer and sends back data via 1 wire. As I mentioned by the DS18B20 temperature sensor, the default pin for 1 wire connection is GPIO4. In Prototype 1 I had to add an additional 1 wire connection, since GPIO4 was already in use. Recent software updates allowed the user to configure other GPIO pins for 1 wire bus. I configured Prototype 1's GPIO18 pin to be a 1 wire bus, to get data from the sensor.

PH-4502C (*Figure 13*) can produce an analog signal. An analog signal varies the voltage continuously over time, representing the measured quantity. In the case of Prototype 1, the voltage range of 0 to 5 volts corresponds to the pH value range of 0 to 14. In pH measurements the start (neutral) value is 7. To measure the right value, I needed to adjust the pH module's settings to set 2.5V as standard. From the measured voltage with the help of a mathematical formula I was able to get the measured pH value from the sensor.

There was 1 more problem Prototype 1faced with. Newer versions of the Raspberry Pi do not support analog connectivity and have no analog pins. To solve this problem, I added an ADS1115 (*Figure 14*) module to Prototype 1. This module takes analog voltage inputs and converts them into digital values (numbers) that the Raspberry Pi can process. From these numbers, with the help of the mathematical formula the computer is able to calculate the pH value.

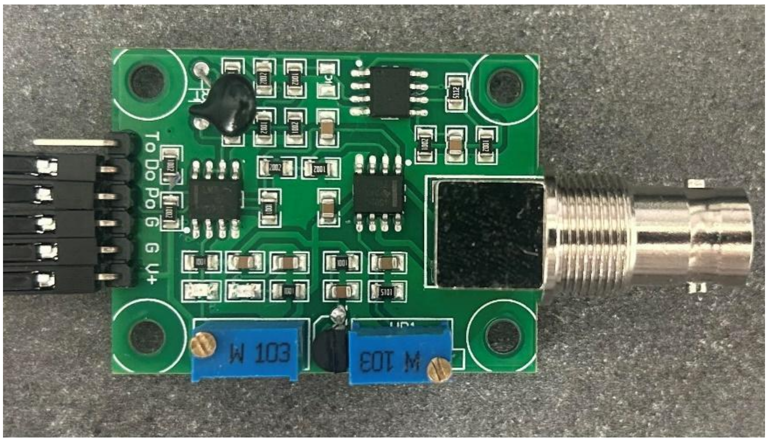

Figure 13: PH-4502C pH Detection Sensor

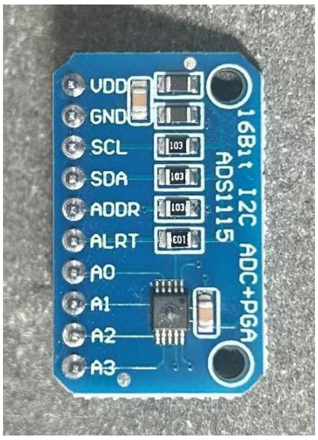

Figure 14: ADS1115 signal modulator module

3.3.2.2. Prototype 2

3.3.2.2.1. Purpose

To test the software in a real scenario, I built a second prototype. With Prototype 2 I would like to run experiments testing the usability of the Bioversee software (with a Raspberry Pi 5 as a platform to control the actuators and sensors). The experiments involved general observations, system diagnostics, user interface experience surveys and an observation of an actual fermentation process.

3.3.2.2.2. Device Planning

Promoting sustainability and environmental protection, I decided to use whatever I can find for Prototype 2, form Prototype 1. I disassembled the modules, and I will use them to build the second device. For the chamber I would like to use an old 5-liter tank form a sand filtered water purification system. I will wrap the tank around with plastic hose, using it as a thermal jacket. Hot and cold water will be circulated in to heat and cool the chamber. The tank can be sealed on top. I will use an axle form an RC boat as the shaft for the agitator. The aerator will be standard aerator for fishtanks.

3.3.2.2.3. Modules Used in Prototype 2

Due to a lack of free time Prototype 2 is still under construction.

4. Business Aspect of Project Bioversee

4.1. Business Description

4.1.1. Company Name

Company Name: Bioversee

Both the company and the product share the name: Bioversee. The name is a combination of 2 words which are “Biotechnology” and “Oversee”. “Bio” represents the target industry where the company aims to bring innovation. The word “Oversee” stands for the functionality of the product, which is supervision.

4.1.2. Mission Statement and Business Goals

Bioversee's mission is to provide affordable automation innovation to companies that cannot afford expensive modernization solutions (example: buying new machinery every time they want to improve their production). By utilizing cost-effective, off-the-shelf customizable computers equipped with the Bioversee automation software, these companies can elevate their productivity by enhancing their existing equipment. The strength of the Bioversee control system lies in its cheap solution and internet connectivity.

Bioversee aims to be the best solution to control bioreactors with its easily understandable user interface and great visual feedback about what exactly is happening with the reactor. Great visualization results in a fast-learning curve using the software.

4.1.3. Planned Legal Structure of the Company

The company is planned to be established in Hungary. There are various types of business entities in this country such as Individual Entrepreneur (EV), Limited Partnership (BT), Limited Liability Partnership (KFT) and Joint-Stock Company (RT). Each type has their own advantages and disadvantages.

4.1.3.1. Consideration

- Individual Entrepreneur (EV)

  Individual entrepreneurial activity can be conducted in two forms: as a sole proprietorship or a sole proprietorship company, each subject to different legal regulations. A sole proprietorship is a business entity without legal personality, which people can operate without any specific background or qualifications, in a commercial manner for profit and wealth generation, assuming their own economic risk [53].

  The advantages of being an Individual Entrepreneur include fast setup and low costs at the beginning, flexible operation, and simple bookkeeping. Disadvantages include unlimited liability, the necessity of personal involvement and the founder's entire assets being liable for the company's obligations [53].

- Limited Partnership (BT)

  A limited partnership (BT) is established through a partnership agreement and must include at least one general partner and one limited partner. There is no specified minimum capital requirement. The entire partnership is responsible for the company's activities, but if the company's assets are insufficient to cover its obligations, the general partner is jointly and severally liable with their entire personal assets [54].

  The general partner brings expertise and marketable knowledge, while the limited partner provides the necessary capital, thus sharing common goals. The general partner has unlimited liability and, in case of bankruptcy or liquidation, must satisfy creditors with their entire personal assets. If the limited partner's name appears in the company's name, they share liability with the general partner for the company's losses or damages caused by them.

  The advantages are that there is no need for large initial capital for the company's establishment and that the members provide the necessary tools for operation. Disadvantages include a higher cost for establishment, publication, and termination compared to a sole proprietorship. The general partner's unlimited liability poses a high risk as well.

- Limited Liability Partnership (KFT)

A limited liability company (KFT) is also a business partnership but is fundamentally different from a BT in several aspects. In a KFT, only one person or a small group manages the business, while other partners contribute capital (share capital) and share in the company's profits. These owners are often referred to as silent partners [55].

Advantages are the limited personal liability, higher prestige, and better creditworthiness compared to sole proprietorships and BTs. Members' ownership and decision-making roles are transparent. Disadvantages are the higher establishment and operating costs compared to sole proprietorships and BTs.

- Joint-Stock Company (RT)

  There are 2 types of Joint-Stock Companies in Hungary. The difference between them is whether the company is privately (ZRT) or publicly (NYRT) owned.

  For a small startup this legal structure isn’t advantageous for a number of reasons. It has high initial capital requirement, complex and costly formation process, inflexibility in management and operation, as well as high administrative costs [56].

4.1.3.2. Decision

For Bioversee, Limited Liability Partnership (KFT) has the most benefits. The owners only liable with the company's assets greatly reduces personal financial risk, which is particularly important for a technology venture with significant initial investments and development costs.

On our target market, bioreactors play the main role in the manufacturing process. A malfunction can cause serious damage for the customers’ workflows. Trust between reactor manufacturers and their customers is a key factor in marketing. The Limited Liability Partnership business form can inspire greater confidence among clients, partners, and investors.

In Hungary, Limited Liability Partnerships have access to favorable tax options, and it is easier to raise capital through bank loans and investors. In addition to that, they have flexible capital structure. The minimum share capital required form establishing a Limited Liability Partnerships is 3 million HUF (ca. $8 300 / 7 600€). The amount of capital shares can be increased as the business grows.

4.1.4. Proposed Establishment Date

To decide when to establish the company, different aspects must be taken into consideration. Everything depends on how the development progresses. If all goes according to plan, Bioversee version 1 will be ready to be officially registered in 2024. Until there is no fully functional version, the company will not be created. Once established, the company incurs costs, such as start-up costs, running expenses and employee wages. Starting a business without a product that is not yet profitable could lead to a financial depth, which makes it harder to reach the breakeven point, where the company starts to generate profit.

4.2. Market Analysis

4.2.1. Target Market Definition

There are many industries that can potentially use a novel bioreactor control system design. Bioversee aims mainly to reach laboratories and smaller businesses.

Some primary target industries include:

The Pharmaceutical Industry:

- Production of drugs such as antibiotics and other medications: Production of compounds that can be used as raw materials in the pharmaceutical industry.
- Vaccine production: Viruses and bacteria can be used in the production of vaccines.
- Production of therapeutic proteins: Genetically modified cells in bioreactors can be used to produce proteins used in the treatment of diseases.

The Food Industry:

- Production of food additives: Production of emulsifiers, stabilizers, and preservatives.
- Production of enzymes: Enzymes are produced for further use in the dairy sector, bakery, or brewing industries.
- Production of dietary supplements: vitamins, minerals, and dietary supplements produced in bioreactors are marketed as nutritional supplements.

4.2.1.1. Size and Growth Rate of Target Markets

The global market for bioreactors is rapidly expanding. According to estimates by several companies[14], the market reached $7.2 Billion in 2023 and is projected to grow to $18.6 Billion by 2032, with growth rate of 10.9% during the period under review[15]. The following factors drive this growth – the application of products produced using bioreactors:

- Increasing incidence of chronic diseases such as diabetes
- Growing demand for organic foods
- Demand for more sustainable manufacturing processes in the food industry

Target markets by region:

- North America: The largest market due to the growing pharmaceutical and food industries.
- Europe: The second-largest market due to strict regulations and high research and development expenditures.
- Asia-Pacific region: The fastest-growing market due to a growing population and increasing discretionary income.
- Latin America: Growing market due to the expanding pharmaceutical and food industries.
- Middle East and Africa: Small market but growing due to increasing investments.

4.2.1.2. Analysis of market needs and trends

For market analysis in bioreactor automation, marketing research methods such as surveys and interviews effectively gather insights into user needs, identifying current features and areas for improvement. Surveys can highlight satisfaction with automation features, while interviews provide qualitative feedback on user challenges, guiding system refinements and innovation in control systems [57].

In Bioversee's case, there are many options to do secondary marketing research. Most competitors have detailed specifications about their product availability online. We can examine their product's capabilities on paper and compare them with Bioversee's. A variety of

[14] https://mckinseywell.com/products/global-bioreactors-market-2024-2028
[15] https://www.imarcgroup.com/bioreactor-market

online resources are available regarding these products that enable their study without the need to purchase them.

Unlike secondary research, doing primary marketing research for Bioversee has its limitations. First, there are only a few people who are working with these machines, and it is difficult to connect with them. Most who work in the field are bound by non-disclosure and confidentiality agreements or they simply don't have the time or keen to answer questionnaires. Participation can be boosted by offering rewards or benefits to motivate them for taking their time to participate, which involves expenses for our company. The best primary research in our case would be conducting personal interviews, which could give us the best look into our target customer's needs.

Table 3 below, shows a research plan schedule for the secondary and primary research. The order of secondary and primary research is interchangeable. Starting with the secondary research is recommended because the collected data will help with the primary research.

	Task	Duration
Secondary Research		2 weeks
Gathering Sources	Collecting scientific articles, books, conference proceedings	1-3 days
Literature Review	Reviewing sources, collecting relevant information	3-5 days
Summary and Analysis	Summarizing literature, highlighting relevant findings	4-6 days
Primary Research		5 weeks
Research Design	Preparing research questionnaires and interview questions	7 days
Selection of Respondents	Identifying specific target groups, selecting respondents	7 days
Data Collection	Conducting interviews and surveys, collecting data	21 days
Data Analysis		3 weeks
Data Preparation	Entering data into SPSS, data cleaning	7 days
Descriptive Statistical Analysis	Frequency analysis, calculation of central tendency measures	7 days
Inferential Statistical Analysis	Correlation analysis, ANOVA, regression analysis	7 days
Summary of Results		1 week
Report Preparation	Summarizing and interpreting results, preparing the report	7 days

Table 3: Marketing research planned schedule for bioreactor customers' needs

4.2.2. Identification and Analysis of competitors

Most modern bioreactors already offer remote control and monitoring capabilities. The Bioversee bioreactor control software is being developed for older or custom-built bioreactors. Its focus is on affordability and fast operation learning curve.

4.2.2.1. Identifying Main Competitors

Bioprocess machinery manufacturing companies usually offer their own control application with their bioreactors. The two biggest companies on the Hungarian market are Sartorius and Thermo Fisher Scientific. Both have their automation solutions, and their customers already have most features available that Bioversee has to offer. Bioversee focuses on reaching the customers with a small budget, however it is still insightful to treat these industry giants as competitors. We can examine their product and figure out ways to improve ours.

There are a few programs which can be purchased as a product and capable of being configured for bioreactor control. Some of these are Applikon V-Control[16] from Applicon Biotechnology (now part of Getine), or Lucullus[17] developed by Lucullus PIMS.

For Bioversee the Applicon V-Control and the Lucullus system are the main competitors. But Bioversee aims to be much more. It is being developed to be not just a device controller software solution, but also an educational tool and a planning tool all at the same time.

4.2.2.2. Analysis of Competitors

In this section I will look at some of the most well-known companies and their place and approach to the bioreactor market.

4.2.2.2.1. Sartorius AG[18]

4.2.2.2.1.1. Company Profile

Sartorius AG is a leading international partner in biopharmaceutical research and the pharmaceutical industry. The company is headquartered in Göttingen, Germany, and it

[16] https://www.getinge.com/uk/products/applikon-v-control/
[17] https://www.securecell.ch/product-biotech/lucullus-scada-software-bioprocess-digitalization-automation
[18] https://www.sartorius.com/en/company/about-sartorius-ag

specializes in laboratory and process technologies for the biotech and pharmaceutical sectors. Sartorius had around 14 600 employees around the world working at one of its 60+ plants.

4.2.2.2.1.2. Economic Profile[19]

Metric	Value
Revenue	€3.31 billion
Operating Income	€487.0 million
Net Profit	€309.7 million
Market Capitalization	€14.9 billion

Table 4: Economic Profile of Sartorius AG in 31/12/2023

4.2.2.2.1.3. Evaluation

The current market position of Sartorius AG is strong due to its stable financial performance, strategic investments, and innovative product developments. It benefits from robust revenue and profit margins, a significant market capitalization, global presence, and a commitment to sustainability and efficiency.

4.2.2.2.2. Thermo Fisher Scientific Inc.[20]

4.2.2.2.2.1. Company Profile

Like Sartorius in Europe, Thermo Fisher Scientific is the largest laboratory equipment manufacturer in the United States. The company contains several brands under its name. Its headquarters are in the Greater Boston Area, East Coast, New England. Thermo Fisher Scientific supplies laboratory information management and scientific data systems, with the goal of helping customers make the world healthier, cleaner, and safer. The company has over 122 000 employees.

4.2.2.2.2.2. Economic Profile[21]

Metric	Value
Revenue	$42.86 billion
Operating Income	$6.86 billion
Net Profit	$5.995 billion
Market Capitalization	$205.08 billion

Table 5: Economic Profile of Thermo Fisher Scientific Inc. in 31/12/2023

[19] https://finance.yahoo.com/quote/SRT.DE/financials/

[20] https://www.crunchbase.com/organization/thermo-fisher-scientific

[21] https://ir.thermofisher.com/investors/news-events/news/news-details/2024/Thermo-Fisher-Scientific-Reports-Fourth-Quarter-and-Full-Year-2023-Results/

4.2.2.2.2.3. Evaluation

Thermo Fisher Scientific demonstrates robust financial health and significant market presence. With a revenue of $42.86 billion and a net profit of $5.995 billion in 2023, the company shows strong profitability. Its operating income of $6.86 billion indicates effective cost management and operational efficiency. The market capitalization of $205.08 billion highlights its substantial value in the market.

4.2.2.2.3. Applikon Biotechnology

4.2.2.2.3.1. Company Profile[22] [23]

Applikon Biotechnology, now a part of Getinge, has been a leading provider of bioreactor systems for the biopharmaceutical and biotechnology industries since 1973. Headquartered in the Netherlands, Applikon specializes in the development and supply of advanced bioprocess equipment. The company offers a range of bioreactor solutions, from small-scale single-use systems for research to large-scale stainless-steel systems for commercial production.

By joining forces with Getinge, Applikon has enhanced its capabilities in the life sciences sector, combining decades of bioprocessing expertise with Getinge's extensive experience in healthcare and life sciences technologies. This integration aims to drive innovation in bioprocessing, contributing to the development of life-saving vaccines, medicines, and therapies.

4.2.2.2.3.2. Economic Profile (Getinge)[24]

Metric	Value
Revenue	$3.017 million
Operating Income	$413 000
Net Profit	$238 000
Market Capitalization	$5.228 million

Table 6: Economic Profile of Applikon Biotechnology in 31/12/2023

4.2.2.2.3.3. Evaluation

Unlike Sartorius and Thermo Fisher Scientific, Applikon is a potential competitor for Bioversee. They focus on bioreactors, and their design for disposable single-use bioreactors is

[22] https://www.getinge.com/int/campaigns/from-culture-to-cure/
[23] https://www.europeanpharmaceuticalreview.com/content_hub/62639/applikon-biotechnology/
[24] https://www.getinge.com/int/

our main competition. As Bioversee's mission statement mentions, we focus on developing affordable bioreactor solutions. Getinge and Applikon are working towards the same goal.

4.2.2.2.4. Securecell[25]

4.2.2.2.4.1. Company Profile

Securecell is a bioprocessing company with over 25 years of experience in creating innovative solutions to improve bioprocessing, medical treatment, and patient health. Their focus lies in developing technologies for the biotech, pharma, and academic sectors. Securecell's mission is to develop ingenious technologies that have a positive impact on people's lives globally. The company works on medical devices designed to improve health outcomes through better bioprocessing solutions.

Their products are focused on end-to-end bioprocessing. They have several products, software, and hardware solutions.

4.2.2.2.4.2. Economic Profile

Securecell has no financial report publicly available at the moment. However, we know that the company has around 100 employees and around 6000 integrated hardware and software solutions already in use.

4.2.2.2.4.3. Evaluation

Securecell, with its 25 years of experience just like Applikon is a main competitor.

4.2.2.3. Analysis of Competitors' Products

4.2.2.3.1. Strengths and Weaknesses of Sartorius BioPAT MFCS:

Strengths:

- Intuitive and Easy-to-Use Interface: The Bioprocess Control Center software features a graphical user interface that is easy to understand and use for experienced users.
- Extensive Functionality: The software offers numerous functions for real-time monitoring, control, and data collection of bioreactors.
- Scalability: It can scale from a single bioreactor to complex bioreactor systems.

[25] https://www.securecell.ch/en/company

- Compatibility: Compatible with a wide range of Sartorius bioreactors, as well as bioreactors from other manufacturers.
- Data Visualization: Provides advanced data visualization tools that facilitate quick and easy understanding of data.
- Automation: Automated functions reduce the need for manual intervention and improve efficiency.
- Remote Access: Allows users to monitor bioreactors independently of their location.

Weaknesses:

- High Cost
- Complexity: The complex functionality of the software can make it difficult for beginner users.
- Limited Customizability: The software is not highly customizable.
- Resource Intensive: Requires significant computer resources to run.
- Frequent Updates: The software needs frequent updates, which can be disruptive for users.
- Limited Technical Support: Does not provide 24/7 technical support.

4.2.2.3.2. Strengths and Weaknesses of Thermo Fisher Scientific Bioreactor Software:

Strengths:

- Wide Compatibility: Thermo Fisher Scientific bioreactor software is compatible with most Thermo Fisher Scientific bioreactors, as well as bioreactors from other manufacturers.
- Scalability: The software can scale from a single bioreactor to complex bioreactor systems.
- Intuitive Interface: The software features graphical user interfaces that are easy to understand for experienced users.
- Extensive Functionality: Offers numerous functions for real-time monitoring, control, and data collection of bioreactors.
- Automation: Provides automated functions that reduce the need for manual intervention and improve efficiency.

- Data Visualization: Offers advanced data visualization tools that facilitate quick and easy understanding of data.
- Remote Access: Provides remote access functions that allow users to monitor bioreactors regardless of their location.

Weaknesses:

- High Cost
- Limited Customizability: The software is not highly customizable.
- Resource Intensive: Requires significant computer resources to run.
- Frequent Updates: The software needs frequent updates, which can be disruptive for users.
- Limited Technical Support: Does not provide 24/7 technical support.
- Thermo Fisher Scientific HyClone Perfusion Management Software: Not compatible with all types of Thermo Fisher Scientific bioreactors.
- Thermo Fisher Scientific BioCommand Software: Lacks advanced data visualization tools compared to competitors' software.
- Thermo Fisher Scientific FermentBench Software: Not as scalable as competitor's software.

4.2.2.3.3. Strengths and Weaknesses of Getine`s Applikon V-control Software

Strengths:

- Tailored for use in laboratory environment
- Scalable with Applicon bioreactors ranging from 250 mL up to 20 L
- It could come with an off the-the-shelf hardware
- The company offers bioreactors designed to be controlled by their software
- The hardware is connectable with other

Weaknesses:

- One hardware is capable of controlling limited number of actuators and sensors
- The software is a desktop application, with limited accessibility. A hardware comes with a limited number of licenses.

4.2.2.3.4. Strengths and Weaknesses of Securecell`s Lucullus Software

Strengths:

- Overall solution for bioprocess planning, control, monitoring and result evaluation
- Designed for basic and advanced control as well
- It has 3rd party data analysis software integration
- Multiple users are capable of monitoring and controlling bioprocess
- Easy and fast data supervision
- Modern looking user interface

Weaknesses:

- Core scada license comes without planning, sampling and data evaluation capabilities
- The software is a desktop application, users need to install them on their computer

4.2.2.4. Competitor's Product Analysis Evaluation

After investigating Bioversee's competitor products it is safe to say, that the Lucullus system is the most similar with our product and hence the main competitor. Lucullus offers a strong overall solution for all purposes as a desktop application, while Bioversee is web-based. Being a webapp can lower the cost of computers needed for the company, since the application is running on a cloud server. By using one main database, Bioversee has great potential to be enchanted with machine learning algorithms, which can bring industrial automation to the next level.

Our company aims to create an automation solution as cheap as possible. The products we compete with are focused on newer machines. Our focus is on creating an easily understandable user interface, while limiting the time to get used to the controls. With a steep learning curve, productivity grows.

4.2.3. Bioversee Product SWOT Analysis

4.2.3.1. Introduction to SWOT Analysis

SWOT Analysis is a strategic planning tool used to identify and analyze the internal and external factors that can impact the success of a business [58]. The word SWOT stands for Strengths, Weaknesses, Opportunities, and Threats. This framework helps businesses assess their current situation, make informed decisions and develop effective strategies to achieve their objectives [58]. Originating from research conducted at the Stanford Research Institute in the 1960s, SWOT Analysis has become a fundamental tool in both corporate and academic settings for strategic management and planning [59].

The application of SWOT Analysis spans various domains, including business planning, marketing strategy, product development, and organizational change management. It provides a structured approach for analyzing a businesses or product`s strategic position and developing opportunities [60].

In the following, I present the SWOT analysis of Bioversee detailed in *Table 7*.

Strength	Weakness
• Favorable pricing • Wide compatibility with bioreactors • Environmentally friendly development opportunity • Revitalization of outdated equipment • User-friendly interface suitable for beginners • Possibility of location-independent control and monitoring • Web based control reachable from any device with a web browser and internet connection	• Hardware-free solution • Installation requiring technical and electrical knowledge. • Dependency on internet connection • Customer needs to provide necessary hardware. • Less functionality compared to competitors' software. • Lack of expert 24/7 support • Each device (bioreactor) requires separate hardware. • Interface cannot be personalized
Opportunities	**Treats**
• Development of new features • Development of customizable user interface • Design, manufacturing, and sale of hardware • Opportunity for expansion of computer capacity • Development of a 24/7 support application • Development for educational purposes • Bioversee is saleable up to control the entire manufacturing process	• Strong competition from competitors • Need for compromise in using the software compared to competitors. • High level of loyalty between customers and the manufacturer • Installation difficulties • Challenges in hardware troubleshooting • Bioversee must earn customer's trust

Table 7: Bioversee SWOT analysis

4.2.4. Market Goals

Bioversee faces relatively slow growth on the market. To determine how the business will grow year after year is risky, therefore it is more practical to set phases for the company, detailed in the following:

Phase 1: We must find our first customers. We expect no profit in this phase because we probably have to provide the company's service for free for the first 10-15 customers. This can be beneficial in the future in terms of marketing. In this phase Bioversee will be only a software.

Phase 2: The company starts to generate some income. The services we offer no longer come without a paycheck. The price will be still minimal, so the net income will most likely be negative.

Phase 3: In Phase 3 we must break even. In this phase we expect to be able to hire employees and expand the network of our customer base.

Phase 4: The company starts its grow. Here we start rapidly expanding. This phase will be all about expanding our customer base and generating profit for the company.

Further Phases: We expect the first 4 phases will last for at least 2-5 years. Further phases will be added in the future.

In a 5-year period we expect the company to have at least 150 to 200 paying customers operating 150-500 bioreactors enhanced with the Bioversee control system.

4.3. Product Line and Services

4.3.1. Product Development Timeline

Starting a company based on innovative technology requires a clear and strategic plan, especially when it involves complex products like a bioreactor controller web application. Our company, Bioversee, aims to bring a new vision in the bioprocessing industry by providing a sophisticated yet user-friendly web application designed to optimize and automate bioreactor control.

Currently our product, the bioreactor controller web application, is designed to enhance the efficiency and effectiveness of bioreactor operations.

Development Phases:

1. **Design and Prototyping (Months 3-5)**
   - Develop initial design prototypes and user interface mockups.
   - Establish core functionalities and outline system architecture.
2. **Software Development (Months 6-12)**
   - Implement the core features and integrate necessary bioreactor control protocols.
   - Conduct iterative testing and debugging to ensure system stability and performance.
3. **Beta Testing and Refinement (Months 13-15)**
   - Launch a beta version for selected users to gather feedback.
   - Refine the application based on test partner user feedback and performance data.
4. **Final Development and Quality Assurance (Months 16-18)**
   - Complete final adjustments and enhancements.
   - Perform quality assurance tests to ensure reliability and compliance with industry standards.
5. **Launch and Deployment (Month 19)**
   - Prepare for official product launch with marketing and sales strategies.
   - Deploy the application to the market and begin customer onboarding.
6. **Post-Launch Support and Upgrades (Ongoing)**
   - Provide continuous support and updates to users.
   - Incorporate additional features and improvements based on user feedback and technological advancements.

This well-defined product development plan positions Bioversee for mission success. It outlines goals, target audience, and key metrics with a flexible timeline. While adjustments may be necessary, this plan currently serves as Bioversee's best roadmap.

4.3.2. Services Offered with the Product

Bioversee is planned to offer customer service. We are planning to create a chatbot for clients and for potential customers as well to help better understanding and to accelerate problem solving. A FAQ (frequently asked questions) is also under construction.

To minimize cost and ensure affordability, Bioversee`s hardware side software is designed to be run on an off-the-shelf customizable computer such as a Raspberry Pi. Connecting a reactor with the computer will be the customer’s task. Our company will provide a detailed digital instructions manual with software, helping the installation. As the company grows, we would like to offer technical services for product deployments.

4.4. Marketing and Sales Strategy

4.4.1. Marketing Objectives and Strategies

Bioversee has a highly specific target market. There are not too many people who are working with bioreactors. With our marketing strategy we must reach 2-3 different types of potential customers. The majority of our users estimated themselves to be companies and small businesses. We have to use B2B (business to business) marketing strategies to create connections, get customers and partnerships. In addition to its main purpose, Bioversee is also being developed to be applicable for even individuals, for homemade bioreactors and fermenters. The number of people who are brewing their own alcoholic drinks for personal use is growing. They are possible secondary customers for our service.

To effectively market Bioversee to both B2B and B2C (individuals brewing at home), we'll need a dual-pronged strategy that caters our approach to the unique needs of each segment.

4.4.1.1. B2B Marketing Strategy

With our B2B strategy we would like to attract businesses who are working with bioreactors and businesses who are part of the bioreactor manufacturing industry.

4.4.1.1.1. Identifying Target Customers

- **Biotech Companies:** Small and medium size firms involved in research, development, and manufacturing of bioprocessing products, especially bioreactors.
- **Brewing Companies:** Microbreweries, craft breweries, and large brewing companies.
- **Pharmaceutical Companies:** Firms that use bioreactors for drug production.
- **Academic and Research Institutions:** Universities and research labs working with bioreactors.

4.4.1.1.2. Marketing channels

We're prioritizing digital marketing to optimize our marketing budget. SEO (Search Engine Optimization) and SEM (Search Engine Marketing) are key components of this approach [64].

- **SEO and SEM:** Optimize search engine for relevant keywords and use these as a marketing channel to attract businesses searching for bioreactor solutions [65].
- **Website design:** Create an attractive and informative page at Bioversee`s website highlighting its benefits, features and describe case studies.

4.4.1.1.3. Network and Partnerships Possibilities

Bioversee is a software solution. It needs a hardware (a bioreactor) to be useful. There is a potential business opportunity, that we create partnerships and collaborations with companies, how wants to implement our control system into their hardware.

- **Industry Conferences and Trade Shows:** Attend and present at key industry events to showcase Bioversee and network with potential clients.
- **Partnerships with Equipment Suppliers:** Collaborate with manufacturers and suppliers of bioreactors to recommend Bioversee to their customers.
- **Professional Associations:** Join and participate in biotech and brewing associations to gain credibility and network.

4.4.1.1.4. Using Case Studies as a Marketing Tool

Case studies can be multipurpose tools for us. On one hand we can evolve our product development process, define where the Bioversee control system has advantages and disadvantages over other products. On the other hand, we can publish them showcasing our work process and product strength.

We can also collect testimonials from satisfied customers to build trust and credibility. These testimonials will be presented on our website.

4.4.1.2. B2C Marketing Strategy

With our B2C marketing we are planning to raise brand awareness and trust in our product.

4.4.1.2.1. Identifying Target Individuals

- **Home Brewers:** Individuals, brewing beer, wine, or other alcoholic beverages at home.
- **DIY (Do It Yourself) Bioreactor Enthusiasts:** Hobbyists interested in creating their own bioreactors for various purposes.

4.4.1.2.2. Marketing Channels

SEO and SEM also work here well, however there are more cost-effective options in B2C marketing, which we can also use.

- **Content Marketing:** Create blog posts, how-to guides, and videos on our website about setting up and using Bioversee witch homemade bioreactors and fermenters.
- **Social media:** Use platforms like Instagram, Facebook, and YouTube to share tips, tutorials, and user-generated content from homebrewers.
- **Online Forums and Groups:** Engage in online communities such as Reddit, homebrewing forums, and DIY groups to share expertise and promote Bioversee.

4.4.1.3. Monitoring and Adjustments

- **Analytics:** Regularly monitor website traffic, conversion rates, and customer feedback to identify areas for improvement.
- **Surveys and Feedback:** Collect feedback from both business and individual customers to refine offerings and marketing tactics.
- **Look for Customer's Needs:** Contiguously monitor online forums and groups to find out customer needs.

4.4.2. Pricing Strategy

As a startup company, it is hard to determine how much our customers will be willing to pay for our product. Our main goal for the early stages is to break even and generate profit if possible. Cost-based pricing is an effective choice, particularly for a new product like Bioversee, because it provides a straightforward, reliable way to ensure that all costs are covered while still achieving profitability. This strategy brings simplicity, ensures all costs are covered, reduces financial risk and it helps in creating more accurate financial forecasts and budgets [61]. Cost-based pricing is also easily scalable, since we will be able to adjust our prices in the future. If we can keep our operational costs lower than competitors, cost-based pricing can highlight Bioversee`s competitive pricing advantage, attracting price-sensitive customers.

Also the cost-based pricing strategy gives as benefits, it also has disadvantages. It ignores market demand. It will be important for us to supplement our pricing with regular market research to ensure that our prices align with what customers are willing to pay [62].

We have to differentiate our pricing into 2 segments. We will have pricing for businesses and for individuals. With segmentation we aim to attract both businesses and individual users, balancing affordability with feature accessibility [63].

4.4.2.1. B2B Pricing Tires

- **Tier 1 Plan:**
    - **Targeted customer:** Smaller businesses, laboratories
    - **Features:** Unlimited users, controlling up to 5 reactors / license, limited support from developers
    - **Price:** $50 per month
- **Tier 2 Plan:**
    - **Target customer:** Medium-sized companies
    - **Features:** Unlimited users, controlling up to 15 reactors / license, limited support from developers
    - **Price:** $100 per month
- **Tier 3 Plan:**
    - **Target customers:** Large corporations, bioreactor manufacturing partners
    - **Features:** Custom access to Bioversee software, admin access to bioreactors, advanced analytics, direct contact to developers
    - **Price:** Custom pricing based on terms in contracts

4.4.2.2. B2C Pricing Tires

- **Starter Plan:**
    - **Target customers:** Individuals and hobbyists
    - **Features:** controlling a single reactor per license, maximum 3 user can be connected to the same device, community support only
    - **Price:** Free access

- **Advanced Plan:**
  - **Target customers:** Serious homebrewers
  - **Features:** controlling up to 3 reactors / license, max 10 users can be connected to the same device, limited support from developers
  - **Price:** $5 - $15 per month

4.4.3. Promotional Plan

Our goal is to effectively reach our target market, which includes businesses and individual users, to build brand awareness and drive adoption of our software solution. Objectives with our fist promotional campaign are ensuring that potential customers know about Bioversee and its benefits, drive interest and convert potential customers into users and build customer loyalty.

4.4.3.1. Marketing Strategies

4.4.3.1.1. Content Marketing

- **Blog Posts:** Publish articles on topics related to bioreactor technology on our website, cost-saving strategies, and benefits of using Bioversee
- **White Papers and Case Studies:** Report detailed documents highlighting successful implementations of Bioversee and the tangible benefits realized by users.
- **Tutorials and Presentations:** Create an instructional video collection about the software promoting our product and helping new users get used to our system

4.4.3.1.2. Social Media Marketing

- **LinkedIn:** Share industry news, product development progressions and success stories to engage with B2B clients
- **YouTube:** We can share testimonials, and use YouTube`s advertisement system to attract potential employees

4.4.3.1.3. Email Marketing

- **Newsletters:** Send regular updates on new features for current users, and industry insights to subscribers. We can encourage our users to subscribe for our newsletter by offering a discount on their price plan

4.4.3.1.4. SEO and SEM

- **SEO:** Optimize the Bioversee website for relevant keywords to improve organic search rankings.
- **SEM:** Invest in Google Ads to drive targeted traffic to the website through paid search campaigns.

4.4.3.1.4. Offer a FREE Trial Version of Bioversee

With the starter price plan, everyone is welcome to try our product without paying. However, this plan was created for individuals and DIY engineers, it can be a promotional tool as well.

4.4.3.1.5. Student Access as a Marketing Tool

We are planning to implement a student version of Bioversee, where an actual bioreactor will not be necessary. A fermentation process simulation will be developed, where the user can try out and learn about how a bioprocess in a bioreactor goes. Based on real data from our database we will develop a software, which can generate problems during the simulation, and the user must solve those problems, to reach the best possible results.

A teacher will be able to give tasks to the students and check their result. For example, the teacher specifies the organism and the nutrient medium for the fermentation and the students will have to decide the best physical conditions for the process.

As users engage with the simulation, they become proficient in operating reactors using our system. We can leverage this in future promotional campaigns aimed at businesses, emphasizing that recent graduates familiar with our control system will need minimal training when employed, thereby reducing onboarding time and costs for new hires.

4.4.3.2. Marketing Budget Allocation

Most marketing techniques we mentioned before were cost effective marketing solutions. Our marketing budget is tight. Most of our net income will be used to cover development costs and provide a stable hosting service for our web application. *Table 8* below shows how our marketing budget allocates. Science Bioversee is a software for a specific cause there is no random traffic here, we need to attract people looking for this specific kind of tools and software. We expect online advertising to make the band known amongst bioengineers. Customer support is on high priority for us because we have to keep our customers.

Item	Percentage
Content Marketing and SEO	35%
Social Media Marketing and Email Campaigns	0-5%
SEM and Online Ads	35%
Customer Support	25%

Table 8: Marketing budget allocations in percentage

4.4.3.3. Metrics to Measure Marketing Campaign Success

In early stages of Bioversee it will be hard to use different measurement techniques to review how marketing campaigns benefit the company. A good way is to ask users, when they create their account on our website, where did they found us. This can show us which strategy we should focus on and where we can save time. Another way for marketing measurement is to use statistics provided by social media platforms we are planning to use.

4.5. Organizational Structure and Management

4.5.1. Flat Structure

Planned to be a small startup company, an ideal flat structure for Bioversee would consists of 3-6 employees. With this size, everyone reports directly to the founder/owner.

- CEO (Chief Executive Officer): The head of the company and is responsible for the overall strategy and direction of the company. In our case our CEO will fulfill the CTO (Chief Technology Officer) position also. He/She will be responsible for the company's technology strategy and infrastructure as well.
- CFO (Chief Financial Officer): Responsible for financial health, including overseeing the accounting, budgeting, and financial reporting functions. To save costs on human resources, our CFO has to handle CMO (Chief Marketing Officer) duties as well, like developing and executing marketing strategies.
- COO (Chief Operating Officer): Reliable for the day-to-day operations ensuring that products and services are produced and delivered efficiently.

4.5.2. Recruitment Plan

4.5.2.1. Recruitment Goals

Our first recruitment plan aims to succeed the following goals:

- Hire 2-5 employees in the following 6 months to accelerate the start of Bioversee software development and deployment.
- Recruit individuals who align with our company's mission
- Hire employees who are capable of filling in multiple positions, roles.
- Find qualified workforce, able to keep up with the company's development speed.
- Candidates must have leadership capabilities; it will be useful in the future.

4.5.2.2. Positions to Fill

Technology staff positions:

- Frontend software developer
- Backend software developer
- Electrical engineer
- Mechatronic engineer

Economics staff positions:

- Marketing specialist
- Financial analyst

4.5.2.3. Target Candidate Skills:

- **Grit and Resilience:** Things won't always go according to plan, and startups often require long hours and overcoming challenges. People with "grit," the combination of passion and perseverance will push through difficulties.
- **Adaptability and Comfort with Ambiguity:** Bioversee will constantly evolve, and there may not always be clear roadmaps.
- **Self-Motivation and Initiative:** In a small team, such as ours, everyone needs to wear multiple hats and take ownership over tasks. We are looking for people who are self-starters, proactive, and can get things done without needing constant micromanagement.

- **Collaboration and Communication:** Teamwork is crucial in a small company. Our future employees are required to communicate effectively, collaborate with others, and build a strong team spirit.
- **Learning Agility and a Growth Mindset:** The industry and the company itself will likely change rapidly. We need people who are eager to learn new things, adapt their skills, and embrace a growth mindset.
- **Passion for the Mission:** Believing in the company's purpose goes a long way. Hire people who are genuinely enthusiastic about what Bioversee was created for.

4.5.2.4. Talent Sourcing Methods

- Online Methods:
  - Employee Referral Programs: Encourage current employees to refer qualified individuals from their networks by offering incentives.
  - Social Media Recruiting: Target platforms like LinkedIn Recruiter or Profession can provide a great platform for job advertisement.
  - Online Communities & Forums: In industry-specific online communities or forums where professionals gather and network it is also likely that we can find employee candidates.
- Offline Methods:
  - Headhunting/Recruitment Agencies: Partner with specialized agencies to leverage their expertise and network for specific roles.
  - Employer Branding: Build a strong employer brand that showcases Bioversee`s culture and attracts top talent organically.
  - Networking Events: Attend industry conferences, meetups, or career fairs to connect with potential candidates directly.

4.5.2.5. Applicant Evaluation Methods

At the start of the company, we will rely on traditional evaluation methods. Our founder will choose personally between candidates. He/She will evaluate their resume and interview them personally. As the company grows, an HR (human resources) generalist will be needed to (besides several other tasks) do the hiring process.

With time, we are planning to choose an HR software to accelerate applicant evaluation process.

4.6. Operation Plan

Bioversee has limited budget and just a few employees. Our founders will handle most of the programming and product development. There will be 1 employee for all economic and customer service tasks. This operation plan will outline daily operational processes to ensure efficiency and productivity.

4.6.1. Objectives

- Ensure all tasks are completed efficiently.
- Maintain high quality and research speed in product development.
- Provide excellent support for customers.
- Ensure operations are sustainable within budgetary constraints.

4.6.2. Daily Schedule

Morning (8:00 AM - 12:00 PM)

- **Daily Stand-Up Meeting (8:00 AM – 8:30 AM)**
  - **Attendees:** All employees
  - **Agenda:**
    - Review previous day`s tasks and progression.
    - Discuss any errors in development progression.
    - Outline tasks for current day.
    - Stand-Up meeting is not mandatory, if the management agrees
- **Programming and Development (8:30 AM – 12:00 PM)**
  - Development team working on programming and planning tasks.
  - Implement new features, fix bugs, and improve existing functionalities.
- **Financial and Administrative Tasks (8:30 AM – 12:00 PM)**
  - Manage financial records, invoices, and budgeting.
  - Handle administrative tasks, such as payroll and expense reports.
  - Monitor cash flow and prepare financial reports for review by the founders.
- **Lunch Break (12:00 PM – 1:00 PM)**

    - Every employee has the liberty to choose freely, when he/she wants to have his/her 1-hour lunch break.
    - Lunch break between 12:00 PM and 1:00 PM is only recommended.

Afternoon (1:00 PM - 4:00 PM)

- **Customer Support (1:00 PM - 2:00 PM)**
    - Development team provide technical support and troubleshooting assistance for our customers.
    - Answer questions about our product on our advertising platforms.
    - Keep in touch with the community.
- **Afternoon Progress Meeting (2:00 PM – 2:10 PM)**
    - **Attendees:** As required
    - **Agenda:**
        - Handle short term problems.
        - Ensure fluent corporate communications.
- **Marketing and Outreach (2:10 PM – 4:00 PM)**
    - Manage social media accounts and post updates.
    - Send out email newsletters and promotional content.
    - Monitor marketing campaigns and analyze their effectiveness.
    - Identify potential partnerships and outreach opportunities.
- **Product Testing and Quality Assurance (2:10 PM – 3:00 PM)**
    - Conduct testing of new features and updates.
    - Perform quality assurance checks to ensure software reliability.
    - Document any issues and work on resolutions.
- **Team Collaboration and Planning (3:00 PM – 3:45 PM)**
    - Long-term projects and planning.
    - Discuss upcoming milestones and deadlines.
    - Brainstorm ideas for new features and improvements.
    - Review feedback from customers and incorporate it into planning.
- **Wrap-Up and Reporting (3:45 PM - 4:00 PM)**
    - Summarize daily accomplishments and create records in project management tools.

- Plan tasks for the next day based on progress and priorities.

4.6.3. Tools and Software Needed for Daily Operation

- **Project Management**: Asana for task tracking and project management.
- **Communication:** Slack for team communication and collaboration.
- **Financial Management:** QuickBooks for accounting and financial tracking.
- **Version Control:** GitHub for source code management and collaboration.

4.7. Financial Plan and Projections

Creating a financial plan and especially financial projections for a startup is not an easy task. We have a software called Bioversee and we would like to fund a company to distribute our invention and generate profit from it. Since we only know what we have already spent on development, our projections will be based on good guesses and suggestions. The financial plan of Bioversee needs to be updated, as we progress with our marketing research.

4.7.1. Initial Capital Requirements and Sources

Bioversee has limited funding. Here we try to collect the variety of initial capital requirements to cover our business operation.

4.7.1.1. Initial Capital Requirements Breakdown

- **Product Development:** In early stages product development will be a small portion of our funding money. Costs associated with developing and refining Bioversee's software such as paying for hosting service or paying for our domain name are relatively cheap during our customer base is limited.
- **Marketing and Sales:** We are planning to spend most of our money on advertising. Initial marketing campaigns, sales team salaries, promotional materials.
- **Operations:** The cost of operations will be minimized as much as possible. We plan to save on not renting an office space immediately, just when the company can afford it from income. Some people do not like fully remote jobs. Meetings are more fluent in person. There are startup incubator services available, which can be a fine middle

ground on saving on office place but have a meeting room at the same time. Operation expenses will occur on utilities, equipment, administrative expenses.

- **Legal and Regulatory:** Fees for legal services, patents.
- **Contingency Fund:** Extra funds reserved for unexpected expenses.

4.7.1.2. Sources of Capital:

- **Equity Financing:** Investments from founders, angel investors, venture capital.
- **Debt Financing:** Loans from banks or other financial institutions.
- **Grants and Subsidies:** Potential government or industry-specific grants. The European Union offers a lot of found nowadays for innovative ideas.
- **Crowdfunding:** Potential campaigns on platforms like Kickstarter.

4.7.2. Sales Revenue Projections

To forecast the financial performance of Bioversee, we have developed detailed sales revenue projections over the next three years. These projections are segmented into business and individual price plans, providing a comprehensive overview of expected income streams.

The projections for business price plans (*Table 9)* suggest a consistent increase in adoption by companies and small businesses. This growth is expected to be driven by our targeted marketing campaigns and the increasing demand for efficient bioreactor management solutions in the brewing, and pharmaceutical sectors. However, we aim to prioritize direct sales in these sectors, our greatest potential for success lies in forming industry partnerships, if we can agree with bioreactor manufacturers about, they use our software on their hardware and create specific pricing agreements.

Business Price Plan	Price	Number of subs in year 1	Number of subs in year 2	Number of subs in year 3
Tier 1	$ 70,00	10	30	50
Tier 2	$ 100,00	5	10	20
Tier 3	$ 300,00	0	1	5
Net sales revenue / month	-	$ 1 200,00	$ 3 400,00	$ 7 000,00

Table 9: Net sales revenue projections for Business Price Plans in the next 3 years

The individual price plans (*Table 10*) show a promising market among homebrewers and DIY bioreactor enthusiasts. Although this segment is smaller compared to the B2B market, the projections indicate a steady rise in revenue as more individuals become aware of the benefits and ease of use provided by Bioversee which can benefit us as a marketing tool. As more individuals start using our service, the brand`s overall awareness and respect will grow.

Individual Price Plan	Price	Number of subs in year 1	Number of subs in year 2	Number of subs in year 3
Starter Plan	$ -	10	30	100
Advanced Plan	$ 10,00	5	10	20
Net sales revenue / month	-	$ 50,00	$ 100,00	$ 200,00

Table 10: Net sales revenue projections for Individual Price Plans in the next 3 years

The combined projections (*Table 11*) reveal an overall upward trend in net sales revenue, reinforcing our confidence in Bioversee's market potential and scalability.

	year 1	year 2	year 3
Net sales revenue / year	$ 15 000,00	$ 42 000,00	$ 86 400,00

Table 11: Net combined sales revenue projections for the next 3 year

The projections we did are optimistic, it is essential to monitor market conditions and correct our strategies accordingly. Potential risks include changes in industry regulations, competitive actions, and economic fluctuations.

4.7.3. Operational Cost Planning

	Year 1	Year 2	Year 3
Material costs of prototype machinery	$ 200,00	$ 100,00	$ 100,00
Personal expenses	$ 8 400,00	$48 000,00	$72 000,00
Depreciation description	$ 600,00	$ 600,00	$ 600,00
Total direct costs	$ 9 200,00	$48 700,00	$72 700,00
General costs of sales	$ -	$ -	$ -
Marketing costs	$ 1 200,00	$ 1 800,00	$ 2 400,00
Administrative costs	$ -	$ -	$ -
Other general expenses	$ 120,00	$ 180,00	$ 240,00
Total indirect costs	$ 1 320,00	$ 1 980,00	$ 2 640,00
Total operation costs	$ 10 520,00	$50 680,00	$75 340,00

Table 12: Operational cost planning for the next 3 years

4.7.4. Financial Result Plan

	Year 1	Year 2	Year 3
Revenue	$15 000,00	$42 000,00	$86 400,00
Total direct costs	$ 9 200,00	$48 700,00	$72 700,00
Coverage amount	$ 5 800,00	$ -6 700,00	$13 700,00
Total indirect costs	$ 1 320,00	$ 1 980,00	$ 2 640,00
Net income	$ 4 480,00	$ -8 680,00	$11 060,00

Table 13: Yearly financial result planning

4.7.5. Loan Repayment and Interest Payment Planning

We are not planning on taking any loans yet. Loans will be not out of question in the future, however with the estimations the second year for Bioversee will be a negative year. Taking a loan can be a solution for that period.

Seeing how the company does in the first couple of months will determine our possibilities for the future.

5. Discussion

With the use of a pre-built programming technology stack called MERN and a few Python scripts, I managed to create a system, where the user can control any bioreactor from anywhere, if there is internet access. Through prototyping the system proves itself and showed that is capable of managing a bioprocess in a reactor.

On the business front, although the market research is still in the planning phase, the anticipated steps involve comprehensive surveys targeting potential customers to assess their willingness for purchase. This planned research aims to confirm a significant interest in affordable and efficient solutions for enchanting aging bioreactors and a new way for controlling them. The feedback gathered is expected to indicate that laboratories and businesses with tight budgets are keen on adopting cost-effective upgrades rather than investing in entirely new bioprocess systems. This insight underscores the potential for Bioversee to fill a niche market need, offering a sustainable alternative that extends the lifespan of existing equipment.

In summary, the Bioversee project not only demonstrated technological feasibility and innovation but is also poised to validate market demand through planned customer feedback. The combination of technical validation and anticipated positive market response lays a strong foundation for the future development and commercialization of Bioversee, positioning it as a valuable tool for enhancing laboratory efficiency and sustainability.

6. Conclusion

Throughout my research I found out that there is room for development in the bioprocess industrial automation controlling. Bioversee lays down the foundation of a new way of developing industrial control systems by focusing on web applications. One of the major advantages of web applications over desktop applications is that, since they do not run locally, the local computer's resource requirements are lower. These can massively reduce cost and make hardware development easier.

My business plan for Bioversee showed, if I commit to my goal with my invention, which is to create significantly cheaper way for industrial automation control as well as creating a proper educational platform, where the students can practice controlling bioprocess systems with great visualization, my business will face may difficulties. At this point I believe my best option with Bioversee is creating partnerships with bioreactor manufacturers to use my invention to control their hardware. The marketing research will show how the market values my product and what the interviewed persons thinks about it.

7. Future Work

The first crucial task for ensuring Bioversee's future success is advancing the market research. I need to understand how the market values my invention, as this will determine necessary adjustments to the business model. My key question is whether the people on my target market is capable of upgrading an older bioreactor with an upgrade module. Bioversee is only a software. I have to provide a detailed guide on installing the local Python codes on an off-the-shelf customizable computer, such as a Raspberry Pi to my customers, but they must install the codes and connect the small computer to their device. This could pose challenges, potentially affecting the number of licenses sold. I will need to find a solution to remain viable.

I have to create an authentication method between the local small computer and the web application. I need to ensure that my customers data is safe, and everyone sees their own devices on the application.

I am planning to create customizable control surface, where the user can add and remove switches and sliders for actuators and graphs for the sensors, to set up a specific dashboard for themselves.

My biggest plan for the future is, when we have customers and their data from their machines is being collected in the database, we build a machine learning application and create a bioprocess simulator. This program will be developed mainly for students focusing on learning about bioprocess systems. Using the same control surface, they will poetically use on a physical device, they can see how the process works in the simulation with randomly generated problems based on real world data. This can be a cost-effective solution for both studying and practicing.

The first type of device I implemented were bioreactors, however the system is prepared to control basically any industrial machinery. Currently I am working on the implementation of a water treatment plant, which can open new markets for Bioversee. I believe that the water filtration industry is rapidly growing nowadays and on that filed there are many individuals and they like modern solution and new ways of thinking.

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