

Air-Balanced Bites - Project Report

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Abstract

In our data-driven society, data representation is a crucial problem that affects decision-making in many different sectors. This project examines the need for the physicalization of abstract data using inflatables in order to make it more accessible and palpable. Our project aims to allow users to build their usual meal and see how it meets the proposed standards. Also, the user is given the opportunity to change their choice in the process by removing or adding certain products, which helps them think about possible changes in their diet and makes their further choice more conscious.

In our case, inflatables act as a pneumatic system that pushes out the table legs at indicators above or below the norm, which makes it possible to clearly see the result of their choices. The table's four inflated components, which correlate to important nutritional indicators and dynamically display meal balance, provide a useful and memorable way to comprehend dietary choices.

The study describes the theoretical underpinnings, driving forces, and design methodology of "Air-Balanced Bites," an interactive dining table that physically depicts the nutritional balance of meals in real time.

Introduction

We live in an era that is characterized by the unending flood of information. Data surrounds us, from our daily step counts to the minutes we spend engaged in our digital interactions. This ubiquity of our data in our daily lives serves as the basis of our research.

Our main concern revolves around the challenge of representing this everyday life data. Data representation is a challenging topic for data scientists and designers. The main challenge lies in our ability to transform this information into a meaningful and comprehensible format. In a world where data governs decisions in every context, the ability to effectively represent it has a significant societal implication and impact. It influences how individuals make everyday decisions, how policymakers develop strategies (Sosa et al., 2018), and direct businesses in tailoring their services to meet customer needs.

Our work seeks to bridge the gap between the abstract nature of data and its tangible representation by exploring diverse approaches. Key questions driving this project include: How can we physically represent data? How can this physicalization be done through specific materials like inflatables? What challenges and opportunities does this present? With Air-Bites we explore the data physicalization through inflatables.

As Jansen et al. (2015) in his work Opportunities and Challenges for Data Physicalization states, Data Physicalization is an emerging field that aims to fill the gaps between Visualization of data and Tangible User Interfaces. They also highlight the advantages of physicalizations over traditional screen-based methods, as they enable individuals to better understand the information by physically manipulating objects, making it interactive as long as there is an input. However, there are also challenges, as Jansen mentions, dynamic physicalizations require materials that fit the variable they encode, often they require computer-driven control of the material properties and dynamic physicalizations. Moreover, it is crucial to select the most suitable physical variables for translating digital data. Another challenge lies in the potential for different people to interpret or represent the same data differently, which can lead to ambiguity or miscommunication.

With Air-Bites we hope to explore and shed light on the potential of data representation through a non-conventional method, inflatables, and ultimately empower people to make informed decisions about their dietary habits.

This report is structured as follows: We begin with an explanation of the theoretical background, the gaps within and the relevance of our work. Then we explain our motivation and design process. Finally, we conclude with the insights, discussion and recommendations that came up from our process.

Theoretical background

The Importance of Dietary Balance

Understanding the fundamentals of a balanced diet, which includes the proper ratios of proteins, carbs, fiber, and healthy fats, is crucial to understanding the underlying principles of this project. A well-known concept in nutrition is achieving dietary balance (Europe PMC, n.d.). It is essential for improving lifespan and general health (Lim, 2018). In addition to ensuring the right amount of necessary nutrients are consumed, a balanced diet lowers the chance of developing chronic illnesses including obesity, diabetes, and heart disease. These factors emphasize the critical part that a balanced diet plays in our wellbeing.

Nutritional User Interface (UI) and User Experience (UX)

Norman and Nielsen's (2010) research highlights the value of user centered design, which takes into account the requirements, preferences, and feedback of the user. Effective UI/UX design is essential to the "Air-Balanced Bites" project since the goal of it is not only to inform

the user about the dietary topic, but also to get and maintain the user engagement in the meal creation process of the project.

Data Visualization and It's Basic Concepts

Data representations in the physical world have been around for thousands of years. The study of computer-supported, physical representations of data and their support for cognition, communication, learning, problem solving, and decision making is known as "Data Physicalization," and it is only now that advances in digital fabrication, actuated tangible interfaces, and shape-changing displays can support this emerging field. The essential tenets of data visualization center on the graphical depiction of data, which allows viewers to see complex patterns, trends, and linkages in the data that are not visible in more conventional textual or numerical representations. Data physicalizations can tap more deeply into our perceptual exploration abilities than traditional computer setups because they are physical artifacts. Additionally, because they are dynamically physical, they have some advantages over static artifacts such as easier creation, support for data adaptation, and user sharing (Alexander et al., 2015).

A key component of the "Air-Balanced Bites" project, data visualization plays a crucial role in making complex nutritional data easier to understand. The effectiveness of data visualization is crucial for assuring the accessibility and understandability of nutritional information by enabling its transmission to a larger and more varied audience (Post et al., 2003). In this project, we used inflatables to visualize data.

The Role of Inflatables in Data Visualization

Data may be represented physically using inflatables in a tactile and engaging way. Designers may visually intuitively communicate information such as numerical numbers, trends, or real-time data by expanding or deflating different elements of an inflatable item. An inflatable globe, for instance, might be used to represent global temperature fluctuations, with various parts expanding or deflating to indicate changes in temperature. In our project, we have used inflatables as a pneumatic device, which, depending on the input parameters, "pushes out" certain table legs.

The term "pneumo tactile feedback" in the context of our study proposes the usage of inflatable actuators to give consumers tactile input. This feedback in data visualization might improve the user's experience by letting them see and interact with the data elements.

In conclusion, the "Air-Bites" project's key components include a healthy diet, UI/UX design, data visualization, and the usage of inflatables. In addition to emphasizing user-centered design principles and the potential of data visualization and inflatables for user engagement and education, existing research also underscores the necessity of nutritional balance for health. These ideas form the cornerstone of the strategy used in "Air-Balanced Bites" to close the knowledge gap in nutritional education.

Design process

Our design strategy focused on the development of concepts meant to encourage user interaction with the data presentation. One concept in particular, the idea of encouraging a fun connection in which users may partake in competitive or recreational activities with the data, struck out as especially interesting among the variety of possibilities we studied. We developed a conceptual framework throughout our brainstorming process that was based on the ideas of balance and imbalance, which we thought might be applied to inflated constructions. However, we needed compelling and impactful data relevant to our user base in order to go forward effectively.

In our discussions, we considered a number of data categories, such as pension insurance and related subjects, individual environmental effects and the dynamics of climate change, air quality indices, carbon emissions, and many more. We carefully excluded data types, such as insurance data, that did not fit well with this overall theme as we dug further into the idea of balance. As a result, we will not elaborate on concepts linked to these data categories in this work; instead, we will only discuss concepts that eventually influenced our final design.

As personal data on environmental impact and climate change is highly relevant, we continued working on this topic. The approach we took here is described by Sosa et al., in his 2018 published paper, "Data objects: design principles for data physicalization", as data to object. As we already filtered data and examined their material properties in the first step we continued our design process with developing concepts for objects especially in this case for real time data and how to distort or break proportion of the chosen object and imbalance it. We chose to do so because the data was supposed to come from the users themselves, which should increase the impact on them. The interaction as well as the product's function therefore should be positively or negatively impacted by the result. We then decided in our aim to provide a playful learning experience for the concept of alternating a table tennis game.

First a questionnaire with several questions about habits that have a negative impact on the environment, such as frequent air travel had to be answered. The user would then be confronted, influenced with this data in a game of table tennis. While his racket, being one inflatable, would be affected by his habits due to the lack of air losing some functionality and making it harder to succeed in the game, the ping-pong table would tilt according to the changing climate conditions, such as the increased temperature during the game. All in all, the project was intended to draw attention to this serious problem and to highlight the increasingly lopsided environmental system.

As this idea turned out to be too complicated, especially in terms of making the bats for the game, we decided to transfer some interesting concepts to another idea. As the table was already quite prominent as a way of representing imbalance in earlier ideas, which included showing four related sets of data over time, such as a country's budget, by inflating or

deflating the legs of the table, we decided to stick with it. This method of object to data is an alternative way to structure the design process by taking an everyday object's materiality and proceeding to shape an instance of it based on the features of the data selected (cf. Sosa et al., 2018). Starting with the table which has different attributes that we could use.

A table as a physical object has various attributes and purposes. Tables and desks are essential pieces of furniture in both domestic and professional settings. Their primary attribute is a flat, elevated surface, typically supported by legs or a sturdy frame. Tables are versatile and serve various purposes, from dining to workspace. While desks are specifically designed for tasks such as writing, studying or working on a computer, and often have drawers or shelves for organization, a table is often of a simpler design. The history of tables and desks dates back to ancient civilizations, evolving from simple stone slabs to intricate woodwork and contemporary designs. Over time, these pieces of furniture have adapted to changing needs, reflecting the ever-evolving nature of human life and workspaces but kept the basic function of holding items elevated over the floor providing a safe space for placing different objects.

We developed a concept of mapping one attribute to each leg supporting the surface of the table. The goal is comparing values and examining distribution of these attributes. To distort and break the expected symmetry of a working table, the inflatable should take part. The aim here is to challenge the essential functions of a table and its flat surface. In our first prototype we wanted to construct each leg as an inflatable making it easier to comprehend with the eyes the changing of the data in real time and give the inflatable a substantial part in our data physicalization. This is similar to the concept of the income tables by Ricardo Sosa which focused as well on representing data through the table legs. The idea is that as the table leg becomes bigger and bigger the table can't be used to sit on it (Sosa et al., 2018). However we noticed issues with stability while working on our concept which resulted in us taking another approach to imbalance the table with inflatables impacted by the real time data.

As for the data relating to user habits, we decided on another actual topic, namely his or her personal diet. A meal divided into the four parameters of proteins, fats, fibers and carbohydrates, each mapped onto a leg of the table, was our idea to convey knowledge about personal nutrition and a balanced meal. In order to incorporate a playful interaction and acquire data real time, we set ourselves the goal of providing the user with a wide range of food products, which he or she could then use to experiment and prepare a meal for himself or herself. They could add or remove ingredients and try to create a delicious and balanced meal. The balance would then be represented by the shifting table, possibly leading to a scenario where the meal placed on the table falls to the floor. Similar to the income tables described above, the table and its expected symmetry would be broken by the shifting, making it unusable to safely place anything on and thus depriving it of its functionality.

The motivation behind our design was, on the one hand, to give the user the opportunity to learn about his or her diet and how balanced and healthy it is, as well as to find out which foods have a major impact on the balance of a meal. On the other hand, the user was able to change the composition of his diet, helping him to understand how to improve the balance of his diet and better his future eating habits.

Because of the physical components and the inflatables used, users can get a real-time understanding of the nutritional balance of their meals. The concept of dietary balance is more approachable and memorable thanks to this practical method.

UCD concepts utilized in the final design

User Involvement: We investigated a number of methods for including users directly in the preparation of meals. The physical arrangement of the elements was chosen because of its tactile and interactive qualities.

Feedback Mechanism: We looked at a number of graphic representations to give users rapid feedback. The unambiguous communication of the balance across dietary indices was a key factor in the selection of the inflatable components.

Usability: To make sure the interface was simple to use and intuitive, extensive user testing was done. For a wide range of users, it was important to make the experience fun and educational.

Explanation of the final design

The final version of "Air-Balanced Bites" is an interactive dining table with a user interface that enables users to choose and arrange components in a bowl to make meals of their choice. Four inflatable parts are essential for the table, one for each of the four nutritional indices (proteins, carbs, fiber, and healthy fats). These inflatables graphically show how close a meal is to obtaining a balanced diet by expanding or contracting depending on the meal's ingredients and thereby lifting the table leg to imbalance the table and tilt it towards the opposite side. The inflatables were placed inside a tube while the table leg rested on them. Now if they get inflated the rising pressure would push the leg along the tube into the air as portrayed in the sketch.

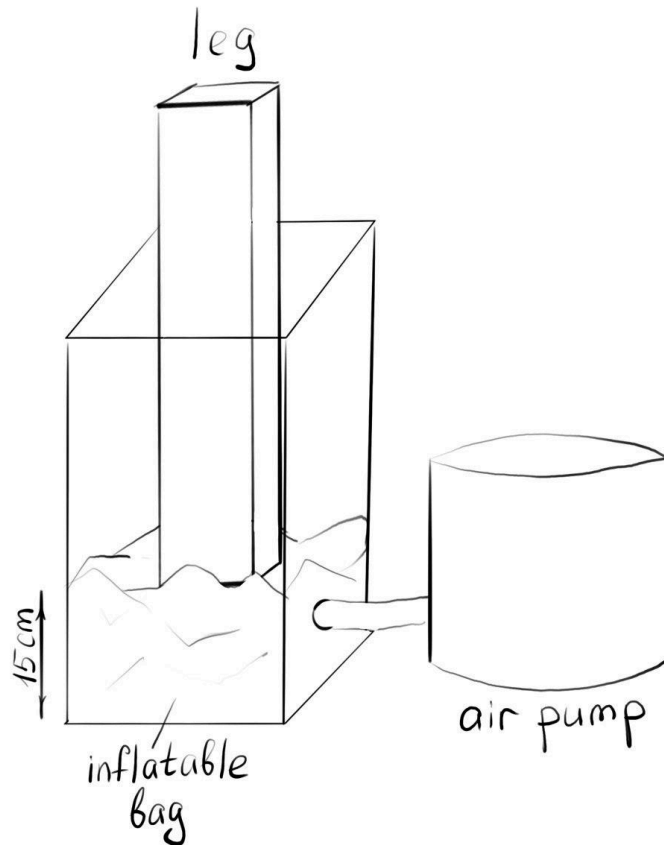


Fig.1: The construction around the table leg with the inflatable

The values for each of the indexes (Fats, Fiber, Protein, and Carbohydrates) were determined following a research into dietary recommendations. Our choice was to rely on the Dietary Guidelines for Americans, which are jointly issued by the U.S. Department of Health and Human Services and the U.S. Department of Agriculture, as they already provide percentage recommendations. Ultimately, we opted to establish a range of percentages for each index due to uncertainty regarding the age range of potential users, aiming to encompass the broadest possible demographic. Consequently, the resultant values for the total percentage per meal are as follows:

Tab. 1: Target percentages per meal

Fiber	10-15%
Protein	20-30%
Healthy fats	25-35%
Carbs	45-65%

For the food products we had cards designed with images of various ingredients to which an NFC tag was attached. Each tag contained the information about the proteins, fats,

carbohydrates and fiber of each ingredient per 100 grams or per piece. The tag's data was read with an NFC-reader placed on the table. There were also cards for resetting, removing an ingredient, adding an ingredient, and a launch (balance) card.



Fig. 2: A excerpt of the food products with NFC tag and controlling cards

The user was required to select the desired ingredients, enter the mode of adding ingredients using the "add" card, scan all the cards with ingredients and place them in the bowl. After composing the meal he would scan the "balance" card. Consequently, the bags would inflate to the specified value only if the calculated percentage for the index fell outside the predetermined range, indicating either a deficiency or excess in one of the nutritional indices.

In a subsequent step, users had the option to remove an ingredient using the "delete" card or add more ingredients in an attempt to balance their initial meal. Afterward, they could rescan the "balance" card to view the resulting changes.

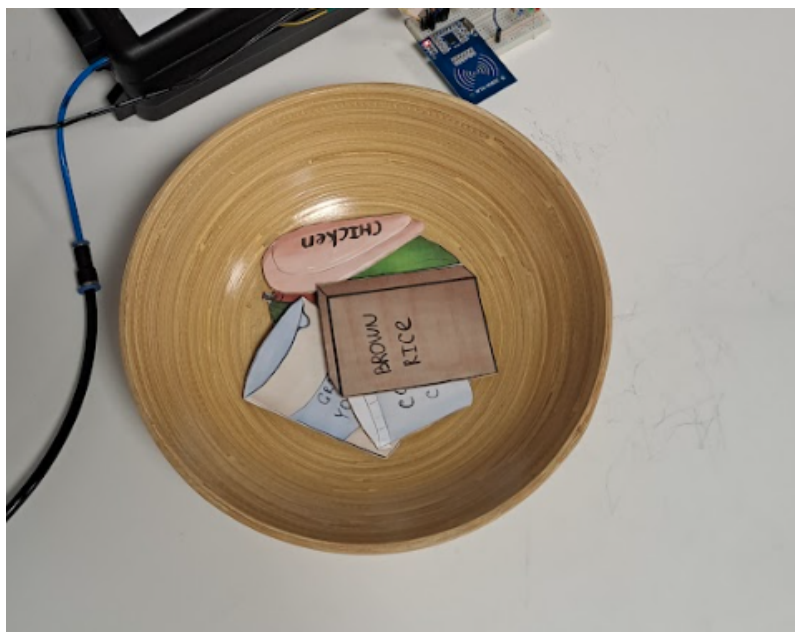


Fig. 3: An example of a meal preparation with the NFC reader next to it

Technical explanation of final design

The technical aspect of the system comprises two components: hardware and software. In the case of the software, we developed an Arduino code based on the logic outlined in the following diagram. It's important to note that the calculated values for each index, once all the desired ingredients are registered, are adjusted according to the following rule to prevent bags from inflating beyond 100%: The median value within the index's range is mapped to 50% in terms of the inflation percentage for the corresponding bag.

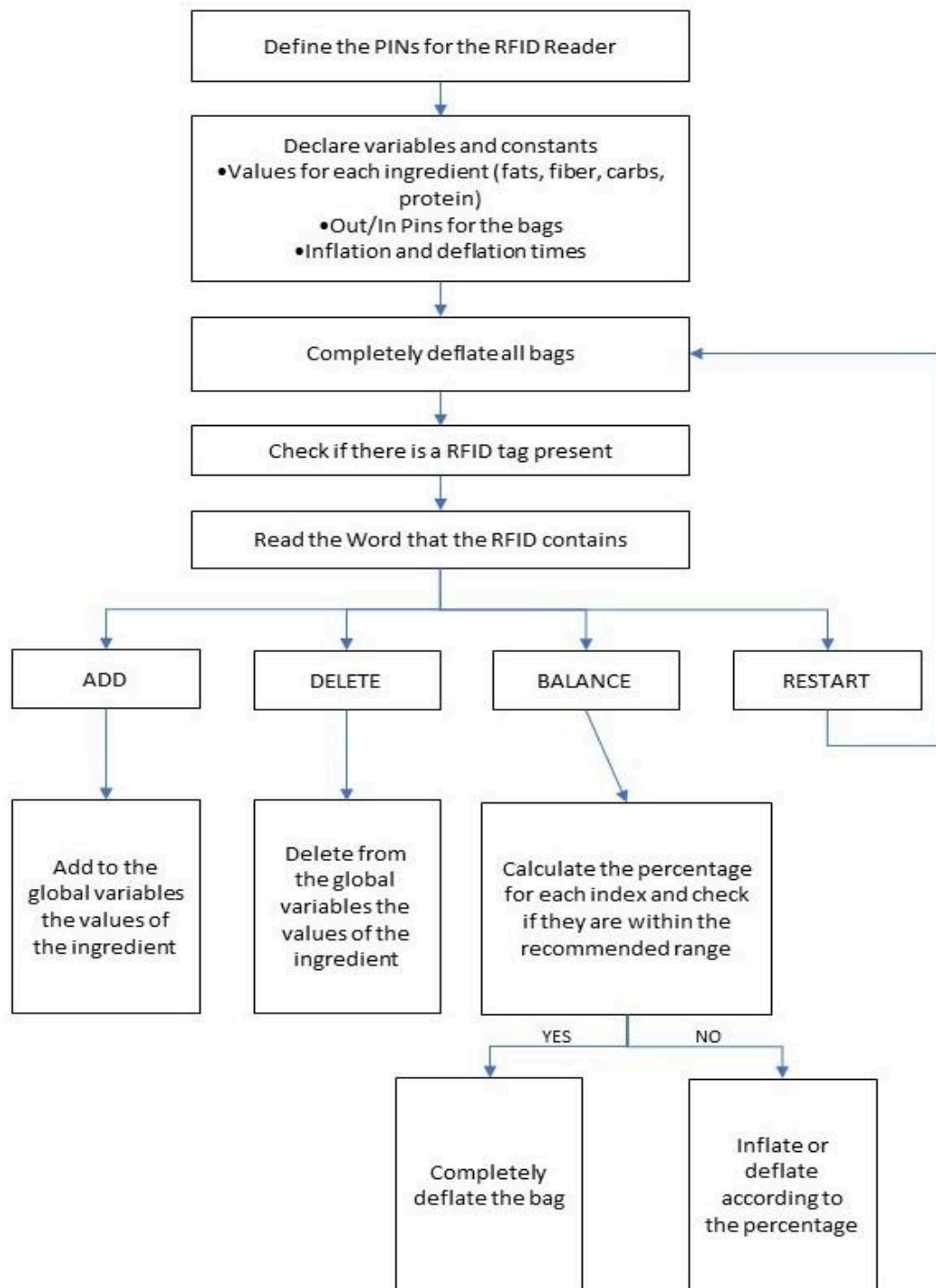


Fig. 4: Code-logic diagram

Regarding the hardware component, we control four air compression regulators using an Arduino Mega board in conjunction with a transistor electronic board. These regulators enable us to either inflate or deflate the bags associated with each index.

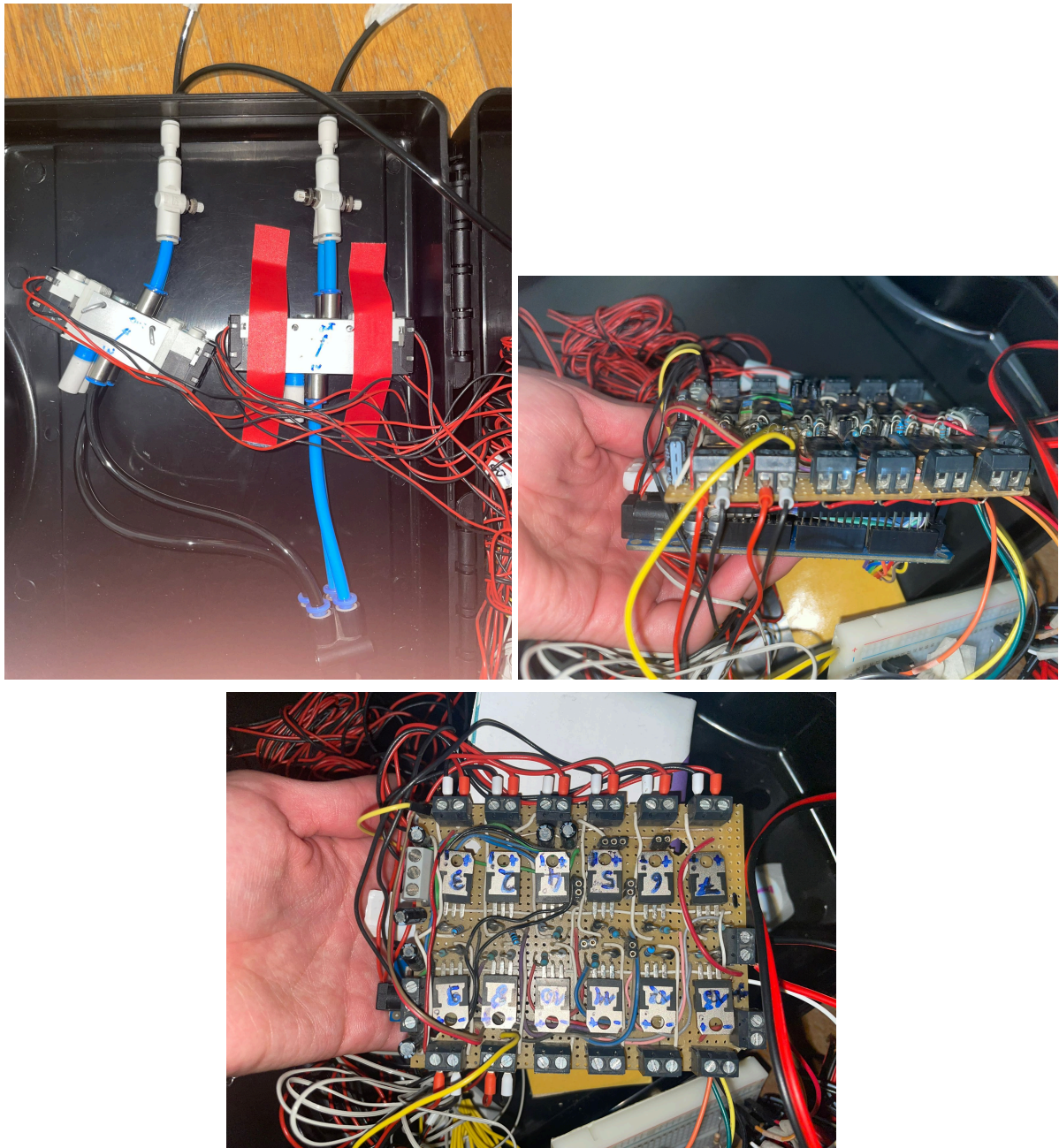


Fig. 5-7: Air compressors, Arduino Mega Board, Transistors electronic board

In addition to the hardware and software components, we also fabricated four airbags with a rectangular design and utilized four PVC tubes to secure the bags in place and insert the table legs into them.

Having explained our design approach and given an insight into our prototype on a functional level, in the next part we want to discuss how this work contributes to related work and to the field of data physicalization, in particular through the incorporation of inflatables.

Discussion

In the framework of this project, we talked about the idea of changing a table's leg proportions to suggest an imbalance, a topic also covered by Sosa et al. (2018) in their study. In the beginning, we considered the use of inflatables as a novel way to offer flexibility in modifying the size of table legs. However, we ran into problems with the physical characteristics of tables, such their size and weight, during the construction of Air-Balanced Bites. We think it's essential to give these things significant thought throughout the brainstorming stage. In addition, we envision a market opportunity for inflatables that can change their shape (Ou et al., 2016).

Additionally, our experiment supports a point made by Jansen et al. (2015) that emphasizes the value of reconfigurability in enabling rich physical interactions. Our user interaction insights confirmed the importance of allowing users the option to reimagine their meal preparation processes. Additionally, the many ways to create imbalance increased user interest. Similar to Jansen's focus on bridging the gap between data visualization and useful user interfaces, "Air-Balanced Bites" uses inflatables to connect abstract data to concrete representation. The advantages of physicalizations in improving data understanding through hands-on manipulatives are acknowledged in both publications, but they also note the difficulties presented by dynamic physicalizations and material choice.

Our project expands on this idea in line with Ou et al.'s study "aeroMorph" (2016), which investigates the use of inflatable materials for interface design. "Air-Balanced Bites" pushes the limits of inflatable material flexibility and dynamic adaptation for data physicalization by using inflatable shape-change materials to communicate nutritional information and meal balance.

In conclusion, the investigation into the use of inflatables to represent data in our project connects with and builds upon the concepts offered in the works cited, adding to the continuing debate in the subject of data physicalization.

Limitations and future work

We observed potential improvements and limitations not only during users' physical interaction with the table but also in our analysis for this report.

While users interacted with Airbites, a common behavior we observed was that, after completing the task of building their meal or even before doing so, they attempted to test the machine's limits by intentionally creating highly unbalanced meals. This is a common phenomenon described as adversarial input, where users deliberately provide input that challenges or exploits the weaknesses of an algorithm or system. This type of testing can be valuable in identifying and improving the robustness of machine learning models and systems, as it helps to uncover potential weaknesses and edge cases that may not have been considered during development (cf. Ju, et al., 2022).

While assigning a task to the users, our intent was to guide their actions, but we failed to instill sufficient motivation to ensure task completion. The allure of exploring the machine's limits outweighed the desire to accomplish the task effectively. Therefore, there is room for enhancement in our approach for future exhibitions. One potential improvement would be to introduce a scoreboard for balanced meals or offer a small prize to encourage users in successfully creating a balanced meal.

Another area for improvement is the optimization of food choices. It became evident that some common food options were missing when meals were prepared, which was a result of foods being selected primarily based on their composition within one of the four categories. To address this, consideration could be given to incorporating commonly used recipes tailored to our demographic, helping identify and include foods that resonate more with users. This could significantly boost user motivation and success rates in creating balanced meals.

Regarding the physical aspects of the project, there are opportunities for enhancement as well. Firstly, the caps on the tubes should be securely fastened to prevent dislodging over time due to the pressure by the inflatable bags. Additionally, a larger table size and increasing the spacing between its legs would improve the visibility of the tables state and the air distribution in the four index bags.

Finally, the exploration of other table shapes with more than four legs or corners is desired in order to map even more detailed food substances and gain insights into their balancing.

Additionally, one of the key limitations of Air-Balanced Bites is its current lack of accessibility for visually impaired individuals. While the physicalization approach offers an engaging way to convey the information, we acknowledge that the input excludes visually impaired persons. This could be one potential area of improvement with the potential integration of tactile or auditory elements.

Another limitation and a potential area for future improvement is that the system cannot be personalized based on the age and physical characteristics of individual users.

An essential consideration for future enhancements is to enhance the visibility of the inflatable component. In the current design, users often remained unaware of how the system would present the outcome of their choices right from the outset. Addressing this issue may involve modifying the materials used in the physical components or exploring alternative methods for displaying the data.

Conclusion

The paper discusses the approach of physicalizing data, enabling the audience to see complex patterns, trends and relationships in the data that are not visible in traditional textual and numerical displays. To this end, we evaluated different ideas and concepts for using inflatables as a physical representation of data. One way is to use them as tactile and engaging opportunities. In our project, we have used the inflatable as a pneumatic device which, in combination with the table object, is intended to represent an imbalance that can be experienced. From there, we developed a step-by-step solution for presenting the chosen data and making it accessible to users. A first concept involved a table whose legs would be influenced by inflatables to unbalance it and illustrate the impact of the real-time data. Based on this concept, the final idea was to have life data collected from the user concerned about their diet and the proportions of fat, fiber, protein and carbohydrates contained in their daily meals. The percentages would then be mapped onto a leg and inflatable, which would then be pressurized or depressurized according to the target percentages. This data could be gathered by letting participants compose their meal by scanning NFC tags on cut outs of food products containing the information for the algorithm. The result was a physical and tangible visualization of the balance in their diet.

The aim was to create an interesting and interactive solution that would educate and inform users about the balance of their actual diet, while giving them the opportunity to learn about nutrition and how they can improve their meals by adding or removing different components to achieve a better balance and a healthier lifestyle.

We generated a number of important contributions to the field of data physicalization during the course of this research. First, by using inflatables as dynamic elements, we have developed a method for displaying abstract data, notably in the context of food patterns. This method not only eliminates the gap between abstract data and physical representation, but it also creates exciting new opportunities for the use of unconventional materials in data transmission. Additionally, our effort sheds light on the advantages and disadvantages of material choice and shape, emphasizing the need of carefully evaluating the physical characteristics of objects engaged in data physicalization. Our findings also support and build on the theories presented in earlier studies, demonstrating the importance of user involvement and reconfigurability in data physicalization. In the end, "Air-Balanced Bites" presents a strategy for communicating dietary data and meal balance, extending the library of data physicalization tools and enhancing the field's conversation.

Attachment

Access to arduino code: <https://github.com/gabrielarosalba/Air-Balanced-Bites>

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