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3 Design

3.1 Design Context

3.1.1 Broader Context

Describe the broader context in which your design problem is situated. What communities are you designing for? What communities are affected by your design? What societal needs does your project address?

List relevant considerations related to your project in each of the following areas:

Area	**Description**	**Examples**
Public health, safety, and welfare	This project has a direct effect on the shareholder groups in this because everyone is going after the same goal of using DNA as storage and everyone is facing the same challenges.	Creating jobs / opportunities for research when money is dumped into it.
Global, cultural, and social	The project is culturally appropriate because we are just trying to figure out a way to store data in DNA and create longer nucleotides of the DNA without any mutations. This would affect everyone in some way because of how big this research is and the possibilities of this.	Could potentially say once this gets figured out, I don't know how all cultures would feel about replacing someone's DNA strand (Take out bipolar gene), so genetics doesn't keep passing it down.
Environmental	There wouldn't be any environmental impacts because there are no harmful chemicals / unsustainable practices being used when doing research. Only good impacts like lower energy consumption.	The amount of energy needed to create the long strands nucleotides / extract the DNA to get the data is unknown.
Economic	The economic impact of this is significant because this could change the way we store data in a more efficient way. Eventually data storage will get more and more expensive.	Every business would store data this way because it would be cheaper and more efficient.

3.1.2 User Needs

List each of your user groups. For each user group, list a needs statement in the form of:

User Groups:

1. Researchers and STEM Institutions
    a. Researchers need a way to affordably experiment with DNA pairs because it will allow them to advance their research faster.
2. Educational Institutions
    a. Educational Institutions need a way to decrease the lead times of outsourcing DNA printing because it allows for faster access to the DNA and more flexibility.
3. Private Corporations
    a. Private Corporations need a way to increase efficiency in storing data because it will eventually become increasingly expensive to do so.
4. Curious Individuals
    a. Curious Individuals need a way to affordably print their own DNA pairs because it is currently far too expensive for a (normal) singular individual to fund.

User group needs (a way to) do something (i.e., a task to accomplish, a practice to implement, a way to be) because some insight or detail about the user group.

3.1.3 Prior Work/Solutions

Relevant background/literature review provided by our advisor, Professor Meng Lu

- Phosphoramidite Chemistry:
    - https://www.twistbioscience.com/blog/science/simple-guide-phosphoramidite-chemistry-and-how-it-fits-twist-biosciences-commercial#:~:text=Phosphoramidite%20chemistry%20is%20the%20gold,200%20base%20pairs%20in%20length
- Oligonucleotide Synthesis
    - https://en.wikipedia.org/wiki/Oligonucleotide_synthesis– If similar products exist in the market, describe what has already been done
- ADS Codex
    - As mentioned in our lightning presentation, the Los Alamos National Laboratory has developed technology that enables molecular storage. The Adaptive DNA Storage Codex (ADS Codex) translates data files from the binary language of zeroes and ones that computers understand into the four-letter code biology understands.
    - ADS Codex is a part of the Intelligence Advanced Research Projects Activity (IARPA) Molecular Information Storage (MIST) program
    - https://www.scientificamerican.com/article/dna-the-ultimate-data-storage-solution/

– If you are following previous work, cite that and discuss the **advantages/shortcomings**

- Advantages
    - The more institutions that get funds and conduct research on DNA storage the quicker it is that this problem will be solved.
- Disadvantages
    - The waste of material / waste fluid when testing on making the nucleotides on the DNA.
    - The energy consumption used to conduct research

– Note that while you are not expected to “compete” with other existing products / research groups, you should be able to differentiate your project from what is available. Thus, provide a list of pros and cons of your target solution compared to all other related products/systems.

Detail any similar products or research done on this topic previously. Please cite your sources and include them in your references. All figures must be captioned and referenced in your text.

3.1.4 Technical Complexity

Provide evidence that your project is of sufficient technical complexity. Use the following metric or argue for one of your own. Justify your statements (e.g., list the components/subsystems and describe the applicable scientific, mathematical, or engineering principles)

1. The design consists of multiple components/subsystems that each utilize distinct scientific, mathematical, or engineering principles –AND–
2. The problem scope contains multiple challenging requirements that match or exceed current solutions or industry standards.

Our project contains three main branches which we have to work on: Software, Hardware, and the Flow System. Individually each branch is complex on its own, from Software needing to create a fully integrated program connecting with both the flow and hardware along with implementing it into an easily usable user GUI to Hardware where we have to learn how to work with an LCD and optimize it enough so it keeps up with the rate we need it to without the heat interacting with the DNA to the Flow System which has up learning to build a system to quickly, reliably, and repeatedly send chemicals through a custom made cell and countering any potential problems working with fluids which we have never been taught to work with. This all being built on top of the work of a previous group, which has us continuing a project from other people like engineers need to do in the field instead of starting from the ground up like most all school projects have us do. We also need to make sure that our software is easily usable from a GUI and well automated enough to do with minimal inputs and manual running of steps, allowing any potential clients to be able to use our printer without intricate knowledge of how it functions step by step. Finally, even our flow system which must have each part designed to our specifications, has to be reliable enough to run several chemicals through it hundreds of times per sample we print in the end.

Design Exploration

3.2.1 Design Decisions

List key design decisions (at least three) that you have made or will need to make in relation to your proposed solution. These can include, but are not limited to, materials, subsystems, physical components, sensors/chips/devices, physical layout, features, etc.

We will be working, replacing and improving these sections and implement them in the project in the next few weeks

1. Software development:

GUI, hardware interface, DNA input/analysis and pattern generation

2. Hardware

LCD panel, UV/blue LED source

3. Flow System:

Flow cell fabrication, fluigent system

3.2.2 Ideation

For one design decision, describe how you ideated or identified potential options (e.g., lotus blossom technique). List at least five options that you considered.

We explored a few methods for identifying our potential options and we settled on the SCAMPER method. The SCAMPER method is a creative thinking technique that can be used to generate new ideas or solutions by exploring different aspects of an existing idea or product. The acronym SCAMPER stands for: Substitute, Combine, Adapt, Modify, put to other uses, Eliminate, Rearrange. By using the SCAMPER method, we can approach problems or ideas in a more structured and systematic way and generate a variety of creative solutions.

We also considered brainstorming, mind mapping, six thinking hats, SWOT analysis and reverse thinking. We were heavily inclined towards reverse thinking based on the nature of our project, but SCAMPER method aligned more with the design decision process.

3.2.3 Decision-Making and Trade-Off

Demonstrate the process you used to identify the pros and cons or trade-offs between each of your ideated options. You may wish to include a weighted decision matrix or other relevant tools. Describe the option you chose and why you chose it.

The SCAMPER method and the other techniques we listed are all valuable tools for generating new ideas and solutions in a team setting. That being said, one potential advantage of the SCAMPER method is its structured approach. The acronym provides a clear framework for exploring different aspects of an idea or product, which can help to guide the team's thinking and ensure that all possible avenues are explored.

On the other hand, some of the other techniques we listed, such as brainstorming and mind mapping, may be more effective for teams that prefer a more open-ended, free-flowing approach to idea generation.

Proposed Design

Discuss what you have done so far – what have you tried/implemented/tested?

3.3.1 Design Visual and Description

Include a visual depiction of your current design. Different visual types may be relevant to different types of projects. You may include: a block diagram of individual components or subsystems and their interconnections, a circuit diagram, a sketch of physical components and their operation, etc.

Describe your current design, referencing the visual. This design description should be in sufficient detail that another team of engineers can look through it and implement it.

Picture:

Currently, our design is fully based on the last group's progress. It includes a high-powered LED, an LCD, a microarray, a micro-fluidic system, a microcontroller, and a laptop to use to run the code and work as the GUI. The LED and LCD are housed below the micro-array to be used to solidify the A, T, G, and C solutions in their proper locations. The microfluidic system will wash over the microarray with the desired solution and then when complete, use a cleaning fluid to dispose pf the unused solution. Everything is housed within a 3-D printed housing unit. There is also an air compressor that will be providing the microfluidic system with pressurized air to be used in moving the liquids around the system.

3.3.2 Functionality

Describe how your design is intended to operate in its user and/or real-world context. This description can be supplemented by a visual, such as a timeline, storyboard, or sketch.

In the real world, this printer would closely resemble the use cases of a 3-D printer. It is compact enough to fit into a lab, classroom, or office. Functionally, the size of the 3-D printing unit would make it an asset in office or research spaces. Our current project fits our users' needs fairly well because of this, however our concerns detailed in 3.3.3 showcase that the practicality of this becoming a widespread technology (or a technology owned by basic consumers) is unlikely. While this technology will impact a wide group, it will more than likely not be operated by users outside of research, education, or large technology firms. However, even with that constriction in mind, the function of the system is still evident.

How well does the current design satisfy functional and non-functional requirements?

The previous team has made enough progress in making the current design work, now we are just trying to make it work more efficiently and get the bugs fixed in the code and upgrade the hardware to optimize the potential of the machine.

3.3.3 Areas of Concern and Development

Based on your current design, what are your primary concerns for delivering a product/system that addresses requirements and meets user and client needs?

What are your immediate plans for developing the solution to address those concerns? What questions do you have for clients, TAs, and faculty advisers?

The difficulties and concerns come into play with the integration of software and hardware. There is separate software that manages the flow control system, separate software for the 3-D printer and LED board, and countless other hardware pieces that need to work together.

NOTE: The following sections will be included in your final design document but do not need to be completed for the current assignment. They are included for your reference. If you have ideas for these sections, they can also be discussed with your TA and/or faculty adviser.

3.4 Technology Considerations

Highlight the strengths, weakness, and trade-offs made in technology available.

Discuss possible solutions and design alternatives

3.5 Design Analysis

- Did your proposed design from 3.3 work? Why or why not?
- What are your observations, thoughts, and ideas to modify or iterate over the design?

Design Plan

Describe a design plan with respect to use-cases within the context of requirements, modules in your design (dependency/concurrency of modules through a module diagram, interfaces, architectural overview), module constraints tied to requirements.