Deliverable B: Problem Definition, Concept Development, and Project Plan
GNG 2101– Introduction to project management and development

Group Z25

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Introduction:

This document aims to address the needs and problems faced by Dany, a client suffering from ALS (Amyotrophic Lateral Sclerosis). Due to severe physical movement limitations, Dany struggles with operating his indoor stationary reclining chair, which has various adjustable settings. In addition, his voice sometimes poses challenges in terms of clarity and intelligibility.

The objective of this document is to propose designs for a voice-controlled solution that will allow Dany to operate his chair effectively, even with his limited motor skills and voice impairments. Dany's stationary chair offers three different settings, each of which can be adjusted in two ways: the headrest, inclination of the chair, and footrest can be moved up and down. To ensure Dany's comfort during long periods of chair usage, it is crucial to provide a high degree of adjustability. Moreover, the ability to access standard positions using voice commands is also important for Dany's convenience.

Considering that the chair is always situated at home, internet access is available, eliminating the need for battery optimization or considerations regarding size and weight. While power supply from the controller is preferred, the option to connect the chair to a wall outlet is also viable. It is essential that the client or caregiver can still interact with the controller physically or via the installed voice command device.

The design should prioritize ease of maintenance and ensure a long operating life with minimal adjustments. Although ease of installation is not deemed critical, modifications to a mock controller will be allowed for experimentation purposes. It is important to note that the mock controller provided will not replicate the complexity of the actual controller, which presents a challenge in the overall design process.

The controller in question is a 9-Pin Standard controller designed for recliner and other chairs. By addressing these requirements and constraints, a robust voice-controlled solution will be developed to enable Dany to operate his reclining chair effortlessly, providing him with independence and comfort in his daily life.

B1: Problem Definition

This section will address the discussed needs and wants by the client, prioritize them, as well as clearly define the problem statement.

1. Needs and problems:

- Client has ALS, therefore has severe physical movement limitations.
- Sometimes he struggles with his voice, will make it hard to understand.
- He has a stationary chair that has 3 different settings, each of which can be adjusted in 2 ways: The headrest, inclination of the chair, and footrest can each be moved up and down.
- It is important for the client to have a high degree of adjustability to remain comfortable whilst using the chair, which can be for hours at a time. Additionally, other standard positions should be accessed with standard voice commands.
- Since the chair is always at home there will be internet access and no need for a battery or size/weight optimization.
- Power supply from the controller would be preferred, but it could also be connected to the wall.
- The client or caregiver should still be able to touch or use the controller with the voice command device installed.
- The device should be relatively easy for the user/designer to install. However, ease of installation was not specified as a critical aspect of the design.
- Ease of maintenance and the ability to have a long operating life with little adjustment is critical.
- Controller is a 9-Pin Standard controller for recliner and other chairs.

2. Knowledge gaps

Given the complexity of the project as well as the limited time available with the client, not every aspect is fully known or understood. Below a list with more specifics on knowledge gaps and things the tea would like to have a better understanding of:

1. Initial controller uncertainty: A mock controller will be sent to the TA's for us to experiment on, modifications to said controller are allowed. However, the mock controller will not be as complex as the real one, as it will only have one function that can be adjusted in two ways, as opposed to three functions that can be adjusted in two ways as would be the case for the actual controller. This will result in necessary revisions to the design, as the electrical circuit modifications needed might be different for each thing.
2. Voice clarity: Thus far, the clients speech impairment has been mentioned but not clearly defined, this might require for later adjustments to the voice recognition software and be a limiting factor in its performance.

3. Needs Prioritization

B.1.1 can be condensed into the following table

Need	Description	Priority: 5 (highest) 1 (lowest)
High degree of control over chair	Ability to make fine adjustments to the chair position	4
Memory	Ability to mark preset positions on the chair and use them	2
Number of chair functions that can be controlled	Number of chair functionalities that can be operated	5
Installation	Relative simplicity of installation of the equipment	2
Maintenance	Necessary maintenance, both time and expertise wise	5
Network	Requirement of an internet connection or other resources	4
Power Supply	Usage of an additional power supply or feed directly from the pin from the remote	3
Reliability	Percentage possibility that the device will successfully understand and execute a command.	5
Cost	Overall material cost of the equipment	4
Manual operation of controller	Ability to manually operate the chair once the voice controller has been installed	4

4. Problem Statement:

Danny suffers from ALS and has difficulty with his motor skills and his voice. He cannot operate the remote to his indoor stationary reclining chair and needs a way to be able to operate the remote with his voice. A robust voice-controlled solution, which will allow for a fine degree of control of the chair without physical touch (and respond even if the tone used isn't perfect) must be implemented.

5. Metrics Units

Attribute (Score)	Best (5)	Good (3)	Bad (1)	Fail (F)
Degree of control over chair	Better than operating with hand (sub-1 second)	As good as operating with hand (1 second adjustments)	Binary control, no adjustability (ON/OFF)	No control
Memory (Presets)	Remembers infinite positions	Remembers 3 positions	Remembers 1 position	Remembers 0 positions
Number of chair functions that can be controlled	3 x 2 (head, reclination, feet) or the same number as those in the remote	NA	NA	Less than 3x2 or worse than that of the remote
Installation	Plug and play, no need for additional work	Requires a short amount of time or a non-trained person to install	Requires highly specialized personnel to install	Requires several days and highly specialized personnel
Maintenance	Requires no maintenance	Yearly adjustments	Monthly adjustments	Daily adjustments
Network	Requires no internet or access to networks	Connects to the internet	Requires another proprietary system to work (ie alexa)	
Power Supply	Works off the remote power supply	Works off a wall outlet	NA	More energy than that of a wall outlet
Reliability	Works 100% of the time	Works 99% of the time	Works more than 80% the time	Works less than 60% of the time
Cost	Assigned budget (150 CAD)	50% below market average (300 CAD)	At market value (630 CAD)	More expensive than market value

6. Benchmarking

1: Alexa VC for Invacare Beds 5400

3: Alexa VC for 15000 Beds

2: Alexa VC for Invacare Beds 5800

4: Alexa VC for CS5 and CS7 Beds

Four options were used as benchmarks. Metrics were chosen based on the criteria and needs established by the client. The existing products do not fully answer our clients need, and what needs they do fulfil they do for least 4 times the budget for the project.
As can be seen from the table below, all benchmarked alternatives have identical performance and can only be differentiated by price. The most expensive solutions would be 1 and 4, and the cheapest 2-3. However, they're all dependent on an Amazon Alexa and its proprietary voice recognition to work correctly.

Attribute	Best	Good	Bad	Fail
Degree of control over chair			1,2,3,4	
Memory (Presets)				1,2,3,4
Number of chair functions that can be controlled	1,2,3,4			
Installation	1,2,3,4			
Maintenance	1,2,3,4			
Network			1,2,3,4	
Power Supply		1,2,3,4		
Reliability		1,2,3,4*		
Cost			2,3 (639 USD each)	1 (854 USD),4 (799 USD)

*Only works with clear voice

7. Target specifications

Attribute	Ideal	Marginal
Degree of control over chair	Sub 1 second adjustability	3 second "push" interval adjustability
Justification	Every benchmarked option only offers either fully deployed or non-deployed position for the settings, which is not adjustable enough for our client. We want to provide at least some degree of adjustability between each position to comply with his needs.	
Memory (Presets)	10 Presets	3 Presets
Justification	None of the benchmarked products offers presets for positions, which was	
Number of chair functions that can be controlled	All systems in the remote independently	All systems but requiring adjustment in between
Justification	The ideal solution would entail the client being able to control all systems without a need to do any adjustments, however if some adjustment to the voice command had to be done to operate each of the functions that would be marginal (ie changing channels for different uses)	
Installation	Plug and Play	Require less than 30 minutes set up
Justification	Ideally neither the client nor the caregiver would have no need to configure the device, it should be able to just be plugged in and work. However, it wouldn't be the end of the world if a quick 30 minute set-up and calibration was necessary	
Maintenance	No maintenance	Calibration/Updates every year
Justification	The best solution would be one that requires no updates and that can run indefinitely without being adjusted, this so the life of the client can be impacted the least amount possible. However it would be acceptable to do some adjustments every year or so to verify good functioning	
Network	No internet or additional equipment	Internet but no additional equipment
Justification	A best system would be one that requires no internet since it wouldn't need to be re-adjusted if the client changes house, or if there's any type of internet blackout. However, since the device will be kept at home and stationary, it would be acceptable to require an internet connection to increase performance of the device. The only hard limit is not allowing for any additional equipment such as an Alexa or Google Home in order to avoid additional expenses.	
Power Supply	Electricity from the existing remote	Standard wall socket
Justification	Using electricity from the remote would be the preferred solution by the client since it would avoid additional complexities or wires to the environment, however if the power requirements for the system cannot be met, using wall power would also be acceptable since the chair is located inside.	

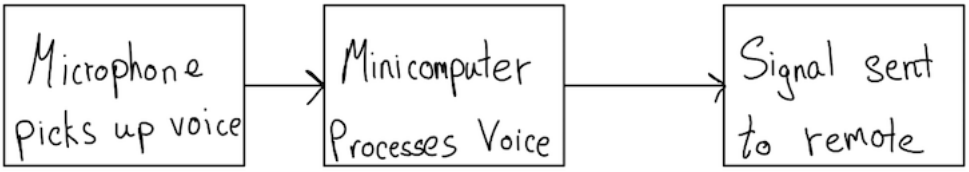
Reliability	Works 100% of the time, robust enough to understand unclear voice	Works over 80% of the time when an unclear tone is used.
Justification	Since the client might have difficulty using his voice, it is critical that the system is able to recognize his commands even when that's the case. The marginal performance would mean that the system might not understand the first time its told, but would definitely understand the second time.	
Cost	Within the 150 CAD limit	Less than 10% over the limit
Justification	Ideally the project would remain withing the budget cap, specially since the client has already made a significant expense with the reclining chair. However since the solution will very likely require electronics which area ballooning in price, and will compete against products that do less and cost over 4 times more, going a little over budget would not be critical	

B.2 Concept Development.

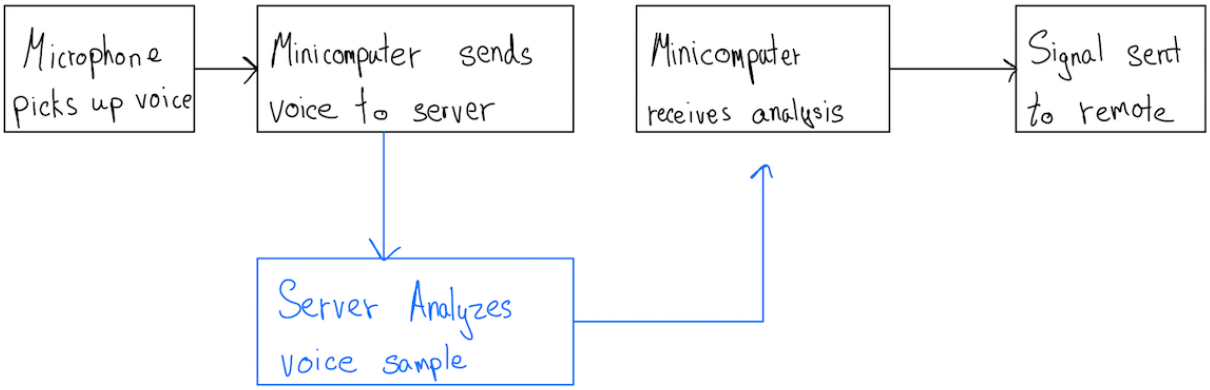
8. *1.* Final prototype concepts for each sub- system, as well as the entire assembled system required to solve the problem.

Sub system 1 – Voice Recognition

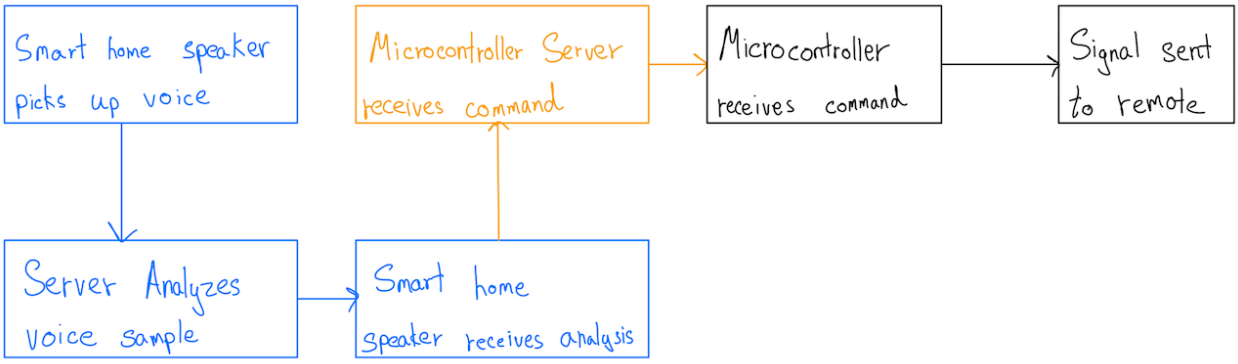
- Concept A: Offline Recognition with custom speech analysis.



- Concept B: Online Recognition using speech analysis servers.

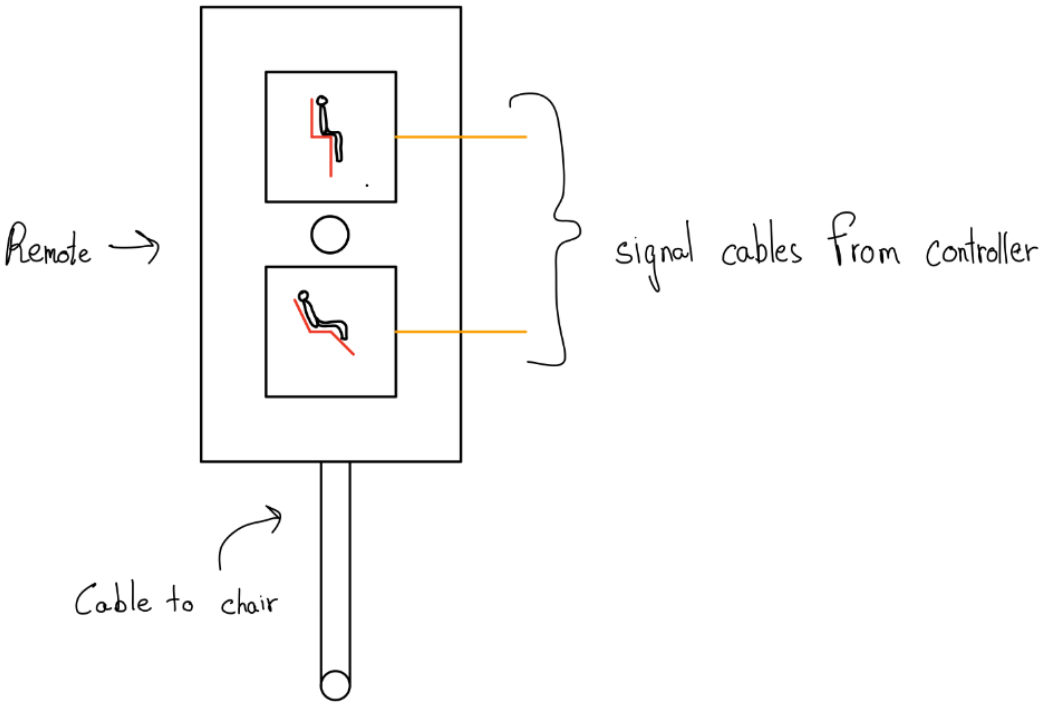


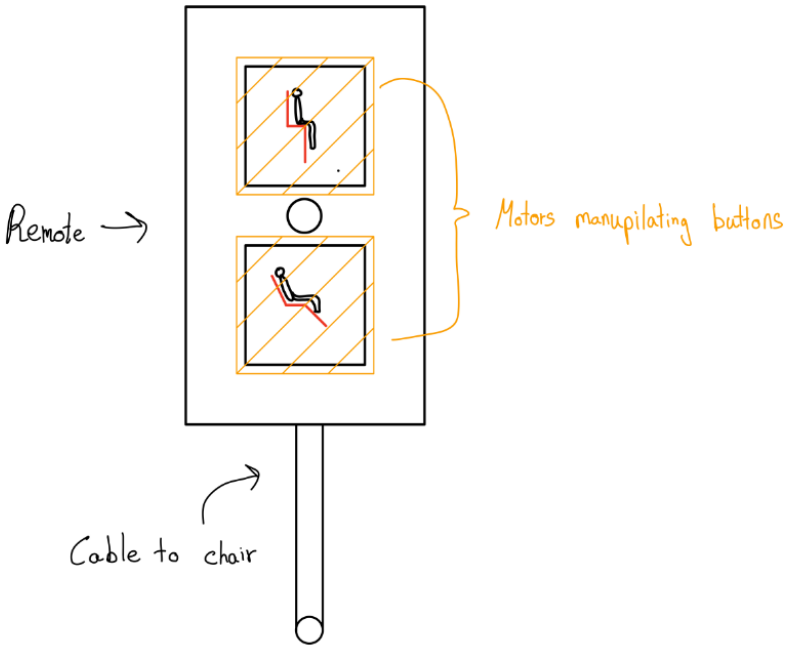
- Concept C: Online Recognition using existing Smart Home Device.



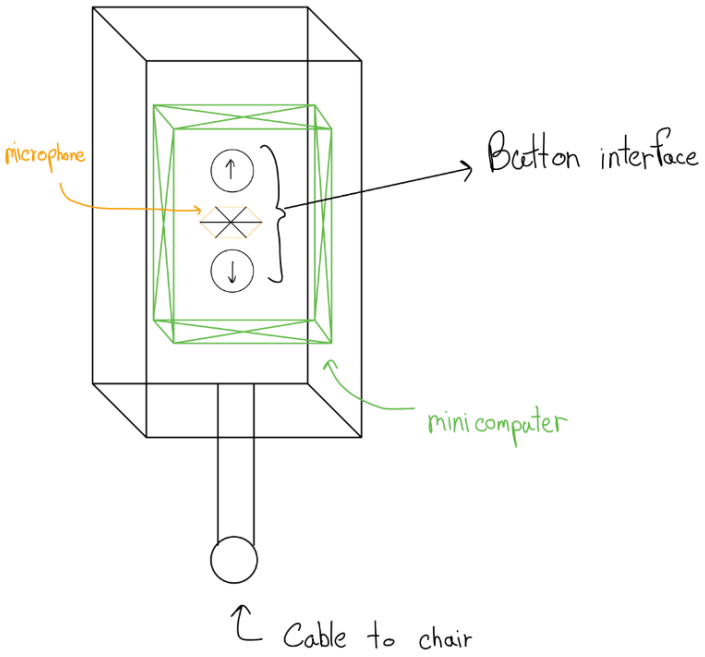
Subsystem 2 – Manipulation of Controller

- Concept 1: Splice into remote.
- Concept 2: Mechanical Parts manipulating buttons.





- Concept 3: Standalone remote



2. Analyze and evaluate all concepts against the target specifications you defined. Use simple calculations and/or simulations to make decisions. Justify the process and methods used for analysis and evaluation.

Sub system 1 – Voice Recognition

Concept A: Offline Recognition with custom speech analysis.

- Analysis:
  - Requires a minicomputer and a connected microphone to listen to client.
  - Utilizes minicomputer to control remote.
  - Client is required to send voice samples of themselves speaking the commands for recognition training.
  - Does not require internet connection to be operational.
  - Custom model trained to client's speech impairment allows for higher probability of successful speech recognition.
  - Minicomputer powered from 15W power supply plugged into wall.
- Evaluation:

Concept A offers a solution custom tailored to the client's speech and requires no internet connection to operate. This approach is the fastest method to process the client's voice as data is not being sent to an external server to be processed. It is the most reliable solution, as it has custom voice recognition and does not require internet access to function.

Concept B: Online Recognition using speech analysis servers.

- Analysis:
    - Requires a minicomputer and a connected microphone to listen to client.
    - Utilizes minicomputer to control remote.
    - Requires an internet connection to be operational.
    - Client Speech is sent to third party speech analysis server to understand what sounds were uttered.
    - Speech analysis server is not calibrated to understand client's speech impairment.
    - Minicomputer powered from 15W power supply plugged into wall outlet.
- Evaluation:

Concept B offers a solution which utilizes a speech analysis server to understand what the client uttered. This will result in a lower accuracy for the client, as the system is not specifically trained to understand their unique speech patterns. The reliance on a speech analysis server introduces a potential vulnerability wherein service disruptions could occur, rendering the minicomputer to be inoperable.

Concept C: Online Recognition using existing Smart Home Device.

- Analysis:
    - Utilizes a microcontroller to control remote.
    - Requires client to have smart home speaker.
    - Requires an internet connection to be operational.
    - Microcontroller needs additional components to connect to internet.
    - Microcontroller depends on additional 3rd party services to communicate with client's smart speaker.
    - Microcontroller powered from 5V power source, can be powered from wall outlet.
- Evaluation:

Concept C offers a solution which utilizes a speech analysis server from an existing smart home speaker to understand what the client uttered. This may result in a lower accuracy for the client as existing smart home speakers do not specifically understand unique speech patterns for commands. The reliance on a smart speaker and other 3rd party software introduces a potential vulnerability wherein service disruptions could occur, rendering the microcontroller to be inoperable.

Sub System 2 – Manipulation of Controller

Concept 1: Splice into remote.

- Analysis:
    - Requires disassembly of controller.
    - Signal Wires form minicomputer/microcontroller must be soldered onto remote's circuit board.
    - Requires 3D modelled part to hold reassembled controller and minicomputer/microcontroller assembly.
- Evaluation:
    - Concept 1 offers a solution that involves modifying an existing remote to integrate it with minicomputer/microcontroller. The disassembly and modification of the controller requires a certain degree of expertise; however, it will allow for the most precise level of control while still rendering the remote operational.

Concept 2: Mechanical Parts manipulating buttons.

- Analysis:
    - Requires motors to be positioned on top of remote to manipulate buttons.
    - Requires 3D modelled part to hold controller, motors, and minicomputer/microcontroller assembly.
- Evaluation:
    - Concept 2 would be bulky and inhibit manual use of the controller due to the buttons being blocked by motors. It may also require an increased level of maintenance due to the presence of multiple motors. Additionally, a 3D printed part will be required to hold the motors in place. Purchasing the required motors along with the microcontroller/minicomputer will also result in the project going significantly over budget.

Concept 3: Standalone remote

- Analysis:
    - Requires research and understanding on how existing controllers communicate and send signals to the chair.
    - Signals will need to replicated according to research data on minicomputer/microcontroller.
    - A 3D modelled plug and custom wiring will need to be implemented.
    - A remote would need to be created with buttons the same as existing remotes.
    - A secondary microcontroller will be needed to understand the signals from when the buttons are pushed.
- Evaluation:
    - Concept 3 involves several points to be analyzed. The need for research and understanding of the communication and signal transmission methods requires knowledge and experience on how to use precise electrical engineering instruments. The generation of signals add further complexity and development.

A 3D modelled plug and custom wiring will be required alongside with the creation of a remote with buttons that match those of the existing remotes. The creation of a standalone remote also requires the use of an additional microcontroller resulting in a complex set of systems that need to be integrated together.

3. Concept comparison

All performance between concepts is the same for degree of control, memory, controllable chair functions and power supply, therefore there is no point doing a mathematical comparison.

For the other metrics, their main differences can be evaluated with the table below.
More information on the rubric can be seen in page 5.

Attribute [Priority] / Performance (Numerical Grade)	A1	A2	B2	B3	C3
Installation [2]	5	1	1	1	1
Maintenance [5]	5	1	1	5	5
Network [4]	5	5	3	3	1
Reliability [5]	5	3	1	1	F
Cost [4]	5	3	3	1	1
Total Score	100	54	36	48	35

In summary, combination A1 achieves the highest score with our metric.

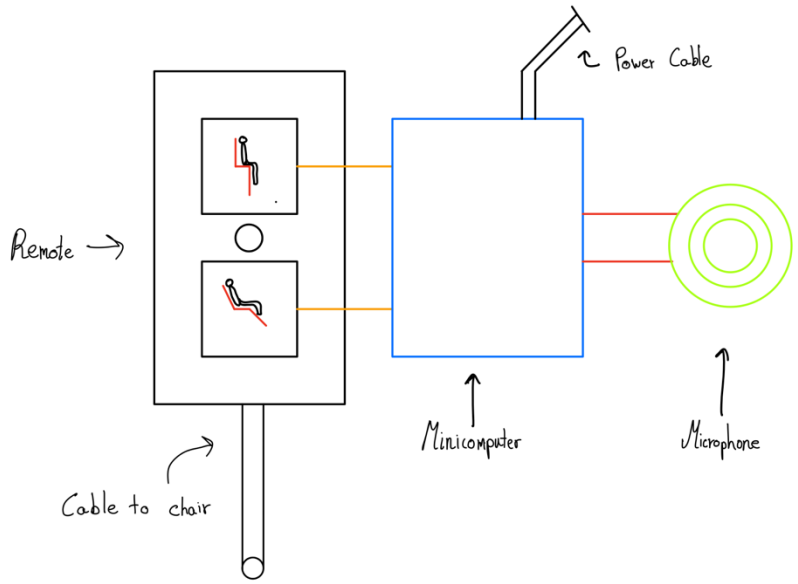
4. Choose one or a few promising solutions you wish to develop further based on your evaluation.

The most promising solution between the two subsystems would be a combination of Concept A and 1. It has custom voice recognition that is tailored to the client and reduces the need for maintenance. With custom voice recognition the device is better able to adapt to the client's speech and account for impairments. In our meeting the client showed more of an interest for a device capable of operating without the internet. This solution requires no internet to operate making it more robust and safer from third party vulnerabilities. A big requirement that was stated is the ability to manually control the chair with a remote. This concept still allows the controller to be operated independently. Components required for this implementation will keep the product within the budget provided.

5. Develop a global design concept which is either an integration or modification of the promising concepts chosen in the previous step, or a brand-new concept created from these ideas. Justify your approach.

    a. The proposed global design concept will be a combination of Concept A1, carefully chosen based on the group's extensive expertise in personalized voice recognition, electrical and mechanical engineering. This approach ensures a higher likelihood of successful implementation with minimal project issues, leveraging the team's specialized knowledge in these areas.

5. Visually represent (sketch, diagram, CAD model, etc.) your global concept.



6. Provide a few lines explaining your concept's relationship to the target specifications, as well as its benefits and drawbacks.

    - Overall, concept A1 satisfies the target specifications to a greater degree than any other concept. It is highly reliable, low maintenance, less expensive than its counterparts and does not require internet connection. Due to this, it will also respond to commands more quickly and precisely than other designs. One drawback lies in the fact that soldering the wires to the circuit board will require a slightly greater level of expertise.

B3: Wrike Snapshot

https://www.wrike.com/frontend/ganttchart/index.html?snapshotId=VkrkiqyPegEWKT9fmtkJb1vMnUdfDCqt%7CIE2DSNZVHA2DELSTGIYA

Conclusion:

In summary, this document focuses on addressing the needs of Dany, an ALS patient, who requires a voice-controlled solution to operate his stationary reclining chair. The objective was to design a solution that enables Dany to use his voice effectively despite his physical limitations and voice impairments.

To this end, a promising solution combining 2 subsystems has been identified: Concept A for voice recognition, which involves offline recognition with custom speech analysis, and Concept 1 for manipulating the controller, which entails modifying the remote through splicing.

The proposed global design concept integrates offline voice recognition with additional physical remote modification. This approach offers a personalized and reliable solution, meeting the target specifications while minimizing maintenance.

By implementing this solution, Dany will achieve independence and comfort in operating his chair, significantly improving his quality of life.