Project Group: Parth Kale, Dhruv Shah, Stephen Dong

Project Proposal:

Goal: Develop a structured proposal to identify the targeted problem, solution, and customer demographic.

Customer Problem:

In Canada, parking spaces must reserve some space for people with disabilities, also known as **handicap parking.** To be able to park in these reserved lots, an individual must go through an **application process** and prove that by obtaining this pass, their life will be improved.

Despite having over **8 million disabled individuals,** which accounts for almost **27%** of all Canadians who could benefit from handicapped parking, some provinces have laws that enforce only **1 disabled parking spot for every 100 lots:** essentially 1% [1]. Although our project doesn't cater to all 8 million of these individuals, it focuses on those who drive and actively search for handicapped parking spaces, still solving a major problem.

Technically having **27 times the demand** than supply, creates a large shortage of this valuable space, making it increasingly difficult for people in need to find such spaces. In addition to this shortage, oftentimes in places such as multi-floor parking lots, handicapped parking spaces are available, but hard to locate in the large maze-like area. This complexity further adds to the already existing shortage, encouraging individuals looking for handicapped lots to park in regular parking spots. Often this leads to **uncomfortable or dangerous situations.** To add to the distress, an increasing number of non-handicap drivers have started to **abuse the reserved spaces** by parking in handicap-marked lots.

In the article, "Illegal Parking in Handicapped Zones: Demographic Observations and Review of the Literature," the author John Cope states that "**inappropriate use** of these spaces by non-handicapped drivers **occurs frequently,**" [2] and that "handicapped individuals perceive illegal use of designated parking spaces to be a major problem." To improve the lives of handicapped individuals who drive a vehicle and actively try to locate handicapped parking, we are developing a system of two microcontrollers that will communicate with each other to update the database of available handicapped parking spots within the lot.

After doing so, a user interface will let the driver know which handicapped lot is available to park in. In addition, for a non-handicap driver, the system would provide them with an available non-reserved parking space, allowing extra reserved parking for those who need it. This problem is further elaborated in an article from the Universiti Sains Malaysia, a leading Malaysian research university in which they cite that "**86% of drivers face difficulty** in finding a parking space in multilevel parking lots," [3] and that "insufficient car park spaces lead to **traffic congestion and driver frustration.**" [3] Sometimes, this promotes the illegal use of handicapped parking. Through our solution, we are resolving a problem that the article hints towards the accessibility of parking through the implementation of some sort of software. Instead of being broad enough to accommodate all drivers, we believe that it is important to **help those with disabilities first,** thereby designing our project in that direction.

Customers:

Our customers would likely be entities responsible for managing or overseeing parking facilities, particularly in locations where compliance with handicap parking regulations is critical. These could include:

1. **Shopping Malls and Commercial Complexes** – They need to ensure parking spots are accessible and compliant with regulations.
2. **Hospitals and Healthcare Facilities** – Handicap parking is essential for patients and visitors with disabilities.
3. **Government Facilities** – They often manage large public parking structures and must comply with regulations regarding accessibility.
4. **Office Buildings and Corporate Campuses** – Companies with large employee or visitor parking lots may want to ensure compliance with handicap parking rules.
5. **Airports and Transportation Hubs** – These locations typically have large, multi-floor parking structures that require organized traffic and parking systems.
6. **Universities and Schools** – Large campuses often have significant parking needs for staff, students, and visitors, including individuals with disabilities.

The value proposition for these customers would be improved parking management, increased compliance with accessibility laws, and a potential reduction in fines or complaints related to handicapped parking misuse.

Stakeholders:

Other than the idea itself, it is also important to consider the **stakeholders** involved in this project. Some of the stakeholders include our **assigned graduate TA, suppliers to the client, customers of the client, government or regulatory bodies, the public and special interest groups.** To satisfy the TA we must properly convey our project idea, its positive effect on society and our efforts to pursue its achievement.

Project Group: Parth Kale, Dhruv Shah, Stephen Dong

As for our suppliers, by **ordering manufacturing components** and **paying balances regularly**, we will have no problem in ensuring the satisfaction of our suppliers. By translating high-quality equipment from the supplier to the consumer and establishing an exemplary product, I believe we can continue attracting our customers. As with any other technology, we need to gain approval and support from the government and other regulatory bodies such as ***The Canadian Parking Association*.** More importantly, we should address the public's concerns as they can play a major **role in endorsing or rejecting** our product. This is why presenting the benefits of our product through advertisements or other forms of media will allow us to persuade the public and provide them with a positive image of our product.

Overall, we have a solid product idea that can help a **large yet niche target market.** Backed by multiple sources, our strong plan to work with our stakeholders shows the strength of our proposal.

Initial Requirements:

Functional Requirements:

1. **User Input Response Time:**
    - **Requirement:** The system must display available parking spots and accept license plate input within 1 to 2 seconds of user interaction [5] at the entrance.
    - **Reasonable:** Testable with a stopwatch to measure the system's response time.
    - **Justification:** Ensures a smooth and efficient user experience. It also makes the whole process faster, helping resolve a part of our problem i.e., saving time, money and resources.

        - **1 second** keeps the user's flow of thought **seamless**. Users can sense a delay, and thus know the computer is generating the outcome, but they still feel in control of the overall experience and that they're moving freely rather than waiting on the computer. This degree of responsiveness is needed for good navigation.

2. **Parking Spot Selection and Confirmation:**
    - **Requirement:** The system must update the database of available parking spots within 1 second after the user selects a spot [6].
    - **Reasonable:** Measurable using a stopwatch to measure the time taken from selection to database update.
    - **Justification:** Quick updates in the system prevent delays and conflicts in

parking spot availability.

A machine or a system that works in real-time takes your input, processes it, and yields a meaningful output in no time (order of milliseconds).

3. **Inter-STM32 Communication:**
   - **Requirement:** The STM32 at the exit gate must communicate the parking spot's vacancy status to the entrance gate within 100 milliseconds [8].
   - **Reasonable:** Testable by measuring the time between sending and receiving messages.
   - **Justification:** Ensures real-time updates and accurate parking spot availability.

     - If your server response time is under 100ms, it's excellent.
     - Between 100ms and 200 ms is considered good.
     - Between 200ms and 1 second is considered acceptable, but should be improved.
     - Above 1 second is too slow. You may need to reduce server response times.

Technical Requirements:

1. **Data Transmission Reliability:**
   - **Requirement:** The STM32 communication system must maintain a 99% reliability rate over a distance of up to 50 meters [7].
   - **Reasonable:** Testable by measuring signal strength and data transmission at varying distances.
   - **Justification:** Ensures robust communication between the entrance and exit gates.

     `rtos_task_Slave_100_0` to ensure communication with the Master microcontroller. It has a cyclicity of 100 ms, it is executed most often, in order not to miss communication requests from the Master.

2. **License Plate Storage Capacity:**
   - **Requirement:** The system must be able to store and process at least 100 unique license plate entries simultaneously.
   - **Reasonable for 1A Students:** Measurable by using a formula to calculate approximate entries.
   - **Measurable:** RAM available in STM32: 96KB = 96 x 1000 = 96000 bytes [9]
     Bytes used while entering a license plate: 8 bytes(8 characters)

Bytes for storing parking spot: 2 bytes
Total bytes used for 1 entry: 8 + 2 = 10
Total entries = (Number of bytes available)/(Bytes per entry)
= 96000/10
= *9600 entries*

Therefore, the system will be perfectly fine while storing 100 entries.

- **Justification:** Ensures the system can handle a reasonable number of entries.

The STMicroelectronics STM32F401RE is a Core - ARM 32-bit Cortex-M4 CPU with FPU - Adaptive real-time accelerator (ART Accelerator) - 84 MHz maximum frequency, 105 DMIPS/1.25 DMIPS/MHz - Memory protection unit - DSP instructions Memories - Up to 512 Kbytes of Flash memory - 96 Kbytes of SRAM Clock, reset and supply management - 1.7 V (PDR OFF) or 1.8 V (PDR ON) to 3.6 V application supply and I/Os -

Safety Requirements:

1. **Power and Energy Restrictions:**
   - **Power Consumption:**
     - **Requirement:** The design must not consume, transfer, discharge, or otherwise expend more than 30 watts of power [10] at any point in time.
     - **Reasonable:** Measurable with a multimeter or power meter.
     - **Justification:** Prevents overheating and ensures safe operation of all components.

     The design must not consume, transfer, discharge, or otherwise expend more than 30W of power at any point in time and within any component of the design during its operation. This includes all forms of energy, including but not limited to: electric energy, electric potential energy, mechanical kinetic energy, or mechanical potential energy.

   - **Energy Storage Capacity:**
     - **Requirement:** The system must not store or contain more than 500 millijoules (mJ) of energy [10] at any point in time.
     - **Resonable:** Use an energy meter to check storage capacity.
     - **Justification:** Limits the risk of electrical discharge or mechanical hazards.

   The design must not store or otherwise contain more than 500mJ of energy at any point in time. This includes all forms of energy, including but not limited to: electric energy, electric potential energy, mechanical kinetic energy, or mechanical potential energy.

- **CSA Approval for Electrical Connections:**
  - **Requirement:** Any component connecting to a 110V AC outlet must be CSA-approved [10].
  - **Reasonable:** Verify components for CSA approval.
  - **Justification:** Reduces risk of electrical hazards.

  Any design component that connects directly to a building electrical supply outlet (110V AC outlet) must be CSA approved. See UW Safety Office for further reference.

2. **Testing on Human or Animal Subjects:**
   - **Prohibition on Human or Animal Testing:**
     - **Requirement:** Testing of the design on human or animal subjects is strictly prohibited [10].
     - **Reasonable:** Use non-invasive testing methods such as simulations.
     - **Justification:** Ensures adherence to ethical standards and safety.

   Any testing of the design on human or animal subjects is strictly prohibited, including the project students themselves. Any studies, experimentation, or research to be conducted on human subjects would require review by the University of Waterloo Office of Research Ethics, which is beyond the scope of this course. Therefore any and all testing or verification of design performance must be done without the use of people or animals as subjects of any experiment or test.

Principles for Testing:

1. Real-Time Embedded Systems

- **Description:** Real-time systems are designed to respond to inputs and process data within a specific time frame. For an embedded system to be classified as real-time, it must meet timing constraints to ensure its functionality remains reliable under different conditions [11].
- **Use in project:** The formula below is used to calculate the worst-case response time of tasks in real-time scheduling systems. Since our system must be operating in real-time to ensure accurate data is being sent to the user, we will use the formula to calculate the worst case scenario of user wait time with respect to the delay of system information. Our goal is to minimize this delay to five seconds.
- **Equation:** The response time R of a real-time system can be represented as:

$$R = C + \sum_{i=1}^{n} \left\lceil \frac{R}{T_i} \right\rceil C_i$$

Where C is the computation time, Ti is the period of task i, and Cii is the execution time of task i.

- **Contribution:** In the parking system, real-time performance is critical to ensure that the system reacts to changes in parking availability without delay. By applying this principle, the system will guarantee that the microcontrollers process sensor data promptly, allowing the driver to be informed about available spaces in real-time.

2. Distance Measurement with Ultrasonic Sensors

- **Description:** Ultrasonic sensors can be used to measure distance by emitting sound waves and calculating the time it takes for the echo to return. This method is effective for detecting the presence of vehicles close to the microcontroller.
- **Use in Project:** We will place ultrasonic sensors to measure whether or not a parking lot is empty or occupied. This will allow us to help the user navigate the space. [12]
- **Equation:** The distance d is calculated as: Where v is the speed of sound in air (~343 m/s), and t is the time it takes for the echo to return:

$$d = \frac{v \cdot t}{2}$$

- **Contribution:** You can integrate ultrasonic sensors into your project to detect whether a parking spot is occupied by measuring the distance between the sensor and the vehicle. This is easily testable with basic microcontroller programming to calculate distances and trigger parking availability signals.

3. Latency Minimization

- **Description**: Latency refers to the delay in data transmission or processing within a system. In real-time systems, such as a parking management system, minimizing latency is crucial to ensure that the communication between microcontrollers occurs in real time. This is essential for fast updates on parking spot availability, allowing drivers to receive timely information and ensuring the system operates efficiently. [13]
- **Use in Project**: We will aim to minimize latency as much as possible in order for the best customer experience. Our goal is to allow a maximum latency time of five seconds. Minimizing latency corresponds to real-time embedded systems, but differs in a way such that latency minimization allows us to reduce latency by

helping us identify points of latency, while real-time embedded systems helps us to find the worst case scenario.

Equation: The total system latency can be formulated by:

$$L_{\text{total}} = L_{\text{process}} + L_{\text{comm}} + L_{\text{response}}$$

Where:

- L_{process} is the latency introduced by the processing time of the microcontroller.
- L_{comm} is the latency from communication between microcontrollers.
- L_{response} is the delay in sending feedback to the display or driver interface.

Minimizing each component of this equation is critical for reducing the overall latency in the system.

Contribution: By prioritizing tasks that are critical for updating parking availability, we can reduce the latency in our project. This ensures that real-time information is relayed quickly, allowing the system to notify drivers of available parking spots with minimal delay. This can be tested by measuring the total latency from the detection of a car occupying a parking spot to the update on the driver's interface.

Citations:

[1] "The Canadian Parking Association – Accessible Parking Enhancements: The New Frontier," Canadianparking.ca, 2024. (Link)

[2] S. C. Government of Canada, "The disability rate in Canada increased in 2022," www.statcan.gc.ca, Apr. 03, 2024. (Link)

[3] J. G. Cope and L. J. Allred, "Illegal parking in handicapped zones: Demographic observations and review of the literature.," Rehabilitation Psychology, vol. 35, no. 4, pp. 249–257, 1990, doi: (Link).

[4] A. Kianpisheh, N. Mustaffa, P. Limtrairut, and P. Keikhosrokiani, "Smart Parking System (SPS) Architecture Using Ultrasonic Detector," International Journal of Software Engineering and Its Applications, vol. 6, no. 3, pp. 51–58, Jul. 2012, Accessed: Sep. 24, 2024. [Online]. Available: (Link)

Project Group: Parth Kale, Dhruv Shah, Stephen Dong

[5] J. Nielsen, “Website Response Times,” Nielsen Norman Group, 2010. (Link)

[6] “What Is Real-Time Processing? A Quick-Start Guide - Learn | Hevo,” May 02, 2022. (Link)

[7] Aurel Mihail Țîțu and A. Bogorin-Predescu, “Modeling of the Communication Process Between Two Microcontrollers to Optimize the Execution of Specific Tasks,” Lecture notes in networks and systems, pp. 490–503, Jan. 2023, doi: (Link).

[8] “8 Ways to Effectively Reduce Server Response Time,” DataDome, Jul. 28, 2023. (Link)

[9] “STMicroelectronics STM32F401RE,” Keil.com, 2019. (Link).

[10] “Project Requirements ECE 198 - Fall 2024,” Sep. 24, 2024 (Link)

[11] “J. Wang *Real Time Embedded Systems* (Link)

[12] A. Latha, B. Murthy, K. Kumar, “Distance Sensing with Ultrasonic Sensor and Arduino,” *International Journal of Advance Research, Ideas and Innovations in Technology* (Link)

[13] A. Fanghanel, T. Kesselheim, B. Vocking, “Improved algorithms for latency minimization in wireless networks,” *Elsevier* (Link)