# Design requirements/constraints

Power wheelchair operation although seemingly innocuous can be a challenging and dangerous task for individuals that are not accustomed to it. Power wheelchairs can weigh in excess of 400 pounds when in use and can cause damage to both people and property if they collide. Therefore, experts observe people who are learning to use power wheelchairs to ensure they are both capable and have the training necessary to be able to operate their chair safely. Even during this training lack of experience or focus can result in scuffs and scratches on walls and furniture. The worst wheelchair collisions can result in injuries to pets, loved ones, trainers, or even the operators of the wheelchair. Some might say that the only way to learn is to make mistakes and learn from the consequences, but that does not have to be the case for wheelchair training.

Train and Go offers an alternative to the high-risk training methods used in the industry today. It provides a safe training environment using virtual reality (VR) and includes features that assist wheelchair users while in VR. Train and Go is designed to work seamlessly with VR and allows users to see how their chair is moving in a VR headset. This allows users to get the valuable training needed to gain confidence operating their power wheelchair in the real world without the anxiety induced by thoughts of possibly hurting a loved one or causing damage to one's home. By simulating real world environments, Train and Go can turn an empty room into a training course filled with obstacles. In order to prevent collisions, Train and Go is also capable of notifying the user when they get too close to the physical walls of the training environment.

## Technical Design Constraints

Train and Go meets all technical design constraints outlined in Table 1.1. These constraints ensure a safe and reliable design.

Table 1.1. Technical Design Constraints

|  |  |
| --- | --- |
| **Name** | **Description** |
| Location Accuracy | The system knows where the wheelchair is within a tolerance of plus or minus 30 centimeters. |
| Detection Distance | The system can detect objects within a radius of no more than 2.235 meters. |
| Output Latency | This system’s latency for sending feedback to the user in response to an object is no more than 250 milliseconds. |
| Robustness | The system’s false detection rate is less than 3 percent. |
| Wireless Range | The system can connect wirelessly to a VR headset at least 5 meters away. |
| Wireless Latency | The wireless latency is less than 250 milliseconds. |
| System Weight | The system weighs less than 5.65 kilograms. |

These technical constraints are explained in more detail in the following sections.

### Location Accuracy

Train and Go’s location tracking system uses sensors to predict where the chair is with an accuracy of at least 30 centimeters. This tolerance comes from the limitations of the sensors available for this application.

### Detection Distance

Train and Go can detect objects within a radius of 2.235 meters in order for the user to have adequate time to react to Train and Go’s feedback. The average powered wheelchair maintains a speed of around 5 miles per hour [2]. Train and Go can be used in a closed room and should not encounter such speeds. If an object is detected at 5 miles per hour, as in equation (1), 2.235 meters is traveled in 1 second.

### Output Latency

Upon detecting an obstacle, Train and Go notifies the user within 250 milliseconds. This is to give the chair operator a reasonable amount of time to react at varying speeds. The average human reaction time is 250 milliseconds [3]. This combined with the system reaction time of 250 milliseconds allows the user to respond to an obstacle in 0.5 seconds, well before they are likely to collide with the obstacle.

### Robustness

Providing feedback to the user when there is not a danger of colliding with an obstacle is called a false detection. False detections are a part of any system, but good systems have as few as possible. The Train and Go system’s systems false detection rate is less than 3 percent. This rate is comparable to other high quality detection systems [4].

### Wireless Range

The connection distance between Train and Go and a VR headset should large enough so that a person of any high will have a good wireless connection to Train and Go. Assuming the maximum distance case, Train and Go may be affixed below the chair, and the VR headset may be on the head of an individual standing on the chair. The average human is less than 180cm tall, and the average chair is 45cm tall [5]-[6]. This combines to give a maximum distance of 2.25 meters that our wireless signal should be able to span. Team and go will be able to connect at 5 meters which is more than twice this distance.

### Wireless Latency

Train and Go’s communication with a VR headset should reflect reality close enough so that the human brain will not notice the difference. This means the latency of Team an Go’s wireless connection needs to be faster than a human can process. As the human reaction time is 250 milliseconds, the virtual environment should update no slower than the 250 milliseconds it would take a human to react to it [3]. This requires Train and Go to send a signal at least as fast as the desired update time of 250 milliseconds.

### System weight

A power wheelchair alone can weigh up to 113 kilograms [7]. For Train and Go to be a viable training system, it should be no more than 5 percent of the original chair’s total weight to ensure the wheelchair’s performance will not suffer. Five percent of 113 kilograms is 5.65 kilograms, which is the maximum weight of Train and Go.

## Practical Design Constraints

The practical design constraints listed in Table 1.2 determine a large amount about the design and marketing of Train and Go. These constraints include sustainability, accessibility, and economic concerns. These areas of concern are addressed in the design of Train and Go.

Table 1.2. Practical Design Constraints

|  |  |  |
| --- | --- | --- |
| **Type** | **Name** | **Description** |
| Sustainability | Reliability | Train and Go is designed to operate over a five-year period without component failure. |
| Accessibility | Modular | The system can be removed from the chair with commonly available hand tools. |
| Sustainability | Sensor Maintenance | Sensor connections are placed strategically to allow simple maintenance or replacement |
| Accessibility | Water Resistance | Sensors and the microcontroller are water-resistant. |
| Economic | Product Versatility | Train and Go offers a flexible packaging system to attach to a variety of wheelchair designs and does not inhibit existing chair functionality. |
| Safety | Collision Detection | Train and Go provides the user with feedback to discourage collisions with obstacles. |
| Functionality | VR Communication | Train and Go communicates with a VR headset. |

These practical design constraints are explained in more detail in the following sections.

### Reliability

Train and Go is designed to last the lifespan of an individual’s wheelchair. Insurance offers funding for a new wheelchair every 5 years, so Train and Go should last the until the user needs a new wheelchair, after which time a new Train and Go can be installed [8].

### Modular

Train and Go is easy to install and remove using common household hand tools. This is to allow users to remove or install Train and Go with the tools they probably already have.

### Sensor Maintenance

All sensors are installed in areas that are easy to reach in case they need to be replaced. The sensors are connected in such a way that they can easily be replaced in the case of component failure.

### Water Resistance

Due to all sensors and microcontroller(s) being attached directly to the chair, they may have to contend with the elements, such as water and dirt. To help minimize the risk of electrical issues, all attached sensors and microcontroller(s) are encased in a water-resistant case.

### Product Versatility

Train and Go’s design allows it to be attached to a variety of different wheelchairs without inhibiting their existing functionality.

### Collision Detection

Train and Go provides feedback to the user indicating the possibility of a collision when the user comes to close to an obstacle. This is to ensure safety while the user is using the VR headset.

### VR Communication

Train and Go is connected wirelessly to a VR headset. Due to the wheelchair’s orientation being unaccounted for in traditional virtual reality environments, Train and Go can communicate wheelchair orientation and movement to in VR separate from the user’s head orientation.

## Engineering Standards

Table 1.3 outlines engineering standards that Train and Go satisfies. These standards guarantee industrially acceptable aspects of the design.

Table 1.3. Appropriate Engineering Standards

|  |  |  |
| --- | --- | --- |
| **Specific Standard** | **Standard document** | **Specification / application** |
| IP-44 | IEC standard 60529 | The system is protected from solid particles that are over 1mm in size and from splashes of water. |
| Bluetooth | IEEE 802-15.1 | The system adheres to IEEE Bluetooth standards. |
| Protection against electric shock | IEC 62638 | The electrical components of the system are isolated from the user to prevent electric shock. |

These engineering standards are explained in more detail in the following sections.

### IP-44

Train and Go complies with Ingress Protection Rating IP44. It states that components should be protected against solid objects greater than 1 millimeter and should not be harmed by the splashing of water from any direction.

### Bluetooth

Train and Go conforms to the statutes set forth in IEEE 802-15.1, which describes how Bluetooth modules are required to operate. This is to ensure wireless compatibility across platforms and to ensure consistent operation.

### Protection against electric shock

The International Electrotechnical Commission standard 62638 gives guidance on protection from electrical shock. The standard classifies DC and AC sources according to their maximum voltage and current magnitudes.

# References

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