Stride: A Boundary Detecting Walking Stick for Parkinson's Patients

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1 Overview

Parkinson's disease (PD) is the second most common age-related neurodegenerative disease. Symptoms include tremors, slow or stiff movement, balance issues and also mental disorders such as depression, insomnia and memory issues. There are over 10 million Parkinson's patients worldwide [1], with nearly 80% experiencing motor symptoms that affect daily life [2]. This highlights the need for assistive products that address such challenges.

2 Product Opportunity

This project aims to empower individuals with Parkinson's disease by developing an adaptive assistive device. The objective is to design a solution that promotes independence, allowing individuals to continue hobbies and daily tasks with improved ease. This final product opportunity was shaped by insights from user research as summarised in the points below.

2.1 Stability

Individuals with Parkinson's disease suffer from a disruption in the body's natural rhythm, which leads to symptoms such as tremors and freezing of gait (FoG). This makes simple daily tasks, such as using stairs or brushing teeth, more difficult. Variations in the environment, such as a change in flooring, can also trigger freezing episodes.

2.2 Discreet Design

Using assistive tools in public may highlight an individual's symptoms, leading to feelings of discomfort and embarrassment. This insight emphasises the importance of incorporating discreet design features to avoid unwanted attention, in addition to the functional design.

2.3 Independence and the Future

The loss of ability in continuing hobbies and daily tasks leads to a diminished sense of independence. Individuals also feel that they can no longer fully commit to familial relationships and responsibilities. Overall, this leads to a decline in mental health and uncertainty of the future.

2.4 Caregiver Strain

The growing dependence on professional and familial caregivers creates emotional, physical, and financial stress on others. Products that reduce this reliance not only support the user, but also improve the well-being of their support system. The independence that comes with the product may also improve familial relationships.

3 Concept Development Approach

3.1 Methods Research

To initiate the project, secondary research was carried out, to build a foundational understanding about Parkinson's disease. From this, target stakeholders (doctors, patients, caregivers and family) to be involved in our primary research stage were identified.

Primary research involved interviews with experts, such as academic neurologist Dr Yen Foung Tai, Parkinson's physiotherapist Dr Julie Jones, and co-founder of Charco Neurotech, Lucy Jung. Various care homes – Bupa Lynton Hall Care Home, Westcombe Park Care Home and an Age UK Centre – were also visited, to connect with Parkinson's patients directly, gaining first-hand insights into their daily experiences.

In order to gather deeper insights and identify user pain points, collated primary research and secondary research were used to create user journey maps, as well as user profiles. This facilitated the formation of final product opportunities – as explained above.

Following an initial market research phase and a comprehensive analysis of competitor products, each team member independently defined product requirements, which were then used to ideate an initial set of solutions.

3.2 Selection Rationale

Concepts were evaluated systematically using methods such as decision matrices and the desirability, viability, and feasibility (DVF) framework. This led each member to propose a final concept:

Boundary Detect Stick: Employs an optical sensor to detect flooring changes and provide vibrational feedback through the handle to help overcome gait freezing.

EasyFlex: An adaptive exercise device with a suction-based base, adjustable resistance, and magnetic attachments, designed to help users perform controlled movements with real-time visual feedback.

Balance Assist Belt: A wearable device designed to correct balance by shifting counterweights and to overcome gait freezing episodes by providing rhythmic vibration cues to encourage movement.

Steady Ring: A wearable cueing device that uses vibrations to manage symptoms, as well as a fall detection feature to alert carers.

To select a final concept, we sent a detailed concept booklet and questionnaire to those interviewed in the initial primary research stage.

Ultimately, the **Boundary Detect Stick** was chosen for further development due to its direct alignment with the needs of individuals with Parkinson's which would be impactful in their daily lives. Additionally, the concept was reinforced by its clear technical feasibility and positive feedback from interviewees.

3.3 Integration Considerations

Received user feedback on the **Boundary Detect Stick** acted as the driving force behind the first wave of product redesign.

Dr Yen Foung Tai pointed out that Freezing of Gait (FoG) can also be situational, for instance, in "crowded" or "tight places". Due to this added factor, he enquired whether an optical sensor would be sufficient for preventing FoG.

Similarly, Dr Julie Jones, agreed that the **Boundary Detect Stick** would aid in spatial awareness, but was sceptical on how reliable and effective the haptic feedback would be, since Parkinson's Disease symptoms greatly vary per person.

From the aforementioned user feedback, as well as user testimonials, some overlooked design considerations were made, to ensure that the presented product catered to Parkinson's Disease patients.

How might we…

- Consider weight distribution and manoeuvrability of the product?
- Make the stick more versatile and sensitive to different user scenarios?
- Ensure reliable usage of functions, for varying symptoms and prolonged time?

3.4 Initial Design Issues

3.4.1 Ergonomics

The original design for the handle had a drastic draft angle. While this design choice was initially made to follow the curve of the user's hand and facilitate placement in multiple orientations, the chances of the user's hand slipping increased drastically when pressure was applied. Since a key design point is that the product should be safe to use, this was immediately highlighted as an area for improvement.

3.4.2 Extension Mechanism

With the selection of the **Boundary Detect Stick** concept, the extension mechanism lacked a fully developed and thought through solution, making the 'how' of the product a priority for immediate action. While a rack and pinion system was initially considered for controlling the extension, this was soon found to be unsuitable due to the size and weight constraints of the product.

3.4.3 Aesthetics

The initial concept featured industrial and mechanical aesthetics. Discussion and analysis of the product market showed this was intimidating and unsuitable for the main target users – those above 60. Due to this observation, a visual redesign was planned. Main areas of dissatisfaction included the product's base, which – through user validation – was found to be visually unappealing and the handle, which looked disproportionate to the rest of the product.

3.4.4 Functionality

As detailed in 3.3 Integration Considerations, concerns were raised regarding the reliability of Freezing of Gait detection and the effectiveness of haptic feedback. Given the crucial role of user experience to the success of the prototype, the need for adaptive or versatile feedback mechanisms was identified as a key requirement, making it an additional initial design issue.

3.5 Resolutions

3.5.1 Ergonomics

The ergonomic problems revolving around Stride were solved through the development and iteration of both the stick's handle and base. The handle was modified to better encompass user comfort (refer to 4.1.1) The base design was developed and improved according to secondary research (refer to 4.1.3). These developments were further fueled by user testing.

3.5.2 Extension Mechanism

By researching pre-existing products and their linear extension, the mechanical logic behind Stride was developed. Firstly, the mechanism was brainstormed with various motor configurations and gears. This was followed by extensive testing, till optimal linear motion was achieved (see 4.2.1 for testing journey).

3.5.3 Aesthetics

Product aesthetics naturally evolved due to ergonomic refinements and brand implementation. Smooth contours along with a more proportional base and mechatronics casing solved previously stated visual issues, as a result of separate design decisions.

3.5.4 Functionality

Finally, the functionality of the product was solved through the introduction of an additional button – as suggested by Dr Yen Foung Tai. The newly incorporated button triggers vibration in the handle, allowing users to trigger the haptic feedback system themselves. This solves the previous oversight of situational Freezing of Gait.

4 Prototyping

4.1 Digital Prototyping / CAD Modelling

Multiple CAD iterations were made on Fusion 360 as an initial stage of prototyping. Beyond exploring visual aesthetics, it was a critical step in testing the internal mechanisms of the product and determining the optimal placement for electrical components. Digital prototyping allowed key design choices to be made without extra expenses or manufacturing waste.

4.1.1 Handle

Stability and comfort being a top priority for this product, ergonomic/anatomic handle designs were explored. The handle was tilted 15 degrees towards the top to allow the wrist to be in a neutral position and reduce the strain on the forearm [39]. This angle also aids in forward propulsion which is helpful for users to counteract the FoG.

Version 1: The initial form was a rounded triangle cross section, with 45mm thickness. This concept looked highly modern but provided little comfort to the hand. Additionally, the size felt unnecessarily large.

Figure 1: *Handle Version 1*

Version 2: The next iterated form was a smaller anatomic handle design with grooves for fingers. While more ergonomic, the handle looked disproportionately small compared to the walking stick. With this iteration, a fourth button was added, to control a constant vibrational mode. This mode was added as a response to Dr Yen Foung Tai's concern of situational freezing. The inclusion of this button enables users to trigger the haptic system, at their own will, thus increasing versatility of the product.

Figure 2: *Handle Version 2*

Version 3: The third concept was a balance between modern aesthetics with comfort and ergonomics. This 40 mm thick handle concept had a rounded triangle cross section, with finger grooves on the lower side.

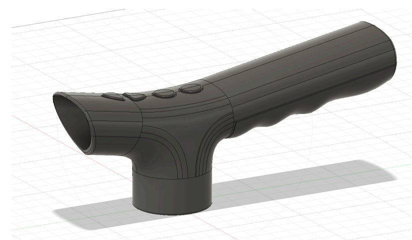

Figure 3: *Handle Version 3 (Final Version)*

4.1.2 Mechatronics Housing

To prevent the load carried by the stick from being applied to the motor shaft, the motor was placed perpendicular to the shaft. Due to this set up and the inclusion of electronic components, an additional housing was necessitated, as the walking stick alone could not accommodate all elements.

CAD permitted the rapid prototyping of this component, and thus allowed for continuous aesthetical evaluation and development. The perceived volume of casing was the predominant design consideration, at this stage.

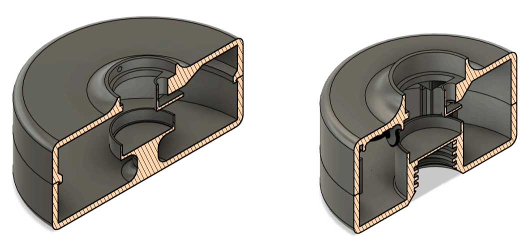

Figure 4: *Housing Version 1*

After several iterations, the shorter but thicker cylinder was chosen as the final form, since this design looked the most proportionate.

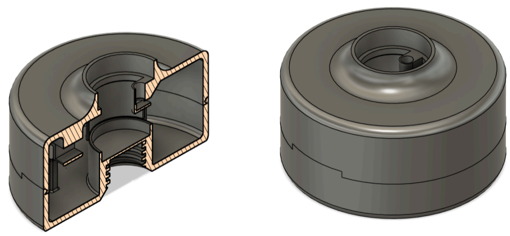

Figure 5*: Housing Version 2 (Final Version)*

4.1.3 Base

An identified pain point from primary research, was the fact that many elderly people struggle to store their walking stick when in a seated position. Due to this, a three-legged base – for free-standing ability – was adopted. Additionally, secondary research revealed that many walking sticks are obtrusive, meaning when users walk with said aid, their natural body positioning is impeded. To prevent this, a rubber ferrule was added between the product's stick and base. The inclusion of this element allows flexion in the stick, so that the stick's movement can align more closely with the user's, creating an unobtrusive product.

Version 1: Through 3D printing and testing, this first iteration was found to be disproportionately small, in comparison to the whole product. Furthermore, with this initial iteration, the tips were not replaceable, which did not meet the ISO 6.3.3. regulation.

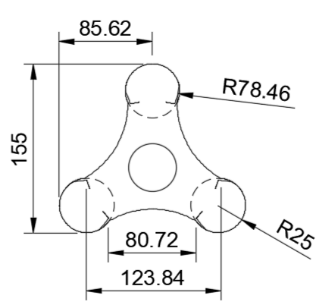

Figure 6*: Base Version 1*

Version 2: With the consequent iteration, the base was scaled by 1.5, in an attempt to correct visual proportions and enhance free-standing stability. However, after testing, this model was found to be excessively large. This larger base also meant that ISO 6.3.5 was violated, since the distance between the frame and the base's outermost point superseded 40mm.

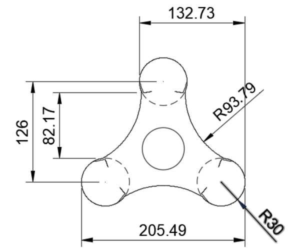

Figure 7*: Base Version 2*

Version 3: The final iteration of the base was a 1.2 scale on the first iteration. This more conservative scaling factor, found a sufficient balance between aesthetics and functionality, therefore was chosen as the final iteration.

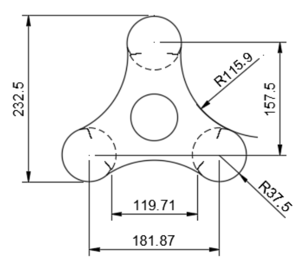

Figure 8*: Base Version 3 (Final Version)*

4.2 Electronics Prototyping

The electronics of the product are controlled by a 7.4V battery and an Arduino Nano microcontroller. The three main electronic systems are: the extension mechanism, boundary detection system and the LED system.

4.2.1 Extension Mechanism

The extension mechanism is controlled by a DC motor with a DRV 8833 H-bridge using two separate buttons to extend and reduce the height of the stick.

During the initial electronics testing phase, a 1.5 – 3V DC motor was used. However, through testing the electronics with the prototype, it was found that a more powerful motor would be required to move the lead screw.

Due to this revelation, an RF-370CA (6 – 7.2V) DC motor was introduced. This secondary motor was able to move the mechanism, but without the added load from the stick. When the additional load of the top PVC pipe and handle was added, the extension mechanism experienced a significant drop in reliability and quality – a design issue stated by Dr Julie Jones.

In an attempt to reduce the friction experienced during the extending process, oil was added to the lead screw and grease was applied to the gears. Through applying these lubricants, some improvement was seen in the extension movement, however the mechanism was still not smooth or reliable. Due to this, a power supply was attached to the RF-370CA motor, to test whether the battery was supplying the optimal voltage and current. This test proved that the battery was supplying sufficient power, but the motor did not have enough torque.

Calculations were done to estimate the torque required by the motor to extend the walking stick supporting the weight of the user (refer to section 5. Power & Load Calculations).

After adaptations were made to the mechatronics casing, to facilitate storing the gearmotor, the extension mechanism was tested again. This test showed significant improvement in the extension process, and thus an N20 gear motor was chosen as the final motor. In addition to supplying more torque, the N20 gear motor is smaller and noticeably lighter than the RF-370CA, increasing manoeuvrability of Stride.

4.2.2 Boundary Detection System

The boundary detection system uses a dual sensor combination with an infrared (IR) sensor detecting when the stick is in contact with the floor, and a RGB sensor to read the colour values of the surface. If the value change exceeds a specified threshold, this indicates a boundary change which results in operating the vibration motors. The vibration motors are operated in conjunction with a 2N2222 transistor.

Initially, the sensors were coded to operate individually. If both sensors detected a change, the vibrational motor would be triggered. However, after testing this system by attaching the sensors to the base, it was realised that this would result in false positives while the stick was off the floor.

Thus, the logic was changed to a dual-sensor system where the RGB sensor operates only when the IR sensor detects the ground. This yielded more accurate results.

4.2.3 LED System

The LED system was incorporated as further assistance to users during the dark. In addition to this, the light could double as a visual stimuli, alongside the tactile stimuli (vibration), to will Parkinson's patients forward and out of freezing episodes.

The LED system consists of the 7.4V battery, Arduino Nano and a push button. When the button is pressed, a signal is sent to the Arduino, which outputs voltage to the LED, thus turning it on. The light code is such that there is a small delay between the button being pressed and the LED being turned on or off. Initially, this delay was set to 1000 ms, but after user testing, it was found that users become impatient and tend to press the button again, resulting in the button being turned off, therefore this delay was reduced to 100ms.

While it was considered to have two buttons, one for turning the light on and one for turning the light off, this was later deemed to be over designing and thus the single button was chosen as the final design.

4.3 Physical Prototyping

The rapid prototyping stage involved machining and 3D printing techniques.

4.3.1 Material Selection

When it came to material selection, the requirements were split into functional and visual needs. The functionals needs were:

- **Biocompatible:** the material must be non toxic and suitable for prolonged contact with the user.
- **Robust and Durable:** the material must be able to withstand repeated applied load (the user's weight) and resist deterioration over time.
- **Lightweight:** since the product is a walking aid, portability is a necessity
- **Slip Resistant:** the base of the walking stick needs to provide secure grip on various surfaces, to ensure the product is safe for use.
- **Low maintenance:** the product must be easy to clean, without exhibiting degradation of quality.
- The material must meet **regulatory compliance** (see 10. Product Compliance).

The aesthetic requirements of the material were made in conjunction with the brand analysis conducted on Ottobock. As stated in section 8. Branding, Ottobock products follow a modern and simple design, therefore this was also considered during the selection process – but to a secondary degree to previously mentioned functional requirements.

PVC: This is a versatile, lightweight material, which forms the main structure of the walking stick. This choice was made due to its strength, durability and lightweight nature. PVC is highly resistant to impact, moisture and environmental wear, making it an ideal choice for long term use in a walking aid. Additionally, PVC can be outsourced in a variety of diameters, simplifying the manufacturing process of this product.

Silicon: This material was used in the base of the walking stick and for the flexible ferrule. This is because silicon enhances grip and stability, preventing slips on various surfaces – a functional requirement. Additionally, it is flexible and shock resistant, making it a suitable choice for absorbing ground impacts, consequently improving user comfort. The role of the ferrule in this product is to allow flexion and thus unobtrusive movement with the stick. This goal is also made achievable through the material choice of silicon.

ABS: The handle and base were chosen to be 3D printed in Acrylonitrile Butadiene Styrene due to its impact resistance, making it perfect for repeated daily use. Despite its toughness, ABS is lightweight, which would ensure comfortable handling. Finally, this thermoplastic is injection moulding compatible, which would ensure consistent quality during scaled production (see 6. Design for Manufacture and Assembly).

While the final product will be made from ABS, these parts were made from PLA in the prototype. This was because PLA is easily machined and has good dimensional accuracy.

Stainless Steel: The lead screw was outsourced in this material since it is a high strength, durable material. Moreover, a stainless steel lead screw would ensure smooth, long-term extension and compression, which is a necessity for the functionality of this product.

Brass: The nut that runs up and down the lead screw, was chosen to be in this material, due to its self lubricating nature.

4.3.2 Wire Pole

Due to the nature of electro-mechanical products, it was imperative to consider how the electronics would fit into the product without interfering with any moving parts. We introduced a stable rod to feed the wires from the electronics housing to the handle. The rod is unaffected by the turning motion of the extension mechanism, and thus the wires will not interfere with the mechanism.

5 Power & Load Calculations

5.1 Power Calculations

5.1.1 Battery Specifications

The product is powered using a 7.4V rechargeable lithium ion battery, selected for its balance between voltage, energy density and form factor. The battery consists of two 3.7V cells in series, delivering a voltage of 7.4V with a capacity of 2000 mAh (14.8Wh).

5.1.2 Power Consumption of Components

Table 1*: Power Consumption of Components*

Component	Current Draw (mA)	Voltage (V)	Power (mW)
Vibrational Motor	85	3.3	280.5
N20 Motor	210	6	1260
Arduino	20	6	120
IR Sensor	20	5	100
Colour Sensor	0.33	5	1.65
LED Light	303	3.3	1,000

Total power consumption = 2,762.15 mW

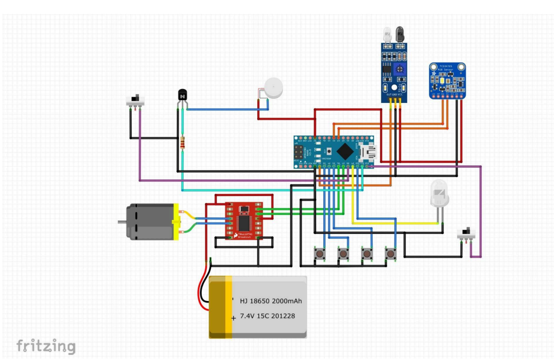

Figure 9*: Circuit Diagram*

5.1.3 Battery Life Estimation

Since all components are not always active during operation, we used duty cycles to estimate the average power consumption. This allows for a more realistic battery life calculation, reflective of typical user interaction.

Table 2*: Average Power Consumption*

Component	Power (mW)	Duty Cycle (%)	Avg. Power (mW)
Vibrational Motor	280.5	10%	28.05
N20 Motor	1260	1.5%	18.90
Arduino	120	100%	120
IR Sensor	100	100%	100
Colour Sensor	1.65	100%	1.65
LED Light	1,000	40%	400

Total avg. power consumption = 668.6 mW

Therefore, battery life = 14.8Wh/0.6686W = 22.13 hours.

5.2 Load Calculations

Theoretical hand calculations were done to validate the design concept and ensure safety of the product.

- **Vertical Load:** The walking stick should be strong enough to safely support the targeted users in the manner intended. Thus, this calculation was conducted to ensure that the material of the stick can support this load without failure.

Evidence suggests that Parkinson's patients exhibit lower body weight compared to healthy patients, of the same age. The average body weight of an elderly person is 63.4kg (males) and 55.8kg (females), therefore to be conservative, the assumed body weight on the stick was taken as 80kg.

For a walking stick, the load on the stick is taken to be 20% of the person's weight.
Static Load = F = *0.2 x 80 x 9.81 = 156.96 N*
Safety Factor (for medical devices) = *3.5*
Load = *156.96 x 3.5 = 550 N*
Therefore, the product must be designed to support *550 N.*
Cross sectional area of the stick = 0.000251 sq m
Stress = 2.19 MPa
Tensile strength of PVC = *60 MPa*
Since 60 >> 2.19, the stick will not break.

In order to further support these calculations, an FE Analysis was done on a slightly simplified CAD model of the walking stick.

The analysis revealed that the walking stick will not fatigue under the load. Additionally, first mode buckling will occur when over 9 times the safety load is applied on the walking stick. These results suggest that the walking stick is strong and robust for the intended use, and has a large safety margin in its fatigue strength.

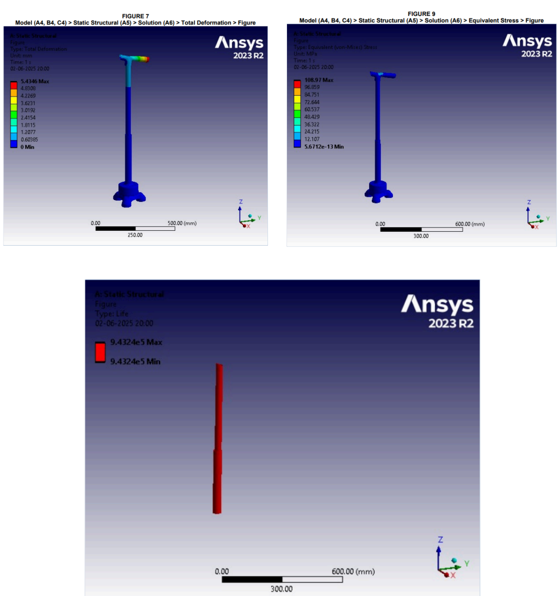

Figure 10*: FEA Failure Results*

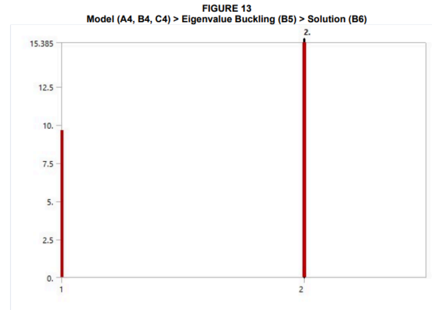

TABLE 28
Model (A4, B4, C4) > Eigenvalue Buckling (B5) > Solution (B6)

Mode	Load Multiplier
1.	9.6195
2.	15.385

Figure 11*: Eigenvalue Buckling*

5.3 Torque Calculations & Motor Selection

$$T = \frac{F \cdot d_m}{2} \cdot \left(\frac{l + \pi \cdot \mu \cdot d_m}{\pi \cdot d_m - \mu \cdot l}\right)$$

Load (of product) = *F = 0.266 × 9.81 N*
Lead = *l = 0.008 m*
Major screw diameter = *dm = 0.0075 m*
Friction coefficient = *μ = 0.08*
Gear Ratio = *1:2*

$$T_{motor} = \frac{T}{2} = \frac{0.0042}{2} = 0.0021Nm$$

With a safety factor of 2, **total torque from motor = *0.0042 Nm = 4.2 mNm***

The previously used RF-370CA motor only supplied a torque of 2 *mNm,* whereas calculations proved that a minimum of 4.2 *mNm was* required. Due to this, an N20 gear motor, with a maximum torque of 33.34 *mNm* was used.

6 Detail Design (DFMA)

To ensure that this product could be manufactured effectively and with industrial methods, parts were made with the intention of being injection moulded. Moreover, standardised components were used, further enabling a more streamlined manufacture process to align with ISO 8887 [29].

6.1 Injection Moulding

The mechatronics housing, handle and base of the walking stick were made with the intentions of being injection moulded, however for the initial prototype they were 3D printed. Advantages of being injection moulded include cost effectiveness and increased production rates.

Considerations in the component design – to facilitate injection moulded production – include chamfered edges and draft angles. These modifications ensure that the component can be removed from the mould. Additionally, the wall thickness was made uniform to prevent warping and ensure proper material flow. These measures follow ISO 8887 recommendations for manufacturability and mould design efficiency. Finally, the gate placement was thoroughly thought out to ensure even flow of molten ABS. The gate was placed at a location where part strength or aesthetics would not be compromised.

6.2 Snap Fittings & Non-Permanent Joints

The top and base of the mechatronics housing are secured using snap fittings. Snap fittings were strong enough to securely store the internal electronics in place (even when the stick is off the ground) whilst also allowing the housing to be opened for disassembly. Additionally, the snap fittings act as self aligning features, allowing easier assembly. This supports ISO 8887's emphasis on designing for ease of assembly and disassembly.

The bottom of the handle is also attached using snap fittings. This was done so that the electronic components could easily be accessed, replaced or removed throughout the product's life cycle – aligning with ISO 8887's focus on life cycle-oriented design.

Screws were used to secure the Arduino Nano, colour sensor, IR sensor and nut pipe connector. Whilst this was a functional choice for the nut pipe connector, this was done for the Arduino Nano and sensors to enable quick assembly and disassembly. The Arduino Nano was secured using four M3 nuts and the sensors used two M3 nuts for modularity and serviceability.

6.3 Standardised Components

Throughout the product, M2 and M3 nuts were used. The two coalescing PVC pipes are also of standardised diameters (40 mm and 36 mm). The implementation of standardised components throughout this product aids in the breakdown process and in reducing waste. Since these parts follow uniform specifications, they can be easily separated, replaced or reused, promoting sustainability and cost-effective repairs. On top of that, standardised fasteners minimise the need for specialised tools, making disassembly more simple.

6.4 Motor Integration

To help design for assembly / disassembly, as well as reliable performance and longevity, some design considerations were made in accordance with ISO 8887 when it came to utilising the motor.

Suitable Tolerances and Clearance Fits: exact tolerances were maintained between the motor gear and bevel gears, to ensure smooth movement, with minimal friction.

Secure Mounting: The motor was firmly secured within the mechatronics housing with four M3 nuts. This was done to prevent excessive vibrations, which could lead to internal wear and tear over time. On top of that, this was done so that the motor positioning could be exact and precise, in mass production, facilitating assembly.

6.5 Bill of Materials

Refer to Appendix A.

7 Branding Considerations

7.1 Benchmarking: Products

During the development process, further secondary research was conducted. Companies which produced walking sticks/ canes were analysed, to identify features or functions which may be advantageous to incorporate in Stride.

7.1.1 CAN Go Smart Cane

***Figure 12**: CAN Go Smart Cane [3]*

CAN Go's Smart Cane is a technologically advanced mobility aid designed for the elderly and individuals with visual impairments. It features a sleek, modern aesthetic. Powered with AI, it is integrated with various functions such as GPS, activity trackers, health reports and fall detection. Additional accessories include a portable charger and wall mount.

7.1.2 WeWALK Smart Cane

***Figure 13**: WeWALK Smart Cane [4]*

WeWALK's Smart Cane is designed for individuals with visual impairment. It is integrated with obstacle detection using haptic and audio feedback, along with a navigation system, intelligent voice assistant and an intuitive push button design.

7.1.3 Phoenix SmartCane

***Figure 14**: Phoenix SmartCane [5]*

Phoenix SmartCane is a cane designed for those with visual impairment. It is marketed as an affordable option, using ultrasonic sensors to detect obstacles within 3 metres.

7.1.4 Ergocane 2G

***Figure 15**: Ergocane 2G [6]*

Ergocane 2G emphasises its ergonomic grip designed to reduce wrist strain during use. It also exhibits its unique shock absorption technology that uses vertical compression for smoother movement. Its patented design with 4 ailerons mimics joint articulation of foot/ankle with durable rubber.

7.1.5 Key Takeaways

Through conducting benchmarking on successful pre-existing products, the following features and functions were abstracted, as desirable for implementation in Stride.

- Portable Charger supplied with product.
- Intuitive push button design.
- Obstacle detection at a far range.
- Joint articulation mimicry.

7.2 Benchmarking: Brands

Three companies which excel in the field of promoting mobility were researched and analysed, to find a suitable brand partner, for the outroll of Stride.

7.2.1 CAN Go

CAN Go is a mobility aid brand dedicated to empowering the elderly and those with mobility impairments. The company's design philosophy centers on sleek minimalism and subtle aesthetics, aiming to reduce the stigma often associated with assistive devices. By blending functionality with a modern appearance, CAN Go enhances user confidence and encourages independence.

7.2.2 Ottobock

"Human, reliable, inventive, smart" are Ottobock's company values [7]. Ottobock is a prosthetics company known for its high-performance materials, advanced technology and user-centred design. With a futuristic, sleek design, Ottobock's devices reflect their principles of solidarity and strength.

7.2.3 byACRE

byACRE is committed to minimalistic, ergonomic design, while maintaining high functionality. One notable example is their Ultralight Rollator – branded as the world's lightest rollator [8]– which exemplifies byACRE's pursuit of freedom of movement without compromise on aesthetics or performance.

8 Branding Implementation

8.1 Selection

Ultimately, Ottobock was chosen as the main source of inspiration. This choice was made for an amalgamation of reasons, mainly, the company's dedication to improved quality of life, technological advancement and outreach and accessibility.

***Figure 16**: Ottobock Products*

8.2 Physical Design

Ottobock products are known for their sleek aesthetics and high quality finishes, which facilitate long term usage. To emulate this, in Stride's aesthetics, materials were chosen with deliberation and ergonomics were a focal point throughout the design phase. Furthermore, Stride was designed to be a modern take on the stereotypical walking stick, overcoming the stigma and shame which come with other and medical devices.

Stride has a subtle colour scheme, which reinstates Ottobock's overarching sophisticated theme - Stride is a product for everyone, anywhere. The use of a subtle colour palette has the added benefit of being gender and age neutral. Although PD is more commonly observed in men and individuals over 60, it can affect anyone, meaning inclusive design is essential.

8.3 Features

Ottobock products are highly functional and user centric. For Stride, this looks like ensuring the product is easy and intuitive to use. The main user interface of this product is the handle. Notable features on the handle include ergonomic contours to fit the hand's natural shape, easy-access buttons and expressive button caps, i.e. the extension is controlled by an up arrow.

Ottobock is a pioneer in merging technology with medical devices. Stride embraces this forward thinking philosophy by incorporating sensory input and haptic feedback to address Freezing of Gait. Additionally, its electromechanical extension mechanism – designed to aid users in both standing and seating – not only enhances mobility and independence, but also exemplifies Ottobock's commitment to technological innovations and its mission to improve quality of life through movement.

9 Product Assembly Process

***Table 3**: Product Assembly Process*

<table>
<tr><th>Subassembly</th><th>Subcomponent</th><th>Required Components</th><th>Process Overview</th></tr>
<tr><td>Handle</td><td>–</td><td>4x Buttons
4x Button Covers
Handle
Handle Electronics Cover
Vibrational Motor
2N2222 Transistor
LED
Light Cover
Wires
Resistor</td><td>Solder wires to the two diagonal legs of each of the four buttons.
Glue the four buttons to the appropriate positions on the handle.
Glue the four button covers onto the corresponding buttons.
Solder wires onto the LED.
Glue the LED onto the light cover.
Solder wires onto the vibrational motor.
Solder wires onto the 2N2222 transistor with the ground wire attached to the ground wire of the vibrational motor.
Solder a resistor to the middle pin of the transistor.
Stick the vibrational motors onto the handle.
Attach the handle cover onto the handle by snap fit.</td></tr>
<tr><td rowspan="2">Pipe</td><td>Extension Mechanism</td><td>Lead Screw & Nut
7 OD x 300 L (mm) Stable Rod
Gear-Lead Screw Connector
Nut-Pipe Connector
3x M3 screws
3x M3 nuts</td><td>Slot the stable rod through the hole in the nut-pipe connector.
Attach the lead screw nut to the top of the lead screw.
Screw the M3 screws and nuts to attach the lead screw to the nut-pipe connector.
Attach the gear-lead screw connector to the bottom of the lead screw.</td></tr>
<tr><td>Pipe Casing</td><td>42 OD x 38 ID (mm) PVC Pole
34 OD x 30 ID (mm) PVC Pole
Pipe Seal
Extension Mechanism (Subcomponent)</td><td>Cut the 42 OD pole to a length of 330 mm.
Cut the 34 OD pole to a length of 600 mm.
Attach the pipe seal onto the 42 OD pipe and slot the 34 OD pipe through.
Fit the extension mechanism subcomponent into the casing, fitting the pipe seal on with a snug fit</td></tr>
<tr><td>Electronics Housing</td><td>Electronics</td><td>Arduino Nano
Wires
TB6612 H-Bridge
N20 gear motor
7.4 Battery
6V Battery
Wires from Handle (Subcomponent)</td><td>Solder wires to the Arduino Nano to pins VIN, GND, 5V, A4, A5, D2, D3, D4, D5, D6, D7, D9, D11.
Connect the Arduino Nano pins VIN and GND to the 6V Battery.
Using the wires from the handle, make the following connections to the Arduino Nano:
5x GND wires to GND</td></tr>
</table>

		● Wires from Base (**Subcomponent**)	○ Up button to D3 ○ Down button to D4 ○ LED button to D5 ○ LED to D9 ○ 2N2222 Transistor to D11 ○ Vibrational Motor to 5V 4. Using the wires from the base, make the following connections to the Arduino Nano: ○ 2x GND wires to GND ○ 2x VCC wires to 5V ○ IR sensor OUT to D2 ○ RGB sensor SDA to A4 ○ RGB sensor SCL to A5 5. Connect the TB6612 H-Bridge pins: ○ VM to STBY ○ VM to 7.4V Battery ○ GND to 7.4 Battery ○ AIN1 & AIN2 to Arduino Nano D6 & D7 ○ AO1 & AO2 to N20 gearmotor
	Electronics Housing Upper	● N20 Gear Motor ● Small Bevelled Gear ● Motor-Gear Connector ● Electronics Housing Upper	1. Attach the small bevelled gear to the N20 Gear Motor shaft. 2. Secure this in place using the motor-gear connector. 3. Attach this subassembly into the snap fit found in the upper electronics housing component.
	Electronics Housing Lower	● Bevel Gear Large ● Bearings ● Bearing-Gear Connector ● Electronics Housing Lower ● Electronics (**Subcomponent**)	1. Attach the bearing onto the centre part of the lower electronics housing component. 2. Attach the bearing-gear connector, then the large bevelled gear into the appropriate slot. 3. Fit the electronics into the housing, with the 7.4V battery in the appropriate slot. Ensure that no wires interfere with the gear mechanism.
Base	Dual-sensor System	● Infrared Sensor ● RGB Sensor ● Wires ● M2 Screws ● M2 Nuts ● Tripod Base ● Sensor Casing	1. Connect wires to pins OUT, GND and VCC of the infrared sensor. 2. Connect wires to pins SDA, SCL, GND and VIN of the RGB sensor. 3. Screw the infrared sensor and RGB sensors to the tripod base. 4. Screw the sensor casing to enclose the dual-sensor system.
	Ferrule & Base	● Rubber Ferrule ● Tripod Base ● Wires	1. Cut a hole in the tripod base and rubber ferrule. 2. Feed the wires from the dual-sensor system through the cut holes to go to the Arduino Nano in the electronics housing.

10 Product Compliances and Labelling

Ensuring regulatory compliance is essential for the development and market release of medical assistive devices, therefore Stride has been designed in accordance with key international and regional standards to meet safety, performance, and usability criteria.

10.1 UKCA & CE

The product carries both the UK Conformity Assessed (UKCA) and CE markings, indicating compliance with regulations for products placed on the market in Great Britain and the European Economic Area (EEA) respectively. These markings confirm that the product meets all relevant requirements related to safety, health, and environmental protection.

Figure 17*: CE & UKCA Symbols*

10.2 ISO

The device also adheres to key ISO standards related to assistive technologies:

- **ISO 11334-4**: Applies to walking aids manipulated with one arm. It specifies general design requirements such as, clause 6.3.1 – handgrip width must be between 20 mm and 50 mm unless an anatomical design is used. Distance between the handgrip and the tips must be ≤ 40 mm for ergonomic efficiency. [10]

- **ISO 13485**: This standard covers quality management systems for medical devices, it is a necessity to obtain regulatory approval. [11]

- **ISO 62304:** This standard addresses the software used for medical devices, ensuring that they are of a safe and reliable standard for continued use. [12]

- **ISO 9999**: Classification of assistive products. The product is categorised under 12 03 16, which includes walking devices with support and balance functions, featuring a handgrip, shaft, and three or more tips. [13]

- **ISO 14971:** Standard focuses on the essentiality of risk management, especially when the device in question consists of moving parts (i.e. components in the extension mechanism). [14]

- **ISO 7176-1:** This standard includes static, impact and fatigue testing methods. It ensures structural reliability under real word use, such as user weight. [15]

- **ISO 22411:** Offers human centered design principles, specifically for products, where the main user targets are those with disabilities and age related limitations. Promotes inclusive design for vulnerable users, therefore is key. [16]

- **ISO 20417:** Details the information that must be provided by the manufacturer (symbols, warnings traceability etc.). [17]

- **ISO 8887**: Outlines principles for designing products to optimise manufacturing, assembly, disassembly and end-of-life processing. [29]

10.3 IEC

Compliance with IEC standards ensures that the product meets rigorous safety and performance criteria for medical electrical equipment:

- **IEC 60601-1**: Specifies general safety and essential performance requirements for medical electrical equipment. This includes provisions for electrical safety, mechanical integrity, and protection against hazards such as excessive temperatures or radiation. [18]

- **IEC 60601-1-2**: Defines the electromagnetic compatibility (EMC) requirements to ensure the device functions reliably without interfering with or being affected by other electrical equipment. [19]

- **IEC 62366**: Addresses usability engineering to minimise user errors and enhance safety. It ensures the device is intuitive and usable under real-world conditions, particularly for vulnerable users. [20]

- **IEC 62133:** Ensures lithium-ion batteries operate safely under both ideal and non-ideal conditions. This covers risks such as overheating and overcharging. This is essential for portable, powered medical devices, used in close proximity to a person. [21]

- **IEC 60529:** This standard classifies the degree of protection provided by enclosures against external particles and liquids. This is vital to ensure components like sensors and motors remain functional in dusty or wet environments, for instance outside. [22]

10.4 Additional Standards & Certifications

Beyond the core standards and regulations above, there are many additional regulations and certifications to consider, which reach broader safety, environmental and ethical expectations.

10.4.1 Medical Device Regulation

In order to obtain a CE or UKCA marking for sale of Class I medical devices in the UK AND EU, MDR compliance is mandatory. This sets strict guidelines for products, including classification, safety, clinical evaluation and post market surveillance.

10.4.2 RoHs (Restriction of Hazardous Substances)

This standard limits the use of hazardous materials, such as lead and mercury, in electronic products. RoHS compliance ensures environmental safety and user protection from toxic components, which is especially important in assistive devices which are handled daily. This is a required standard for all products with electronic components placed on the EU/ UK market, therefore a CE or UKCA marking cannot be obtained without it. [23]

10.4.3 WEEE (Waste Electrical and Electronic Equipment Directive)

Frequently paired with CE, UKCA and RoHS standards for consumer electronics, this standard addresses correct collection, treatment and recycling of products. [24]

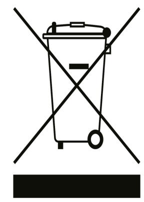

***Figure 18**: WEEE Symbol*

The inclusion of this is vital for Ottobock products, since end of life environmental impact and circular design is a key part of their sustainability pact.

10.4.4 Forest Stewardship Council Certification

FSC certification guarantees that relevant materials (see 12.4 Materials) are sourced from responsibly managed forests. This certification ensures that environmental, social and economic benefits are delivered to the communities involved in the supply chain.

***Figure 19**: FSC Symbol*

The above certification not only supports Ottobock's sustainable design philosophy, but also their value of promoting the sense of community. [25].

11 User Guide

Given that the product is geared towards individuals with Parkinson's, it is crucial to have clear instructions, enforcing proper use of the product to ensure the safety of the individual. It has a generally minimalistic style, with large font for readability and a consistent blue theme that reinforces the brand identity of Ottobock.

11.2.1 Covers, Foreword & Contents

The covers of the user guide include the product name, company name and relevant regulatory logos for clarity. The foreword provides general information and the contents page helps users quickly navigate to specific sections.

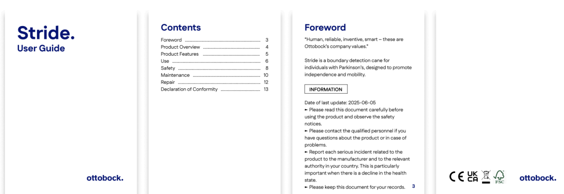

***Figure 20**: Covers, Foreword & Contents*

11.2.2 Product Information

The different parts of the product are labelled and product features are explained. The operation of each of the buttons are shown clearly to the user.

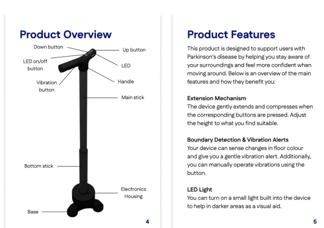

***Figure 21**: Product Overview & Features*

***Figure 22**: Product Use*

11.2.3 Safety

Safety information is categorised into three sections, Warning, Caution and Notice:

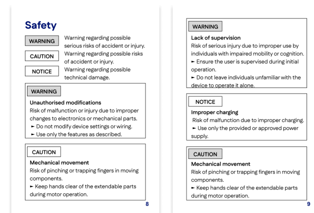

***Figure 23**: Safety*

11.2.4 Maintenance & Repair

The maintenance section outlines routine checks to be done by the caregiver every two weeks and every month. If the product appears to be damaged, one should contact the support team.

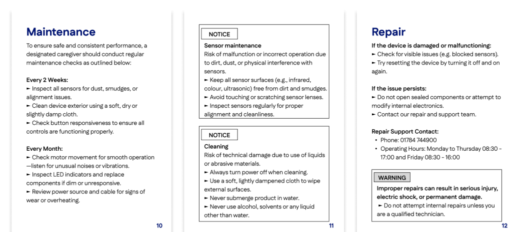

***Figure 24**: Maintenance & Repair*

11.2.5 Declaration of Conformity

The declaration of conformity shows that the product meets all required safety, technical and legal standards outlined in section 10. Product Compliance.

Declaration of Conformity

Product Name: Stride
Model Number: 03051929

This product has been developed in line with key safety and performance guidelines for assistive devices, suitable for prototyping purposes.

Applicable Directives:
- Medical Device Regulation (EU) 2017/745
- UK Medical Devices Regulations 2002
- RoHS Directive 2011/65/EU

Key Standards Referenced:
- ISO 13485 – Medical device quality systems
- ISO 14971 – Risk management
- IEC 60601-1 – Electrical safety
- IEC 60601-1-2 – EMC requirements
- ISO 20417 – Information from manufacturers

Note: This declaration supports an academic prototype only and does not imply official CE or UKCA certification.

13

***Figure 25**: Declaration of Conformity*

12 Product Packaging

12.1 Design Inspiration

From the interview with Lucy Jung, co-founder of Charco Neurotech, the idea that the packaging of the product should feel like a gift, rather than a medical device was gained. Following this interview, Charco Neurotech packaging was analysed [36]. Through analysis, the key takeaways emphasised a packaging design that was both simple and chic, ensuring a modern, appealing look. Furthermore, the idea that clear branding enhances recognition and reinforces product identity was gained.

12.2 Packaging Views

Figure 26*: Product Packaging – Outer*

The outer packaging of Stride consists of a simplified, embossed walking stick, with Stride written in Fustrat, the primary type of Ottobock. The case was chosen to be of uniform colour, to reiterate the modern aesthetic of our chosen brand.

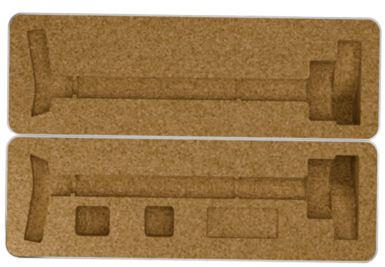

Figure 27*: Product Packaging – Inner*

The internal packaging features a negative imprint of the product, ensuring secure transportation while offering a familiar, intuitive unboxing experience. This reduces intimidation and enhances approachability – especially for an older demographic, seeking effortless adoption. On top of that, the internal casing includes designated spacing for a charger (see 7.1.5), replaceable rubber tips for the base (in accordance with ISO 6.3.3) and the user guide.

12.3 Accessibility

Parkinson's Disease is most commonly observed in those above 60 [9]. Due to this, extra design considerations were made, to ensure legibility and readability. The minimum font size was 12pt, as many individuals within this target demographic, experience a deterioration in eyesight. Furthermore, icons were used alongside instructions to assist in presenting information, in a clear and concise manner.

12.4 Materials

Ottobock prioritises sustainability by using recyclable and eco-friendly materials in its packaging [35]. The negative imprint is made from cork, chosen not only for its low environmental impact but also for its durability and shock absorbency, offering added protection during transport. A sleek aluminium casing enhances Stride's premium feel while being lightweight and long-lasting. Both materials promote reusability, allowing the packaging to double as a protective accessory – reinforcing Ottobock's commitment to sustainable and practical design.

12.5 Production Processes

The casing is made of recyclable grade aluminium, which is deep drawn into the required concave shape. CNC machining is used to create the hinge system of the product, and die stamping is done to emboss the writing 'Stride' and walking stick iconography onto the product. As for the cork negative, FSC certified granules are compressed and moulded into the desired shape. The surface is then sanded and sealed with natural wax, for enhanced durability. This part is made slightly larger than required, to allow a snap fit between the internal and external, removing the need for permanent glueing. This is another instance of design for disassembly.

13 Final Design

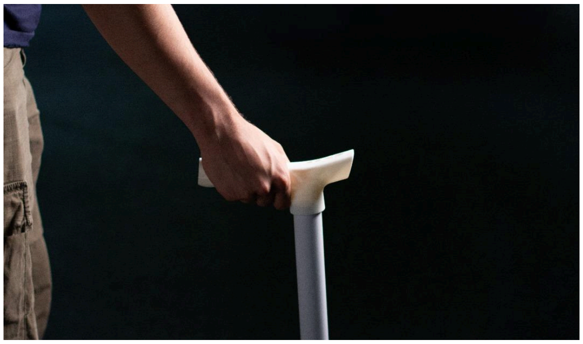

***Figure 28**: Final Design Photo*

13.1 Objective and Features

Stride by Ottobock is an assistive walking device designed to help Parkinson's patients overcome Freezing of Gait (FoG) – a phenomenon where movement temporarily halts due to disruptions in the body's rhythm, often triggered by environmental or cognitive overload.

Stride addresses this through three key features:

- **Vibration:** Sensors in the product's base detect changes in boundary (e.g. entering a new room), triggering haptic feedback in the handle. Users can also manually activate the vibration via a push button on the handle – a feature added based on user feedback.
- **Extension and Compression**: Adjustable height via intuitive buttons, supports smoother transitions from seated positions and to navigate uneven terrain (e.g. stairs).
- **Light:** An LED in the handle provides visual cues (an additional form of stimuli) to overcome FoG and enhances user safety.

Stride integrates both functional and design features for a cohesive product. The handle includes ergonomic contours for comfort, a three-legged base for stability and a flexible rubber ferrule that adapts to the user's movement. Stride aims to be a highly functional, user-centric product while having a sleek, modern aesthetic.

13.2 Final Prototype

After several iterations, the final prototype, with all the aforementioned functions, was created.

***Figure 29**: Final Prototype – Various Images*

13.3 Limitations and Improvements

During the development process, a few problems, with the potential for further improvement, were discovered.

- Although sufficient for the prototype, the reliability of the colour sensor was a major problem – it was prone to false positives. Moving forward, the implementation of calibration against standardised colours or the use of computer vision, to enhance image processing, may be more reliable.
- Moreover, the IR sensor had trouble detecting darker surfaces, and therefore would not sense certain floorings – using an ultrasonic sensor could be more suitable in future iterations.

13.4 Commercial Positioning

Stride by Ottobock weighs 900g, similar to most smart walking sticks [40][41], while still delivering advanced features like multi-sensory cueing height adjustability and ergonomic design. Unlike competitors that rely on laser based cueing, and lie within the range of £200 and £500 [37][40][41], Stride offers a more holistic, personalised experience. Priced at £590 with an estimated £180 production cost, it maintains a healthy 69.5% profit margin, while justifying its value through enhanced functionality and usability.

13.5 Link to Video: [IDE Video - Group 5 (Stride.)]

14 Project Report

ClickUp™, a project management website, was used to streamline the progress of this project. All tasks were synced to be referred to in varying features such as the Gantt chart, Kanban board, task lists and meeting notes. All members had access to the

14.1 Gantt Chart

Due to the iterative nature of this project, we adopted a hybrid project management approach. This combines iterative, Agile-inspired design cycles with the use of a Gantt chart for timeline planning and milestone tracking. Refer to the Gantt Chart page in the portfolio.

14.2 Milestones

Milestone 1: Extension Mechanism (*22nd May*)
We decided to use a lead screw mechanism with a motor in order to extend the stick. The system itself worked on its own, however we found that with the added load of the pipe casing, the motor did not have enough torque to move.

Milestone 2: Handle Design (*29th May*)
The handle design was optimised to integrate modern aesthetics, functionality and safety. Initially, the handle was angled at 15 degrees – this was altered to improve safety. Moreover, finger grooves were added for improved ergonomics.

Milestone 3: Casing & Perceived Bulk (*29th May*)
Previously, the electronics housing had been too large, making the overall aesthetic of the product seem bulky. The casing was optimised, ensuring there was enough space to fit the electrical components while maintaining the overall intended aesthetic.

Milestone 4: Haptic Feedback (*30th May*)
The vibration motor was able to operate based on the inputs from the sensors.

Milestone 5: Dual-sensor System (*7th June*)
The sensor system was changed from operating independently to a dual-sensor system for improved accuracy. The RGB sensor only operates when the IR sensor detects the floor.

Milestone 6: Wiring through Base (*10th June*)
In order to improve accuracy, the sensors were moved from the pipe to the bottom of the base. Holes were cut in the ferrule and based so that the wires could be fed through from the housing to the base.

Milestone 7: Extension Mechanism with Sufficient Torque (*12th June*)
Earlier iterations of the extension mechanism were revised, aiming to solve the initial issue of the added load of the stick. Using lubrication on the gear, as well as a change in motor proved successful in operating the extension mechanism with the added load of the stick.

14.3 Reflections

The hybrid approach of using both Agile principles and traditional Gantt planning provided the team with structure, while still allowing flexibility in responding to testing outcomes and design changes. Agile-inspired practices, such as weekly reviews and iterative prototyping, enabled faster detection of issues – especially during mechanical testing of the extension mechanism and the integration of the dual-sensor system. However, the Gantt Chart helped anchor the project to recommended deadlines, preventing scope creep and maintaining team accountability.

One key lesson was the importance of early-stage physical testing. While concept development progressed efficiently, several mechanical challenges could have been identified sooner with earlier testing (e.g. the torque limitations of the initial motor). Thus, future projects would benefit from allocating more time in the early stages to prototyping and failure testing, even when initial concepts are not fully developed.

Another takeaway was the value of effective team communication. Regular check-ins, use of shared tools such as ClickUp™, and in-person collaborations helped avoid duplicated work and ensured consistent progress. Despite working under tight time constraints, the team remained cohesive, collaborative, and open to change.

15 References

1. Go C. *CAN Go*. CAN. https://can.co/products/can-go?srsltid=AfmBOoq6iAaQoZsiKevmKHxlrym6pEEuf8ro0uY0xbbHUoYfDRySFdPK [Accessed 22nd May 2025].
2. *Product*. WeWALK Smart Cane. https://wewalk.io/en/product/
3. *Phoenix Medical Systems | SmartCane*. www.phoenixmedicalsystems.com. https://www.phoenixmedicalsystems.com/assistive-technology/smartcane
4. *Ergocane 2G*. Ergoactives. https://www.ergoactives.com/products/ergocane-2g [Accessed 22nd May 2025].
5. *Mobility for people – this is Ottobock's mission*. corporate.ottobock.com. https://corporate.ottobock.com/en/company/values-culture
6. Parkinson's Foundation. *Statistics*. Parkinson's Foundation. https://www.parkinson.org/Understanding-Parkinsons/Statistics
7. Cleveland Clinic. *Parkinson's disease: Causes, Symptoms, Stages, Treatment, Support*. Cleveland Clinic. https://my.clevelandclinic.org/health/diseases/8525-parkinsons-disease-an-overview
8. National Institute of Neurological Disorders and Stroke. *Parkinson's Disease: Challenges, Progress, and Promise | National Institute of Neurological Disorders and Stroke*. www.ninds.nih.gov. https://www.ninds.nih.gov/current-research/focus-disorders/parkinsons-disease-research/parkinsons-disease-challenges-progress-and-promise
9. *Carbon Ultralight*. Byacre.com. https://shop.byacre.com/en/carbon-ultralight-rollator.html [Accessed 18th June 2025].
10. International Organisation for Standardization. *Assistive products for walking manipulated by one arm - Requirements and test methods - Part 4: Walking sticks with three of more legs. Geneva: ISO 11334-4*.
11. International Organization for Standardization. *Medical devices – Quality management systems – Requirements for regulatory purposes. Geneva: ISO 13485*.
12. International Organization of Standardization. *Medical device software – Software life cycle processes. Geneva: ISO 62304*.
13. International Organization for Standardization. *Assistive products for persons with disability – Classification and terminology. Geneva: ISO 9999*.
14. International Organization for Standardization. *Medical devices – Application of risk management to medical devices. Geneva: ISO 14971*.
15. International Organization for Standardization. *Wheelchairs – Part 1: Determination of static stability. Geneva: ISO. 7176-1*.
16. International Organization for Standardization. *Ergonomics data and guidelines for the application of ISO/IEC Guide 71 to products and services to address the needs of older persons and persons with disabilities. Geneva: ISO 22411*.
17. International Organization for Standardization. *Medical devices – Information to be supplied by the manufacturer. Geneva: ISO 20417:*
18. International Electrotechnical Commission. *Medical electrical equipment – Part 1: General requirements for basic safety and essential performance. Geneva: IEC 60601-1*.
19. International Electrotechnical Commission. *Medical electrical equipment – Part 1-2: General requirements for basic safety and essential performance – Collateral standard: Electromagnetic disturbances – Requirements and tests. Geneva: IEC. IEC 60601-1-2*.
20. International Electrotechnical Commission. *Medical devices – Application of usability engineering to medical devices. Geneva: IEC. IEC 62366:*
21. International Electrotechnical Commission. *Secondary cells and batteries containing alkaline or other non-acid electrolytes – Safety requirements for portable sealed secondary lithium cells, and for batteries made from them, for use in portable applications. Geneva: IEC. IEC 62133:*

22. International Electrotechnical Commission. *Degrees of protection provided by enclosures (IP Code). Geneva: IEC. IEC 60529*.
23. European Union. *Directive 2011/65/EU on the restriction of the use of certain hazardous substances in electrical and electronic equipment (RoHS 2). Official Journal of the European Union, L174, 88–110.*
24. European Union. *Directive 2012/19/EU on waste electrical and electronic equipment (WEEE). Official Journal of the European Union, L197, 38–71.*
25. Forest Stewardship Council. *FSC-STD-40-004 V3-1: FSC standard for chain of custody certification. Bonn: FSC.*
26. AlGhazi A. *About us*. CAN. https://can.co/pages/about-us [Accessed 15th May 2025].
27. Bachmann CG, Trenkwalder C. Body weight in patients with Parkinson's disease. *Movement Disorders*. 2006;21(11): 1824–1830. https://doi.org/10.1002/mds.21068.
28. *Innovative strength for sustainable, profitable growth: Ottobock 2024 with 7 percent revenue growth and earnings increase of 17 percent*. Ottobock. https://corporate.ottobock.com/en/company/newsroom/preliminary-business-figures-2024 [Accessed 15th May 2025].
29. International Organization for Standardization. *Design for manufacture, assembly, disassembly and end-of-life processing (MADE) – General concepts and detailed considerations. Geneva: ISO. ISO 8887*.
30. *Ottobock*. Ottobock. https://www.ottobock.com/en-gb/prosthetics/lower-limb-prosthetics/c-leg4 [Accessed 15th May 2025].
31. Berggreen A. *The byACRE story - Who is byACRE?* byACRE. https://www.byacre.com/uk/our-story/ [Accessed 15th May 2025].
32. *byAcre Overview*. ZoomInfo. https://www.zoominfo.com/c/byacre-aps/426967827 [Accessed 15th May 2025].
33. Cockx HM, Oostenveld R, Yuli A Flórez R, Bloem BR, Cameron IGM, Richard. Freezing of gait in Parkinson's disease is related to imbalanced stopping-related cortical activity. *Brain Communications*. 2024;6(5). https://doi.org/10.1093/braincomms/fcae259.
34. Ge HL, Chen XY, Lin YX, Ge TJ, Yu LH, Lin ZY, et al. The prevalence of freezing of gait in Parkinson's disease and in patients with different disease durations and severities. *Chinese Neurosurgical Journal*. 2020;6(1). https://doi.org/10.1186/s41016-020-00197-y.
35. *Sustainability*. Ottobock. https://corporate.ottobock.com/en/sustainability [Accessed 18th June 2025].
36. *Charco Neurotech | A Non-Invasive Wearable Device for People with Parkinson's*. Charco Neurotech. https://charconeurotech.com/ [Accessed 16th June 2025].
37. *Parkinson's Cane 120 kg, Laser Light, PUSH BUTTON with two different handles and colors by Ossenberg*. Medicalcorner24. https://www.medicalcorner24.co.uk/parkinson-s-cane-120-kg-laser-light-push-button-with-two-different-handles-and-colors-by-ossenberg/OB3200K [Accessed 17th June 2025].
38. *The technology | Path Finder for freezing of gait in people with Parkinson's disease | Advice | NICE*. www.nice.org.uk. https://www.nice.org.uk/advice/mib170/chapter/The-technology [Accessed 16th June 2025].
39. *ART WALKING STICKS*. ART WALKING STICKS. https://artwalkingsticks.com/en-gb/blogs/blog/how-to-use-your-walking-stick-properly-tips-and-tricks-for-beginners [Accessed 16th June 2025].
40. *Lasercane - Part Ref. US003 - Attainability UK Ltd*. Attainability UK Ltd. https://attainability.co.uk/product/lasercane-vat-included/
41. *NexStride*. Anatomicalconcepts.com. https://store.anatomicalconcepts.com/nexstride [Accessed 19th June 2025].

Appendix A – Bill of Materials

Item Name	Item Number	Procurement Details	Cost	Qty.	Material	Dimensions (mm)	Weight (g)	Assembly
Colour Module - TCS34725	E1	Amazon	8.29	1		20.5 x 20.5	3.23	Screws
Arduino Nano	E2	Amazon	13.99	1		45 x 18	7	Screws
Vibration Motor 1027	E3	Amazon	4.99	2		R5 x 2.7	8	Sticker Glue
Infrared Sensor	E4	Amazon	1.1	1		39 x 15.50	6	Screw
Lead Screw	M1	Amazon	22.49	1	Stainless Steel + Brass Nut	R8 x 300	200	Interference Fit
Pole 1	S1	Hardware Shop	6	1	PVC	OD42 x ID38 x 330	130	Interference Fit
Pole 2	S2	Hardware Shop	7.5	1	PVC	OD34 x ID30 x 660	180	Interference Fit
Bevel Gear - Large	M2	Amazon	42	1	Steel	OD15 x 12	30	Interference Fit
Bevel Gear - Small	M3			1	Steel	OD8.5 x 12	15	Interference Fit
Bearing	M4	Amazon	5.39	1	Steel	32OD x 25 ID	25	Interference Fit
N20 Gear Motor	E5	Amazon	9.99	1		34 x 12 x 10	15	Holder screwed in
Light	E6	Amazon	0	1			2	Glue
Bottom Ferrule	S3	Amazon	10	1	Silicone	R12.5	10	Glue + Screw
Battery 4LR44	E7	Amazon	0.7	1			24	Snap fit
Push Buttons	E8	Amazon	0	4		6 x 6 x 3	4	Glue
H-Bridge	E9	Amazon	4.5	1		15 x 18	6	
Stable Rod	M5	Amazon	6.49	1	Stainless Steel	7mm OD x 300mm L	50	Interference Fit
Handle	S4	Injection Mould		1	ABS	40 x 200	60	Interference Fit
Handle Electronics Cover	S5	Injection Mould		1	ABS	40 x 100	10	Snap Fit
Handle Buttons	S6	Injection Mould		4	ABS	20 x 20	4	Glue
Light Cover	S7	Injection Mould		1	Clear PLA	40 x 50	20	Interference Fit
Base Electronics Housing Upper	S8	Injection Mould		1	ABS	126OD x 37 mm	50	Snap Fit

Base Electronics Housing Lower	S9	Injection Mould		1	ABS	126OD x 37 mm	50	Screw
Bearing-Gear Connector	M6	Injection Mould		1	ABS	OD25 x 10	9	Interference Fit
Motor-Gear Connector	M7	Injection Mould		1	ABS		1	Interference Fit
Pipe Seal	S10	Injection Mould		1	ABS	OD42	4	Interference Fit
Nut-Pipe Connector	M8	Injection Mould		1	ABS	OD36	3	Interference Fit
Gear-Lead Screw Connector	M9	Injection Mould		1	ABS	OD10	4	Interference Fit
Sensor Casing	S11	Injection Mould		1	ABS	21 x 40	14	Screw
Base	S12	Injection Mould		1	ABS	155 x155 x mm	200	Glue
Transistor	E10			1			1	
Resistor	E11			1			N/A	
Connectors								
M3 Nuts and Bolts	C1			3	Steel		6	
M2 Screws	C2			8	Steel		7	

Appendix B – Code

```
//LIBRARIES
#include <Wire.h>
#include "Adafruit_TCS34725.h"


//IR Sensor
const int irPin = 2;
bool irState = 1;
bool irPrevState = 1;


//RGB Sensor
Adafruit_TCS34725      tcs      =      Adafruit_TCS34725(TCS34725_INTEGRATIONTIME_600MS,
TCS34725_GAIN_1X);
bool colourChanged = false;
const int colourThreshold = 20;
uint16_t r, g, b, c;
uint16_t prevR = 0, prevG = 0, prevB = 0, prevC = 0;
// New scaled variables
uint8_t scaledR = 0, scaledG = 0, scaledB = 0;
uint8_t prevScaledR = 0, prevScaledG = 0, prevScaledB = 0;


//Buttons
const int kButton1 = 3;
const int kButton2 = 4;
const int kledButton = 5;


//DC Motor
const int kMotorPin1 = 6; // IN1
const int kMotorPin2 = 7; // IN2


//Vibration Motor
const int vibMotorPin = 11;


//LED
const int kledPin = 9;
```

```
bool LEDOn = false;
bool prevButtonState = HIGH;



void setup() {
Serial.begin(9600);
//IR Sensor
pinMode(irPin, INPUT);


//RGB Sensor
if (!tcs.begin()) {
Serial.println("TCS34725 not found. Check your wiring or I2C address.");
while (1); // Halt execution if sensor not found
}
Serial.println("TCS34725 is ready!");
//Buttons
pinMode(kButton1, INPUT_PULLUP); // Using internal pull-up
pinMode(kButton2, INPUT_PULLUP);
pinMode(kledButton, INPUT_PULLUP);


//Motor
pinMode(kMotorPin1, OUTPUT);
pinMode(kMotorPin2, OUTPUT);


//Vibration Motor
pinMode(vibMotorPin, OUTPUT);
digitalWrite(vibMotorPin, LOW);


//LED
pinMode(kledPin, OUTPUT);
}



void loop() {
irState = digitalRead(irPin);  // make sure no 'int' here
Serial.println(irState);
```

```
if (irState == 1 && irPrevState == 0) {
 // Object placed — store *previous* scaled values
 prevScaledR = scaledR;
 prevScaledG = scaledG;
 prevScaledB = scaledB;
}

if (irState == 0 && irPrevState == 1) {
 // Object removed — take a new reading
 delay(750);
 tcs.getRawData(&r, &g, &b, &c);
 if (c == 0) c = 1;  // Prevent division by zero

 scaledR = (float(r) / c) * 255;
 scaledG = (float(g) / c) * 255;
 scaledB = (float(b) / c) * 255;

 Serial.print("Scaled R: "); Serial.print(scaledR); Serial.print("\t");
 Serial.print("Scaled G: "); Serial.print(scaledG); Serial.print("\t");
 Serial.print("Scaled B: "); Serial.println(scaledB);

 // Reset detection flag
 colourChanged = false;

 if (
   abs(scaledR - prevScaledR) > colourThreshold ||
   abs(scaledG - prevScaledG) > colourThreshold ||
   abs(scaledB - prevScaledB) > colourThreshold
 ) {
   colourChanged = true;
   Serial.println("COLOUR DETECT");
 }
}

// Vibration Motor
if (colourChanged) {
 Serial.println("VIB");
 digitalWrite(vibMotorPin, HIGH);
 delay(1000);
 digitalWrite(vibMotorPin, LOW);
 colourChanged = false;  // Reset to avoid repeat vibrations
```

```
}

irPrevState = irState;
delay(100);  // Adjust as needed

// DC Motor
bool forward = digitalRead(kButton1) == LOW; // Active when pressed
bool reverse = digitalRead(kButton2) == LOW;


if (forward && !reverse) {
digitalWrite(kMotorPin1, HIGH);
digitalWrite(kMotorPin2, LOW);
}
else if (reverse && !forward) {
digitalWrite(kMotorPin1, LOW);
digitalWrite(kMotorPin2, HIGH);
}
else {
digitalWrite(kMotorPin1, LOW);
digitalWrite(kMotorPin2, LOW); // Stop motor
}



//LED
bool currentButtonState = digitalRead(kledButton);


// Detect rising edge (button press)
if (prevButtonState == HIGH && currentButtonState == LOW) {
  LEDOn = !LEDOn;
  digitalWrite(kledPin, LEDOn ? HIGH : LOW);
  delay(200);
}

prevButtonState = currentButtonState;
```