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Step-Up: Elderly Walking Assistant

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Abstract: **Each year, millions of elderly people—those 65 and older—fall [1]. Even the smallest fall for elderly citizens could lead to serious injuries and deteriorate their self-confidence [2]. In spite of using the walking sticks, many seniors lose balance. Many walking stick users hold onto nearby furniture/walls to maintain balance since most walking sticks are single handled. My research mainly focused on causes of their tripping or imbalance and redesigning the walking stick based on their input.**

To improve the stability, a dual handle walking stick (Step-Up) has been designed using Autodesk® Fusion 360.

This foldable, User-Centered Design minimizes the chances of falling, and is designed to support both the user's hands, especially when climbing up and down stairs.

Along with age, seniors also face hearing or vision problems, hence a SOS button and an Arduino UNO ultrasonic proximity sensor have been provided. The SOS buzzer quickly alerts people nearby of any emergencies. The proximity sensor alerts the user of any obstacles with varying frequency of sounds based on distances. Additionally, a multipurpose USB outlet is provided, which allows users to add a portable device of their choice: adding a mini fan during hot summers, a portable light, or charge a phone, etc. Step-Up, a smart walking stick, not only reduces the fear of falls and but also assists a peaceful walking experience for elderly.

Keywords: **walking assistant, elderly walking, dual handle, fusion 360, Arduino uno, Ultrasonic proximity sensor.**

I. INTRODUCTION

According to the United Nations (UN), in 2019, the elderly made up 9% of the population. This percentage has been growing over the years [9]. Although the elderly occupies only a small percentage of the population, they are very important and require assistance in various areas. One of the 17 Sustainable Development Goals (SDGs) proposed by the UN is "Good Health and Well-Being." To achieve this SDG, it's important to consider the needs of everyone, especially those of the disabled and elderly. The elderly are prone to falls; even the smallest fall for elderly citizens could lead to serious injuries and deteriorate their self-confidence [2]. To maintain their balance, elderly citizens commonly use mobility devices such as walking sticks, but even then, many seniors lose balance and fall.

So, there's a need for redesigning a more stable walking stick that reduces the chances of falling in different environments through the utilization of User-Centered Design (UCD). After conducting a survey on walking stick users to understand their views on existing product, approximately 58% of the respondents stated that they dislike using a walking stick, and 40% of the respondents had experienced falls from a loss of balance. Out of these, 44% believe that walking sticks don't prevent falls. This reflects the inefficiency of walking sticks.

Although no product can be made 100% effective, its efficiency rate could be increased by thorough analysis and design. The shortcomings of current walking sticks have been researched through scientific journals, digital surveys and also by observations (streets of India), which will be addressed in this article.

II. OBJECTIVE

The objective of the paper is to analyze the difficulties in the existing walking stick and propose a walking stick prototype that improves stability through the selection of materials, its design, and smart features that enhance usability.

III. LITERATURE REVIEW

Evaluation of Existing Walking Sticks and Recommendations for Modified Walking Stick [4]:

Evaluation and recommendations for the walking stick modifications from the viewpoints of ergonomics. Study results: 100% patients need modification in existing walking stick, 30% reported that the stick is too long to use, 30% reported that the handle was slipping out while in use, 26% felt that the stick is too heavy to them, whereas others reported palm and figure injury in long-term use of walking stick. In all, 54% reported slipping out of the stick on the floor, and 66% preferred cane as the stick material. Study conclusion: The present study concluded that the elderly population need modification in existing walking sticks. The slipping rate of the stick could be minimized by adapting some modifications in the stick.

Smart Blind Walking Stick with Integrated Sensor [5]:

Smart Blind Stick was designed to help visually impaired people move and perform their tasks more easily. This stick is equipped with infrared sensors to detect stair cases, and a pair of ultrasonic sensors to detect any other obstacles in front of the user, within a range of four meters. A water sensor is also used in the system, which detects water on the user's path. All found obstacles alert the user through a buzzer.

Assist apparatus and method [6]:

Numerous devices exist that prioritize aiding people with walking disabilities or difficulties especially in stairways. The invention provides an apparatus for assisting a person in walking up or down a stairway which can bear substantially the entire weight of the user. The apparatus is typically operated while disposed in a horizontal position across the stairway, but it can be folded and neatly placed in a vertical position to the side of the stairway when not in use, without having to detach the support bar from the guide rail.

IV. USER POPULATION RESEARCH

When considering UCD, there are various research techniques for different user populations. The elderly includes a variety of walking-stick users, making it difficult to design a product that reaches everyone's needs. Some users may need special attention due to arthritis, previous injuries, etc. To design a generalized product with a greater target audience, it's better to consider the needs of walking stick users who don't have these additional health problems.

To survey a large group of people cost-effectively, a questionnaire was prepared and the responses were collected with the permission of the respondents. Details of the questionnaire were pre-explained to the nurses at the elderly homes, so they helped struggling elderly citizens fill out the questions. Using a digital survey made it easier to analyze quantitative data such as the difficulties faced, material used in the walking sticks, time spent walking every day, experience with falls, etc. The results are summarized in Table 4.1.

Additionally, most roads in India don't have sidewalks, and there are many unexpected potholes, which hinder pedestrians from walking comfortably. The edges of the road are often filled with parked cars/bikes, litter, or advertisement boards. This reduces the space available to walk. Moreover, many houses, malls, and temples have stairs at the entrance, which sometimes have uncomfortable railings or don't have railings. These factors need to be considered when designing a walking stick for Indian elderly citizens.

Table 4.1: Responses from elderly, using walking sticks

User Input	*Parameters*	*Responses (%)*
Age group	50 to 60 years	13 (21)
	61 to 70 years	21 (34)
	71 to 80 years	18 (30)
	80+	9 (15)
Gender	Female	37 (60)
	Male	24 (39)
Duration of using walking stick	Less than 30 mins	22 (36)
	Less than 1 hour	22 (36)
	More than 1 hour	17 (28)
Walking stick using time	Morning	52 (85)
	Afternoon	17 (30)
	Evening	46 (75)
	Night	14 (23)

Environment	Indoors outdoors	44 (72) 17 (28)
Places for high chance of tripping	Bathrooms Indoors Outdoors/uneven area	6 (24) 6 (24) 13 (52)
Duration of using walking stick	Less than 2 years More than 2 years	14 (23) 11 (18)
Material of the walking stick	Wood Metal Plastics	6 (10) 15 (25) 6 (10)
Discomfort about the walking stick currently being used	Lack of confidence after using walking stick. Difficult to walk upstairs (when the handrails or surrounding furniture don't provide stability) Hard to walk in uneven areas Uncomfortable Handle Too heavy / Hard to get up after a fall.	
Changes required in walking stick	Foldable / Height adjustment Struggle with poor eyesight – a bell could be added to alert people nearby Space to hold mobile, key, bag Including a multipurpose function to change the walking stick into a seat/chair.	

V. SELECTION OF MATERIALS

Materials and their load are important factors when designing walking sticks. The handle of a walking stick bears the initial load, so it should be made of a material with high compressive strength. To ensure the safety of the users, the method of the extremes could be used to design a handle that withstands the weight of the 95th percentile of users. The method of the extremes focuses on the 5th-95th percentile, but in this case, it's unreasonable to focus on the 5th percentile of users since they represent users who apply the least amount of load.

5.1 Handle

Metal is heavier than wood and plastic. So, the walking stick's handle should be made of wood/plastic to reduce weight and production costs.

Wood: Man-made timbers generally don't have high compressive strength compared to natural timber. Plywood may be an exception. In terms of natural timbers, Black Cherry, Ash, and Maple have high compressive strength and have been used previously for walking sticks.

Plastic: Thermosetting plastics are stiffer and stronger than thermoplastics. Polyurethane and acrylic have good compressive strength despite acrylic being thermoplastic.

To determine the ideal material for the handle, the compressive strengths of wood and plastic is compared in Table 5.1

Table 5.1: Compressive strengths:[3],[7]

Material	***Compressive Strength***
Black Cherry	5.90 MPa
Ash Wood	10.8 MPa
Maple Wood	3.59 MPa
Polyurethane	Ranges between 40 to 43 MPa and 83 to 92 MPa
Acrylic	Ranges between 110 to 124 MPa

Out of these, acrylic seems to be the most appropriate material to use for the handle since it has the greatest compressive strength.

5.2 Walking Stick Load

In the questionnaire, some respondents suggested they preferred three-legged walking sticks. Having three legs instead of four also reduces the weight of the walking stick without compromising the stability provided. Hence, three legs can be implemented in the final design. Considering the 95th percentile, overweight people in the age group of 50 to 80+ weigh approximately 90kg, which can be rounded to 100kg. It's better to overestimate the values for safety. The load on the material can be calculated as below:

Load ≈ 100×9.81 N (9.81 ms^{-2} gravitational force can be rounded to 10 ms^{-2})

Load ≈ 1000N

5.3 Body of the Walking Stick

Depending on the user's height, the appropriate walking stick height ranges from 77cm to 96cm. To make the design inclusive, the height adjustment for my stick design should also maintain this range for users to maintain their posture and health. Although the stick's weight reduction is one of the users' wants, it's more important to ensure that the stick functions properly with high loads. The body bears most of the load, so aluminum can be used for the body since it has a high compressive strength.

5.4 Specifications:

Materials, Dimensions: Body and legs shall be made using aluminum, whereas the handle will be using acrylic. Height of the body should be adjustable from 77 to 96 cm.

Safety Considerations: Because the elderly will be using the product, it's important that it doesn't have any sharp edges.

Table 5.2: Proposed solutions to the problems mentioned by respondents

Problem	*Solution (Specification)*
With age, vision worsens, so some users may bump into people/objects. (Respondent requested to include a bell in the walking stick, but having a bell ringing constantly might be uncomfortable).	When reversing, cars have a proximity sensor that alerts the driver how close they are to objects. A similar sensor should be used to alert the user about being too close to people/objects.
Hard to lift the walking stick sometimes.	The walking stick will have 3 legs, one of which could have wheels attached while the other two have ferrules at the bottom. Hence, the stick can be moved with ease without necessarily lifting it.
Hard to get up after a fall. Users might not have assistance all the time.	Adding an SOS button that can quickly alert a nurse, ambulance, or close contact helps users receive assistance faster.
Walking at night/darker places could be dangerous.	Including a small lightbulb will be useful for navigating through any area.
Walking Stick handles aren't comfortable.	Ergonomic handles (Fischer Handles) could be used. Fischer handles are made for people suffering from arthritis in their hands, so this handle will be comfortable.
Hard to walk up/down the stairs.	Walking up/down stairs is hard because of the lack of support for both hands. The new walking stick design should have two handles for the user to hold.

VI. WALKING STICK DESIGNS

The following designs don't show features such as proximity sensors, lightbulbs, and SOS buttons. It can be assumed that they will be applied to every design presented below. Moreover, the material, cost, and aesthetics can be decided later, so only the walking stick structure is drawn and evaluated here.

6.1 Ergonomic Support - Idea 1

When users stand up using walking sticks, they generally put pressure on their palms. There are chances of the handle breaking if the pressure point exceeds the upper yield point of the plastic or material used in making the handle.

Although the chances of this happening with acrylic are low, it's safer to add a connecting piece (angular piece connecting the handle to the body of the walking stick) as shown in Figure 6.1 that can avoid the propagation of cracks.

Figure 6.1

Stair Support - Idea 2

Having two handles allow the users to hold onto the stick with both hands.

This design acts as half a walker. This mainly helps climb up/down stairs,

which addresses one of the main specifications.

Users may not want to use both handles all the time, so this design may be uncomfortable to use sometimes.

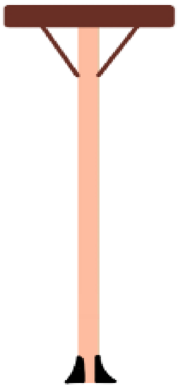


Figure 6.2

6.2 Developing Stair Support

By giving support to both hands, the user will be putting less stress on only one hand. This helps reduce the stick's weight because users will be using two hands to lift the stick rather than one. To improve this design, CAD (Fusion 360) is used. As shown in Figure 6.3, users can open and close the handles on both sides.

Having the body in the center evenly distributes the load, but this can cause problems: specifically, when climbing stairs, the body would be in-between users' legs when using both handles. This is uncomfortable: in India, many females wear sarees/frocks, so the body and legs of the stick could easily get stuck in the saree and cause the user to trip.

Figure 6.3

6.3 Final Idea

To avoid the body being in the center, the stick can be redesigned to contain the body on the user's left/right side with one handle extending out. But, when this handle is long, and there is a high load applied to it, the handle could break. To avoid this, a supporting piece should be added to hold the handle in place without bending/snapping.

In real life, traffic signals/sign boards are heavy and the rods holding them are long, but they remain steady without bending:

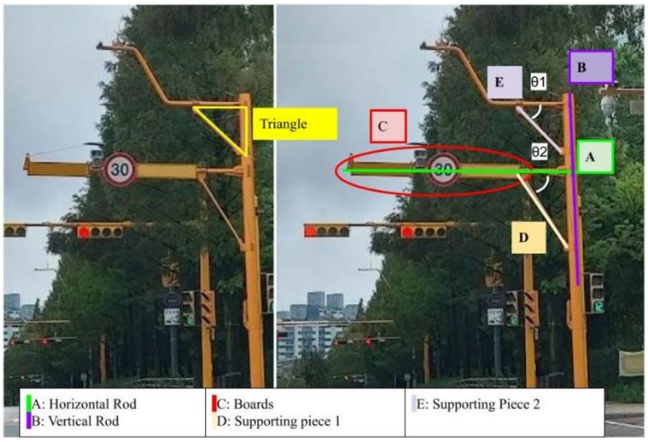


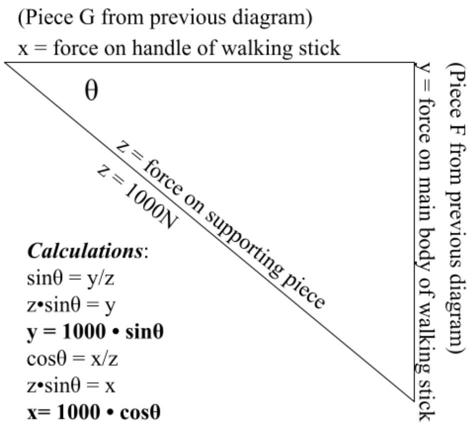
Figure 6.4

As shown in Figure 6.4, the horizontal rod can balance the weight of the boards since the supporting piece 1 distributes the load. The supporting piece forms a triangle with the vertical and horizontal rods, and triangles are known to be stable. This concept can be applied to the walking stick design. In Figure 6.4, pieces E and D are placed at different angles (θ1 and θ2), which emphasizes the importance of the angle in balancing the load. Hence, the angle should be calculated.

Figure 6.5

Generally, an angle of 45º equally distributes the load between the horizontal and vertical components. But, in this case, it's better to distribute most of the weight to the walking stick body (piece F rather than piece G in Figure 6.5). The load on the additional handle can be taken as 1000N again.

Table 6.1: Calculation for θ



Vertical force component: y = 1000sinθ

Horizontal force component: x = 1000cosθ

Vertical force component should be greater than the horizontal force component (y > x).

θ $(degrees)$	θ $(radians)$	**y = (1000sinθ)**	**x = (1000cosθ)**
10	0.175	174	985
15	0.262	259	966
20	0.349	342	940
25	0.436	423	906
30	0.524	500	866
35	0.611	574	819
40	0.698	643	766
45	0.785	707	707
50	0.873	766	643
55	0.960	819	574
60	1.047	866	500
65	1.134	906	423
70	1.222	940	342
75	1.309	966	259
80	1.396	985	174
85	1.484	996	87

As shown in the table 6.1, as θ increases, 1000sinθ increases. After 45˚, 1000sinθ is greater than 1000cosθ. Therefore, a stable walking stick has θ greater than or equal to 45˚. If θ is maximized, the supporting piece would start from the additional handle and end at the base/legs of the walking stick. This makes the whole walking stick take a triangular shape. This is obviously not ideal. If the stick is supposed to be height-adjustable, having it in a triangular shape restricts it from doing so.

6.4 Solution to Avoid Having a Triangular Walking Stick

Even with height-adjustable walking sticks, there is a part of the stick's body that remains unchanged.

By having the supporting piece start from the handle and end at the bottom of the constant piece, θ is maximized and more stability is given to the walking stick as shown in Figure 6.6.

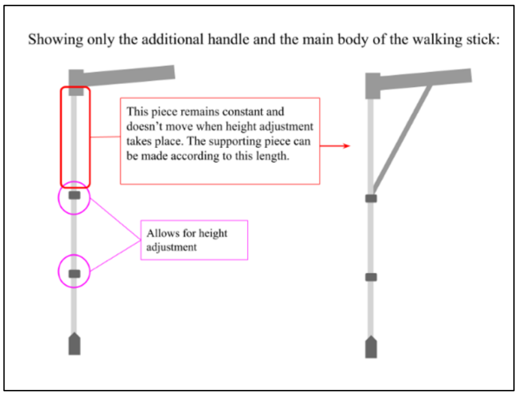


Figure 6.6

VII. Designing the Walking Stick Prototype

A protype is built using aluminium rods, acrylic sheets, laser cutters, and jigsaws, and a proximity sensor is also added using an Arduino board. The proximity sensor has a transmitter and receiver. The transmitter continuously emits ultrasonic waves, which reflect off of objects in front of the sensor and are received by the receiver. This causes the proximity sensor to beep, alerting the user about getting too close to objects/people, preventing them from bumping into people/objects in front of them (ex: an animal (dog/cat) or rolling balls in parks).

The proximity sensor and buzzer warn about objects nearby (within 20cm) and farther away (50cm) with high and low-frequency sounds respectively.

7.1 Circuit:

The Picture of proximity sensor circuit shown in Figure 7.1 from Autodesk Instructables [8].

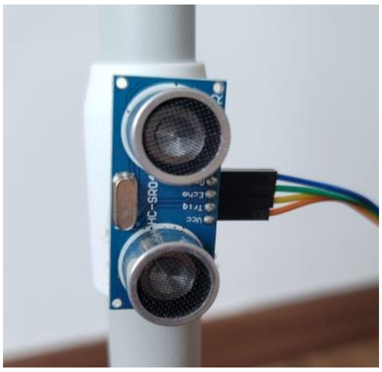


Figure 7.1

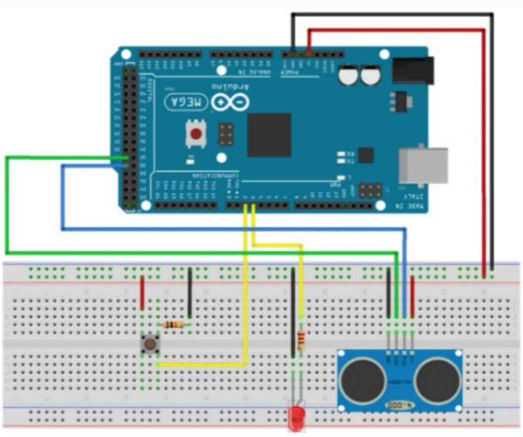


Figure 7.2

The circuit shown above is used to incorporate the proximity sensor and an additional speaker that beeps whenever an object/obstacle detected in the specified distance and alerts via varying frequency of sounds. This sound can be changed through programming. Additionally, an SOS button is provided to alert nearby people in case of emergencies. If this walking stick is manufactured, the SOS button could have another feature incorporated that sends a "help me" message to a nurse and a user's family member.

7.2 Leg Design on Fusion 360: Orthographic Views

As per the design specifications, aluminum should be used for the walking stick legs. But, due of the lack of resources, the legs are made using four interlocking acrylic pieces as shown in Figure 7.3.

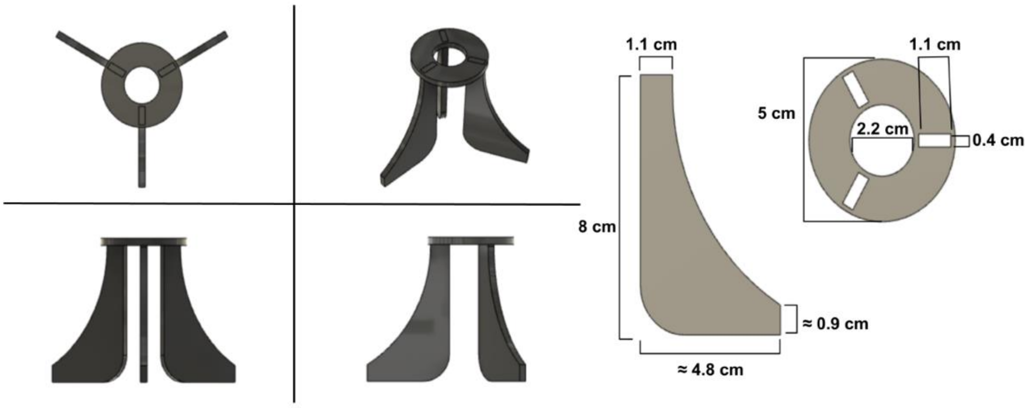


Figure 7.3

7.3 Prototype

Because this is a prototype, all circuits are visible and shown to display the different mechanisms present in this design. θ also isn't maximized here. If the walking stick were to be manufactured, all batteries, sensors, and speakers would be placed inside the walking stick and θ would be maximized. The additional handle opens up on the left side, supporting right-handed users. This is a constraint for left-handed users. Hence, a separate walking stick should be manufactured where the handle opens on the right side.

Label Description:

A - Permanent Handle

B - Additional Handle

C - Additional Handle Support

D - SOS buzzer

E - Ultrasonic sensor

F - Acrylic Legs

G - Arduino Uno board

Figure 7.4

7.4 Add-ons

To improve user-interface, extra features were incorporated. In the questionnaire, many users mentioned they enjoy listening to music. A majority of the users surveyed are from South India, where the climate is very humid. To help the users comfortably walk, the USB port battery could be utilized: a music player, USB fan, or a LED light could be connected.

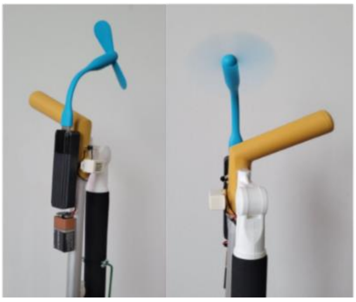


Figure 7.5

7.5 Evaluation

The final prototype has middle to high fidelity because it allows user interaction, but the wires are sticking out and the extra handle could break if too much pressure is applied, so the prototype isn't fully functional. The product was also tested by Indian elderly citizens.

They mentioned a few strengths and weaknesses:

7.5.1 Strengths

- The inclusion of the proximity sensor and SOS buzzer is helpful for users walking on busy streets.
- The extra handle provides good support in environments with and without stairs. Very suitable for Indian streets.
- The product has a low memory burden and high learnability, so users will be more satisfied with the product.

7.5.2 Weaknesses

- When walking downstairs, the walking stick is too short: every time a person walks downstairs, they have to increase the stick height. Then they have to decrease this height when they reach the bottom of the stairs. Continuously adjusting the height based on the place could be a hassle. This repetition could wear out the spring and height adjustment mechanism inside faster.
- The stick's legs are too short and thin, so they don't provide enough stability. It needs to be larger.

The prototype was tested in a natural environment, so it provided authentic, qualitative data from a real context. If this was tested in usability laboratories, quantitative data could have been collected as well.

7.6 Future Changes

If this design were to be remodified, the design could also have a moving handle as shown in the Figure 7.6. The handle height can be manually adjusted as per the staircase dimensions.

Figure 7.6

VIII. CONCLUSION

User Centred Design is an iterative process, and by continuously redesigning the walking stick and obtaining feedback from users, Step-Up was designed to provide stability on all terrains. This redesign of the long-known walking stick includes features such as an additional handle, proximity sensor, and SOS button, which enhance user-experience and meet user needs to a great extent where users feel safer and more comfortable in different environments - especially Indian streets, stairs, and hilly areas. These features will also benefit users in poorly lit areas, help navigate busy streets and stairs, and also help receive assistance faster during emergencies.

No design can meet user needs perfectly, but through UCD the walking stick can be redesigned to be efficient in meeting user needs to a greater extent than before. Similarly, Step-Up can be further improved for users coming down stairs: the additional handle should be height adjustable. This would better support the users' needs. Therefore, through the utilization of user centred design and user research, Step-Up can become an ergonomic and pleasureful product to use in India for the elderly.

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