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M. Haddad , D. Sanders , A. Gharavi & M. Langner

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Novel approach for powered wheelchair user identification and steering

M. Haddad[a], D. Sanders[b], A. Gharavi[c] and M. Langner[d]

[a]Northeastern University London, London, UK; [b]School of Mechanical and Design Engineering, University of Portsmouth, Portsmouth, UK; [c]University College London, London, UK; [d]Chailey Heritage Foundation/Engineering, Chailey Heritage Foundation, Lewes, East Sussex, UK

ABSTRACT

A new approach to improve powered wheelchairs users' driving ability and enhance their quality of life is described. The approach installed on shared powered mobility platforms used by multiple users, reducing time and effort required by helpers to adjust user settings and increase the driving duration. This paper presents development and preliminary testing of four integrated systems based on stakeholder consultation. The development process involved interviews with helpers, caregivers and occupational therapists at Chailey Heritage Foundation, alongside clinical observations. These consultations identified that driving sessions typically lasted 50–60 min, with significant time for setup, leaving short duration for actual driving. Based on these findings, four integrated systems working collaboratively were developed: facial recognition for user identification using one-shot learning, Digital Scanning Collision Avoidance Device range control, contactless Infra-red sensor input and automated session data collection. Prototype testing was conducted. The facial recognition system successfully identified users and correctly rejected non-registered users. The digital range system provided faster response and more options than original hardware. The contactless input system operated silently without generating clicking sounds and included an auto-calibrate function. All systems demonstrated successful integration, with driving session data collected and stored for future analysis. Preliminary observations indicated reduced setup time and increased driving time. The integrated approach reduced setup time and effort required by caregivers while increasing driving time. The systems showed proficient synergy and improved user autonomy. Future controlled trials are needed to quantify these improvements and statistically analyse data.

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Disabled; assistive technology; facial recognition; image processing; Python; powered mobility; steering

IMPLICATIONS FOR REHABILITATION

- The new approach would be installed on powered wheelchairs and mobility platforms used by multiple users. That would reduce the effort required by helpers/carers to adjust user settings and could improve social interaction among users, which could improve their quality of life.
- Mobility was improved, less effort was required to control powered wheelchairs and the system provided a safe steering direction for powered wheelchair users.
- The effort needed by helpers/carers to adjust powered wheelchairs/platforms to different user settings was reduced.
- User autonomy was improved, and the need for and cost of carers were reduced.

Introduction

This paper presents a new approach to identify users of shared powered mobility devices and assist them with steering.

According to the World Health Organisation's report on disability, approximately one-sixth of the global population were diagnosed with some type of disability [1,2], with 2–4% of them diagnosed with significant difficulties with mobility [3]. Due to modern medical advancements, population ageing and the spread of chronic health diseases these numbers have been increasing [1,3]. Many researchers

CONTACT M. Haddad malik.haddad@nulondon.ac.uk

conducted studies to examine the quality of life of youths with physical disabilities and results showed that people with disabilities often experienced lower quality of life than others[4] [5]. Sathananthan et al. [6] conducted a study to explore the challenges in manual-powered wheelchair operation for new users. The study revealed that many users shared common issues, including difficulty with basic propulsion skills. Participants stressed the need of proper wheelchair adjustments to improve mobility and comfort.

In many cases, people with disability have relied on powered mobility for daily activities [7]. Powered mobility devices include assistive devices such as powered wheelchairs, are used by approximately 27% of patients diagnosed with spinal cord injury [8].

During the past three decades, many researchers created systems that aimed to improve powered mobility devices and enhance the quality of life of powered wheelchair users. Wheelchair capabilities aim to accommodate individual users' differences, wheelchair designs should utilise a user-centred design approach to cater for a wider range of individual needs and requirements [9].

Researchers used sensors to control wheelchair veer and improve driving [10]. Ultrasonic transducer to create a Scanning Collision Avoidance Device (SCAD) [11]. Expert system to interpret users' hand tremor to improve steering of a powered wheelchair [12]. Self-reliance factors were analysed to create a system that shared control between powered wheelchair drivers and ultrasonic sensors [13]. Rule-based approach were used to select a steering route for a powered wheelchair [14]. Readings from ultrasonic sensor were used as inputs to a multiple criteria decision making (MCDM) system and combined suggested output from the MCDM system with desired input from user to provide a safe steering direction for a powered wheelchair [15–17]. PROMETHEE II, a MCDM method, was considered to suggest a safe route [18]. Microcomputers were used to create an intelligent human machine interface to safely drive a powered wheelchair [19]. Deep learning architecture was created to safely steer a powered wheelchair [3]. The system described in this paper targeted shared powered mobility users to improve their driving ability and enhance their quality of life.

Following some recent technical developments, powered mobility is gaining importance and becoming more accepted by people with disabilities, as well as reducing the need and cost of carers [10]. Improvements to social relations were included when assessing improvements to the quality of life of users with disability [20]. Therapists have been noticing many advantages to technology in rehabilitation [21]. Moreover, powered mobility has offered direct therapeutic effects as well as improving medical management for users with long-term disabilities [21].

The recent breakthrough in computational power and AI has enabled the successful application of image processing algorithms to numerous challenges in assistive technology. Researchers have demonstrated the versatility of these algorithms across various applications: Yu et al. developed algorithms for accurate human gesture recognition in different environments [22], while Ju proposed methods for recognising motion types from finger joint angles [23]. In industrial applications, Sanders et al. created pattern recognition systems that distinguished between ship parts and provided welding requirements [24]. Further developments include Hua et al.'s moving target detection algorithm with improved accuracy through average background methods [25], and Al-Zaydi et al.'s enhanced people detection approach [26]. Particularly relevant to powered wheelchair control, Haddad et al. successfully used image processing algorithms to detect user limb movements for wheelchair operation [27–29]. Advanced implementations have incorporated human pose estimation in coloured images [30], multi-modal data fusion with convolutional neural networks for gesture recognition [31] and cascaded feature pyramid networks for facial expression recognition [32]. Sanders et al. further refined image processing accuracy for ship part detection [33]. These diverse applications of image processing technology provided the foundation for developing the user identification system presented in this paper, which applies facial recognition to address the specific challenge of multi-user powered wheelchair platforms.

This paper addresses three key questions: (1) What factors limit effective driving time in shared powered wheelchair sessions? (2) Can integrated technological systems reduce setup burden while maintaining safety? (3) How can user identification and settings management be automated for multi-user platforms? A new approach is presented consisting of four systems working collaboratively to enhance mobility by recognising drivers and steering their powered wheelchair safely. That will improve the quality of life of powered wheelchair users and reduce the need and cost for carers.

Materials and methods—the new approach

This research was conducted at Chailey Heritage Foundation, a specialised facility for young people with complex disabilities. The development process involved iterative design with stakeholder input.

Development context and stakeholder consultation

Interviews were conducted with helpers, caregivers and occupational therapists (OTs) at Chailey Heritage Foundation.

Initial needs assessment

Clinical observations were performed to understand current practice. Key findings from these consultations included:

- Session timing: total sessions lasted 50–60 min
- Setup phase: 20–30 min required for safely transferring users, installing input devices and adjusting settings
- Driving time: actual driving limited to 20–30 min depending on user cooperation and session environment
- Teardown phase: final 10 min needed for safe transfer back and equipment removal

Identified challenges

Each powered wheelchair user had their own settings and preferences. Helpers/carers often struggled with changing wheelchair settings when changing users. Different users often required different interfaces, sensors and input devices. Changing user settings was often time consuming, reduced actual user driving time and required a lot of effort. Through stakeholder consultation, several critical issues emerged, and these are described in the 'Results' section.

System development approach

Based on stakeholder feedback, four integrated systems were developed to address identified challenges. The development followed an iterative design process with regular stakeholder input. A block diagram of the integrated approach is shown in Figure 1.

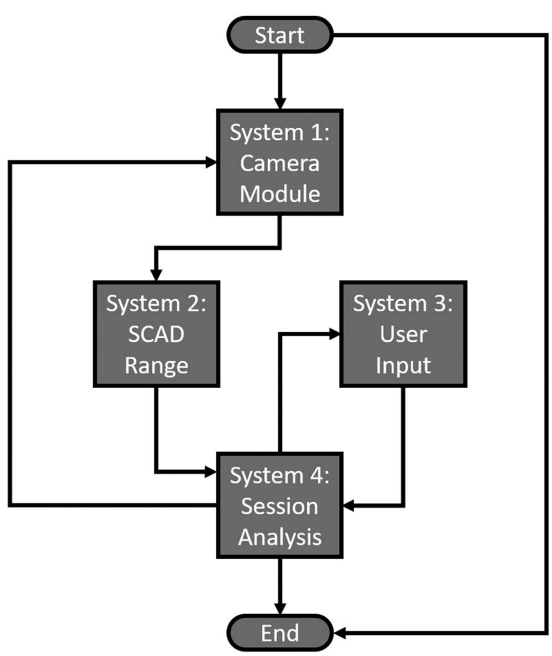

Figure 1. Block diagram of the new approach.

System description

The new approach consists of four systems working collaboratively to identify a powered wheelchair user and steer a powered wheelchair safely.

System 1: facial recognition for user identification

A new system to identify powered wheelchair users was created based on an image processing algorithm. A flowchart of System 1 is shown in Figure 2.

The new system used a Raspberry Pi connected to a camera module. The camera was directed towards powered wheelchair users. The Raspberry Pi camera used is shown in Figure 3.

One-shot learning used a similarity function that considered two images as inputs and evaluated a degree of dissimilarity between the two input images. If the two images were for the same person, the function would output a small number. If the two images were of different people, the function would output a large number [34]. A threshold could be set to assess the degree of similarity. A Python program was created and installed onto the Raspberry Pi. The Python program controlled the function of

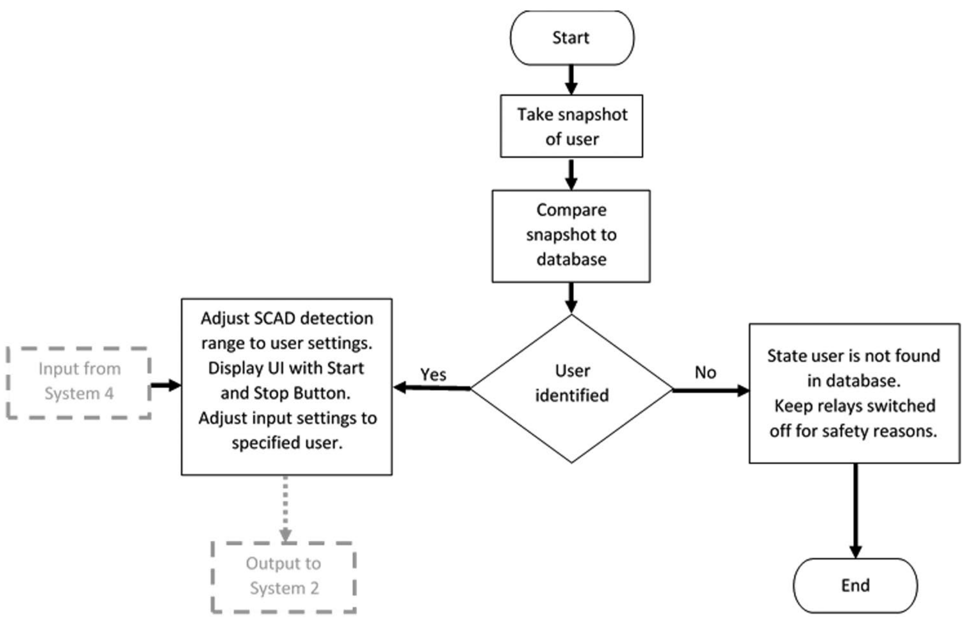

Figure 2. Flowchart of System 1.

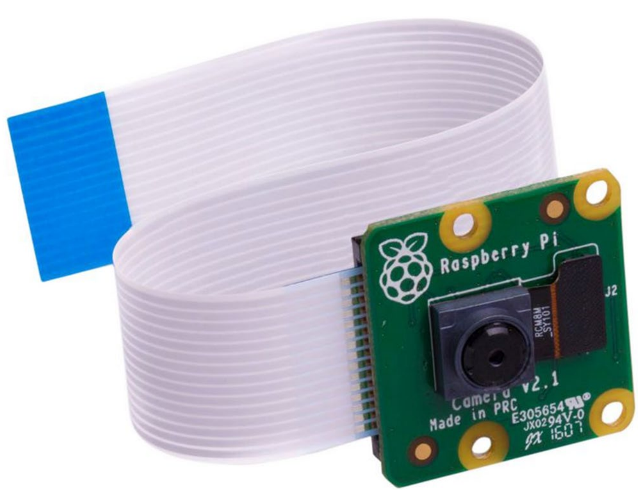

Figure 3. Raspberry Pi camera V2 used.

```
#import libraries
from subprocess import call
from tkinter import ttk
from tkinter import *
from tkinter import messagebox
import sys
import threading
import tkinter
import P3picam2
from time import sleep
import RPi.GPIO as GPIO
import os
import face_recognition
import time
import picamera

x = True

#set up tkinter box
root = tkinter.Tk()
root.title("Select User")
root.geometry("1000x600")

def CompareImage():
    # make a list of all the available images
    images = os.listdir('images')

    # load your image
    image_to_be_matched =
face_recognition.load_image_file('PotentialUser
.jpg')

    # encoded the loaded image into a feature
vector
    image_to_be_matched_encoded =
face_recognition.face_encodings(image_to_be_mat
ched)[0]

    # iterate over each image
    for image in images:
        # load the image
        current_image =
face_recognition.load_image_file("images/" +
image)
        # encode the loaded image into a
feature vector
        encoding =
face_recognition.face_encodings(current_image)
        if len(encoding) > 0:
            current_image_encoded = encoding[0]
            # match your image with the image
        and check if it matches
            result =
face_recognition.compare_faces([image_to_be_mat
ched_encoded], current_image_encoded)
            # check if it was a match
            if result[0] == True:
                print ("Match found, Welcome",
os.path.splitext(image)[0],", Enjoy your
driving session.")
                return
(os.path.splitext(image)[0],"is driving the
wheelchair")
                quit()
            else:
                print("Searching....")
    if result[0] == False:
        print("User not found in database")
        return ("User not found in database")

def StopFun():
    global x
    x = False
    root.destroy()

def TakeSnapShot():
    with picamera.PiCamera() as camera:
        camera.resolution = (1024, 768)
        camera.start_preview()
        # Camera warm-up time
        time.sleep(2)
        camera.capture('PotentialUser.jpg')
        camera.stop_preview()
        result = CompareImage()
        messagebox.showinfo(result, result)

User=tkinter.Button(root, text="Start", fg =
"black", bg="green", font=('comicsans', 50),
command=(TakeSnapShot))
User.grid(row = 15, column=10)

User=tkinter.Button(root, text="Stop", fg =
"black", bg="red", font=('comicsans', 50),
command=(StopFun))
User.grid(row = 25, column=10)
```

Figure 4. Python program used in System 1.

the camera, triggered the camera to take snap shots and ran facial identification algorithm to detect if there was a face in that snapshot, if a face was found, face boundaries were identified.

To use the similarity function in image recognition, the new picture was compared to images in a database. If the new image was for a person in the database, the function would output a small number when compared to that person and large numbers when compared to images of other users in the database. If the image was not in the database, the function would output large numbers for all images in the database which implied that the image was not for any user in the database. That solved the problem of adding new users to the database without the need to retrain the whole system. The Python program used in System 1 is shown in Figure 4.

A simple user interface (UI) was created containing two buttons: Start and Stop as shown in Figure 5.

The simple UI matched the capabilities of users with disability. The simple UI provided a straightforward operation for steering powered wheelchairs and a suitable match between desired commands and user capabilities [35]. If the Start button was clicked, the Python program would trigger the Raspberry Pi camera to take a snapshot, then the program would identify the face in that snapshot. Once a user was identified, their settings and preferences could be downloaded to a powered wheelchair/platform. If the face in the snapshot did not match any of the user's facial images in the database, a message would pop up showing that the user was not found in the database. The Stop button was used to exit the program.

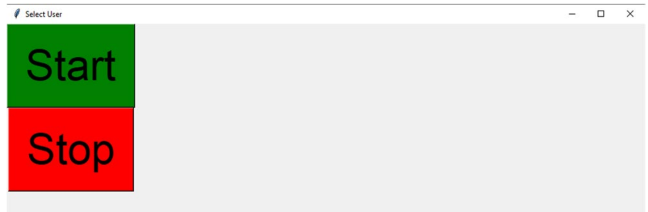

Figure 5. UI used to control Python program for System 1.

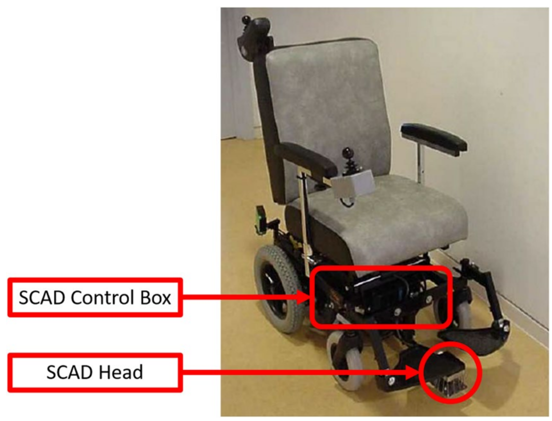

Figure 6. SCAD mounted on a powered wheelchair. Figure 7.

Figure 7. SCAD range select hardware.

System 2: digital SCAD range control

This system digitised the existing SCAD developed by Langner [11]. The SCAD uses a single rotating ultrasonic transducer mounted at footrest level. Figure 6 shows the SCAD mounted on a wheelchair.

The original six-position dual-pole rotary switch shown in Figure 7 was replaced with a dual digital potentiometer, controlled via Python programming. A flowchart of System 2 is shown in Figure 8.

System 2 controlled the SCAD detection range. A flowchart of System 2 is shown in Figure 8.

The Python program was created to digitise the SCAD detection range. The program consisted of two functions: CheckCombo and SetValue. The program was loaded onto the same Raspberry Pi. A UI containing a drop-down menu and Set Range will pop up once a user is identified by System 1, a button allowed users to select from five different range options.

If a user accidently clicked the Set Range button without selecting a range from the drop-down menu, a message was displayed requesting the user to select an option as shown in Figure 9 to ensure user safety.

System 3: contactless user input

Many disabled powered wheelchair users used lever-switches to control their wheelchairs. Many researchers have successfully digitised the function of lever-switches used to control a powered wheelchair [19,36–38]. Interviews conducted with helpers, carers and OTs at Chailey Heritage Foundation/

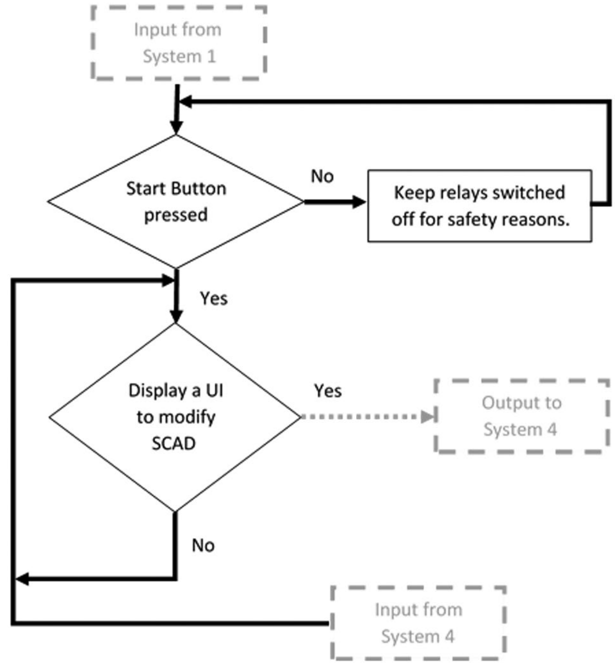

Figure 8. Flowchart of System 2.

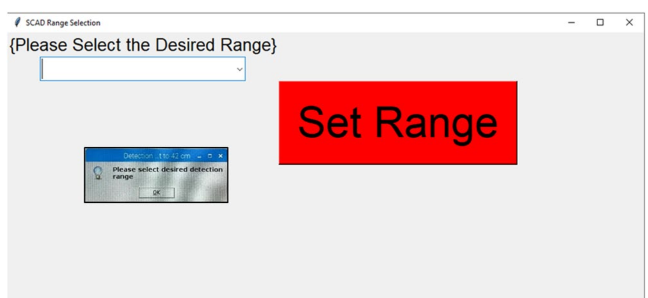

Figure 9. UI showing a message requesting user to select desired detection range.

School revealed that clicking noise from switches caused discomfort and reduced focus. Additionally, switches often required repositioning during sessions. That often disrupted driving sessions and user engagement.

A new system using Infra-Red (IR) range sensors was created to replace the lever-switch used to operate a powered wheelchair. A flowchart of System 3 is shown in Figure 10.

The new system did not generate a clicking sound and overcame the problem of repositioning. The prototype circuit was created that considered an IR sensors and an analogue to digital converter (ADC) connected to the same Raspberry Pi to replace the lever-switch. The prototype circuit is shown in Figure 11.

The system features:

- Detection range: 4–30 cm
- Auto-calibrate function for automatic reference distance calculation
- Silent operation without clicking sounds
- Adjustable parameters via technical UI
  - Threshold: minimum distance interpreted as movement
  - Cut off Time: switch mode vs. time delay mode
  - Minimum/maximum distance: detection range limits
  - Sampling Time: filtering for unsettled terrain

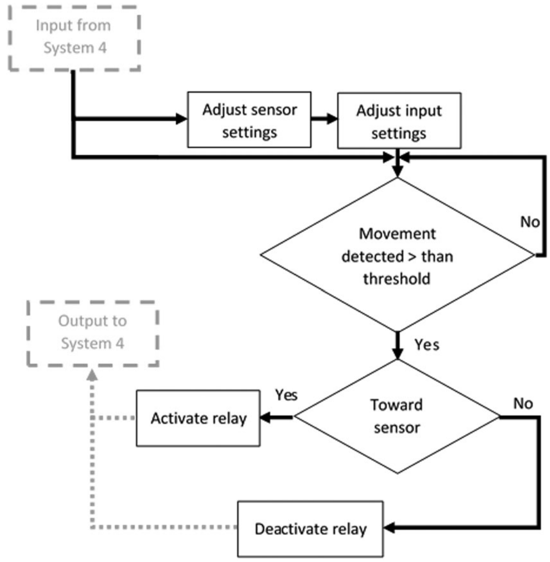

Figure 10. Flowchart of System 3.

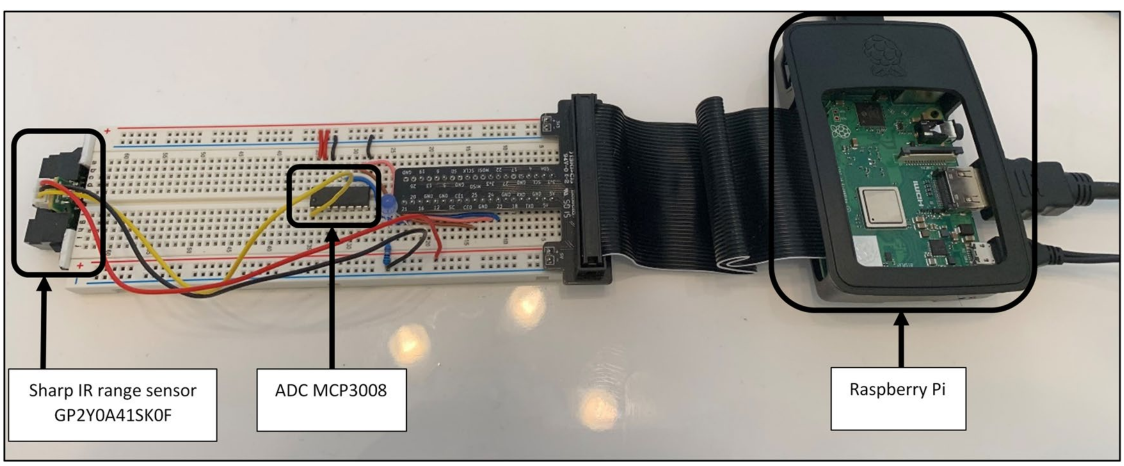

Figure 11. A prototype electrical circuit used to replace lever-switches used to operate a powered wheelchair.

A Python program was created and installed on the same Raspberry Pi to control the function of the IR sensors. The new program did not require a UI since it operated on boot-up of the Raspberry Pi. Clinical trials for an early prototype of System 3 are shown in Figure 12. Figure 12(a) shows System 3 installed onto a powered wheelchair. Figure 12(b) shows IR sensors being used as head switches.

The new programme featured an 'Auto-Calibrate' function where the sensors automatically calculated the reference distance. This function could improve powered wheelchair users' self-confidence and self-reliance and reduce the need for helpers' intervention when sensors slip from their position.

Testing of the new system revealed new factors that needed to be addressed. A student at Chailey Heritage School is considered a case study. The student could produce voluntary movement with their head and use that movement to control a powered wheelchair. Head switches were used to transform that movement into the steering direction of a powered wheelchair. The voluntary movement was used to steer the powered wheelchair left or right. The head switches were replaced with System 3. The sensors detected the movement of the student's head and transformed the voluntary movement to steering directions for the powered wheelchair.

A technical UI was created to allow helpers to modify user settings. The technical UI is shown in Figure 13.

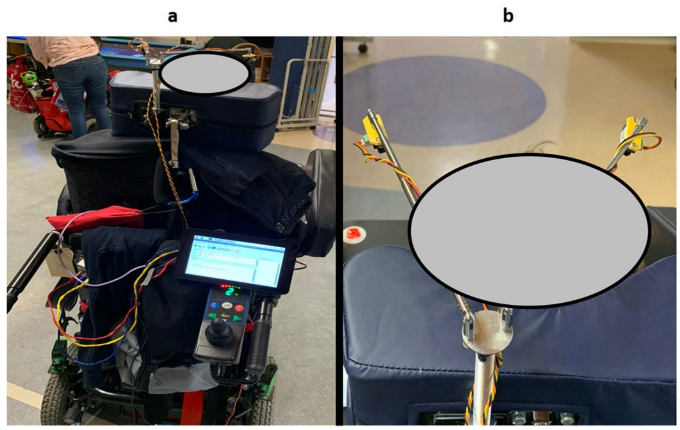

Figure 12. System 3 installed onto a powered wheelchair (a) and IR switches used as head switches (b).

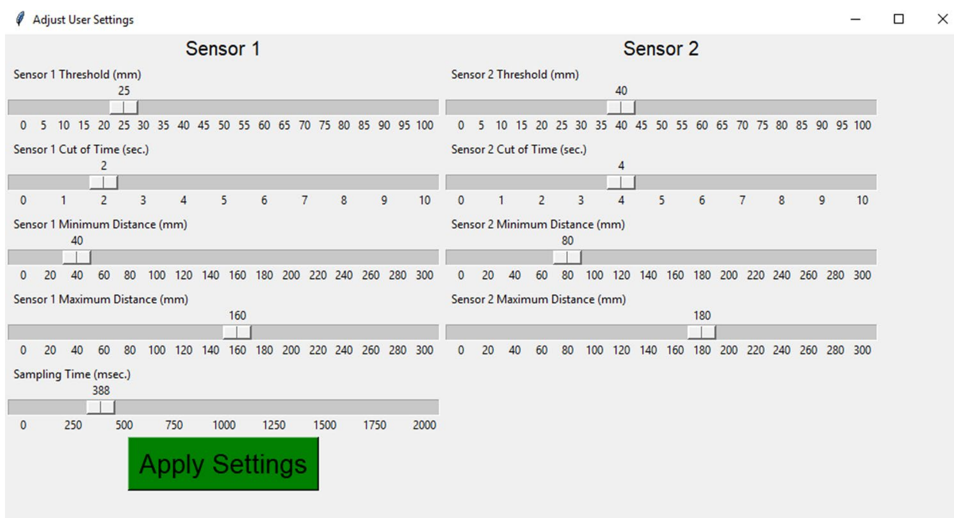

Figure 13. Technical UI used to modify user settings.

The technical UI allowed helpers to modify different parameters using track bars as shown in Figure 13. The following parameters could be modified:

- Threshold: This value represented the minimum distance the sensor would interpret as movement. The larger the Threshold value the less sensitive the sensor would be to user movement.
- Cut off Time: This value allowed the system to operate in two different modes: Switch mode and Time Delay mode. Setting the Cut off Time track-bar to 0 would trigger the system to operate in Switch mode, where the system would use the sensors as switches. If an object was detected in a sensor range, a specific relay would be triggered on and would remain triggered until the object was no longer detected in the sensor range. Setting the Cut off Time track-bar to any value other than 0, would allow the system to operate in time delay mode, where if an object was detected in a sensor range, a specific relay would be activated for a period specified by the track-bar in seconds, then the relay would be switched off if no object was detected in that sensor range.
- Minimum distance: This value represented the minimum cut off distance, where the sensor no longer detected objects closer than that distance.
- Maximum distance: This value represented the maximum cut off distance, where the sensor no longer detected objects beyond that distance.
- Sampling Time: This value was used to allow powered wheelchair users to drive their wheelchairs safely on unsettled terrain. If the terrain was unsettled, the sensors could provide a reading that did

not represent the actual users' desires because of unwanted vibrations, head movement or momentary sensor movement. The new system considered two readings for any object detected in its range with the Sampling Time in between the two readings. That allowed the new system to overcome the problem of momentary sensor movement and head movement due to unsettled driving terrain.

Once driver settings were modified and the Apply Settings button was clicked, the program would store all the settings in a CSV file. The CSV file was used to install the driver's settings during Raspberry Pi boot-up. The Auto-Calibrate function would read the CSV file and install the driver's settings during Raspberry Pi boot-up.

System 4: session data collection

Based on previous work [37], this system collects driving session data including user ability metrics, session details and input device usage. A flowchart is shown in Figure 14.

Adjustments to the system were made to maintain users' privacy. Data were used for future analysis to study the ability of a driver and observe users' progress from one session to another, analyse the progress of various users with same type of disabilities and identify the most suitable input device for each driver and route.

Testing and evaluation

Prototype testing was conducted at Chailey Heritage Foundation involving:

- Functional verification of each system
- Integration testing of all four systems
- Preliminary trials with wheelchair users
- Observation of system performance in clinical setting

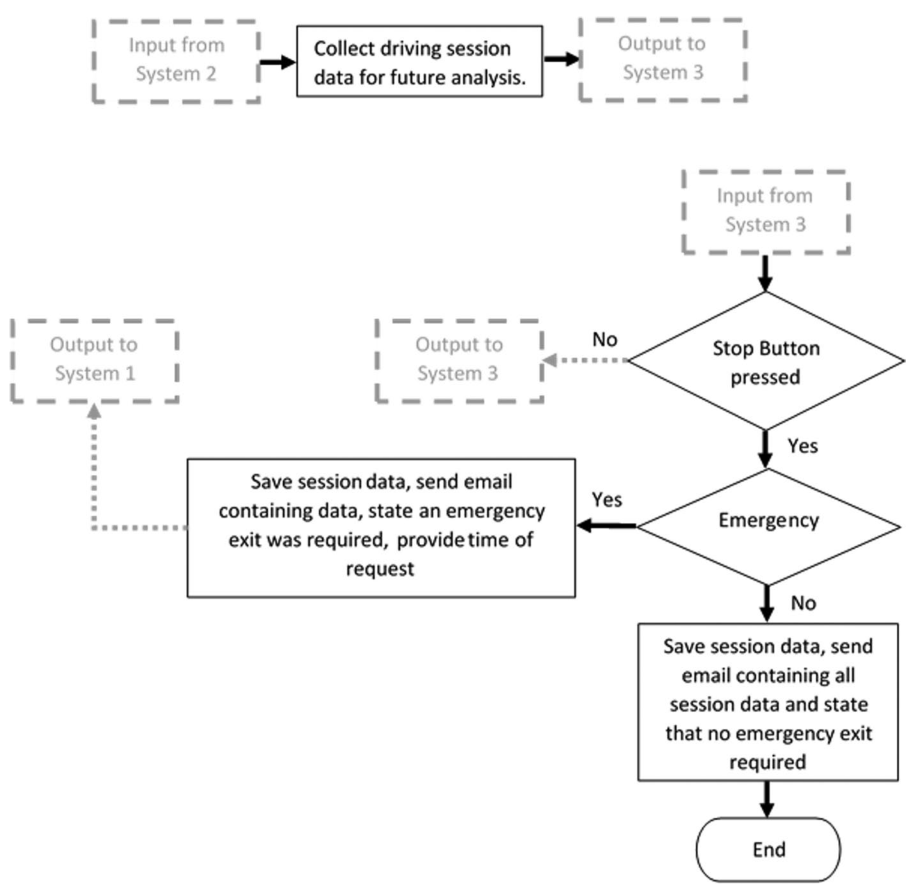

Figure 14. Flowchart of System 4.

Results

This paper presented a new approach to intelligently identify powered mobility users and aid them in driving as shown in Figure 1. This preliminary development phase focused on technical validation and proof-of-concept testing. While functional testing was conducted with wheelchair users, systematic quantitative data collection with a defined user cohort was not performed during this initial phase. The following results represent technical performance observations and qualitative feedback rather than controlled trial outcomes. The work conducted revealed important findings to improve the quality of life of powered mobility device users.

Stakeholder consultation findings

Through stakeholder consultation, several critical issues immerged:

- Multiple users sharing the same powered wheelchair or platform
- Each user requiring different settings, interfaces and input devices
- Time-consuming setting adjustments between users
- Mechanical switch clicking sounds causing distraction for some users switches requiring repositioning during sessions due to movement

The consultation process revealed critical insights:

- Time allocation issues: Only less than 50% of session time involved actual driving
- Setting adjustment burden: Helpers reported struggling with changing settings between users
- Sensory concerns: Clicking sounds from mechanical switches caused distraction
- Physical challenges: Switch repositioning frequently required during sessions

System implementation results

All four systems were integrated and worked in full synergy.

System 1: facial recognition for user identification

The facial recognition system demonstrated:

- Successful identification of users present in the database
- Correct rejection of users not in the database
- Ability to add new users by uploading facial images without retraining
- Clear UI feedback on identification status

System 2: digital SCAD range control

The digital range system showed:

- Faster response than original dual-pole rotary switch
- Reduced hardware requirements compared to mechanical system
- More range options than original SCAD
- User-friendly interface for range modification

System 3: contactless user input

The contactless system achieved:

- Silent operation without clicking noise generation
- Faster response time than mechanical lever-switches
- Successful auto-calibration addressing sensor repositioning
- Successful case study implementation for head movement control

System 4: data collection system

The data collection system demonstrated:

- Successful collection and storage of session data in CSV format
- Capture of data suitable for future intelligent system training
- Appropriate privacy protection measures

Integration testing results

The four systems demonstrated successful integration with:

- Proficient synergy between systems
- Reduced time for setting installation
- Reduced effort required from caregivers
- Increased actual driving time during sessions

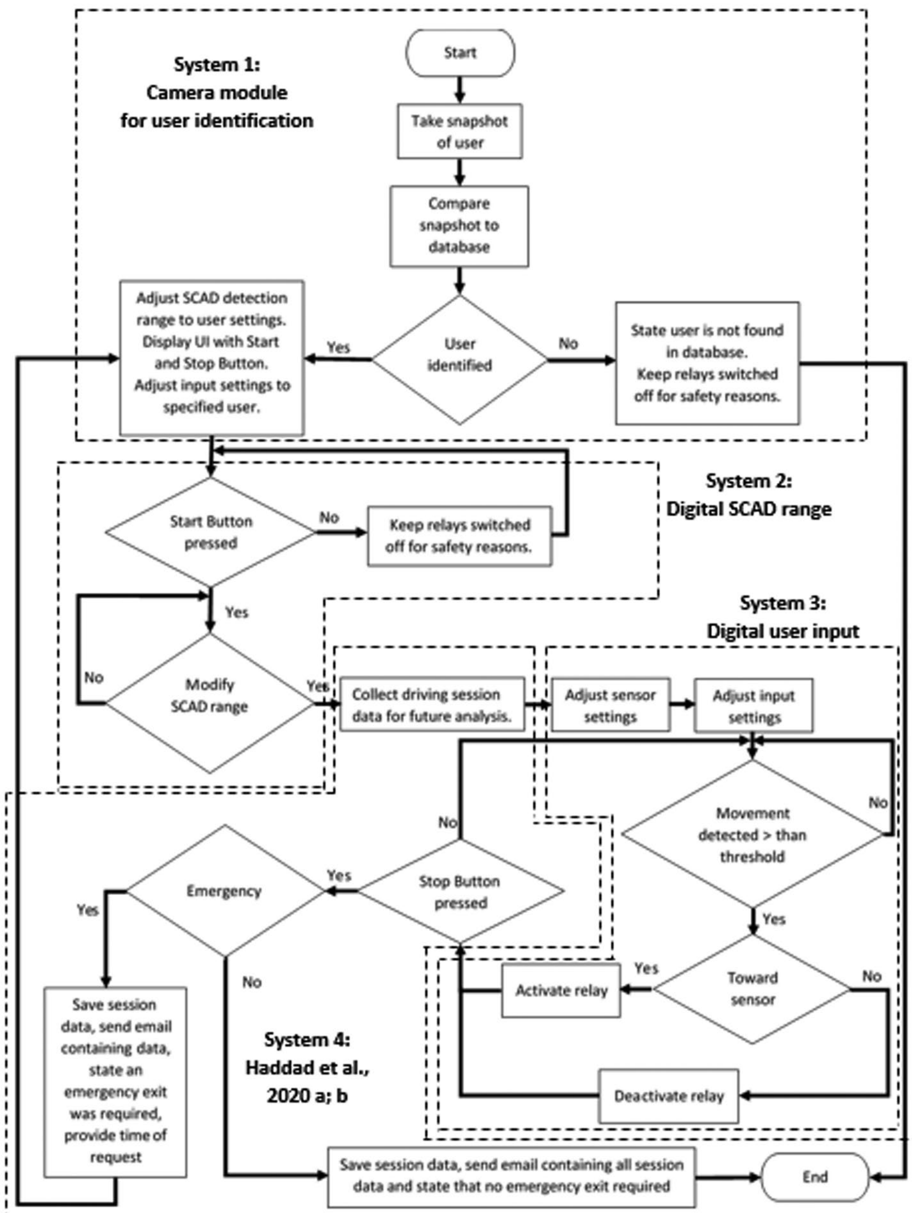

Figure 15. Flowchart of the new approach showing a split out of the four systems considered.

While stakeholder observations suggested reduced setup time and increased driving duration, these improvements were not quantitatively measured during this development phase.

A flow chart showing a split out of the four systems considered in the new approach is shown in Figure 15.

Preliminary clinical observations

A case study at Chailey Heritage School demonstrated successful System 3 implementation:

- Student's head movement successfully detected by IR sensors
- Voluntary movement translated to wheelchair steering commands
- Two IR sensors successfully replaced traditional head switches
- System parameters customised via technical interface

Discussion

This section will discuss the findings of the work conducted and presented in this paper, present the proposed future work and the limitations faced while testing the new approach.

Principal findings

This research successfully developed four integrated systems addressing key barriers to effective powered wheelchair use in multi-user settings. The stakeholder consultation approach proved essential in identifying previously unrecognised issues, specific to operational challenges that had not been previously documented in the literature particularly the sensory distraction from mechanical switch sounds and the substantial time lost to setup procedures.

Addressing the research outcomes

The following outcomes resulted from conducting this research:

Research outcome 1: limiting factors for driving time

Consultation with stakeholders including helpers, caregivers and OTs revealed that driving sessions typically lasted 50–60 min total, with only 20–30 min dedicated to actual driving. The consultation identified that the first 20–30 min were required for safely transferring users to powered mobility platforms, installing input devices and adjusting user settings. The final 10 min were needed for safely returning users to their wheelchairs and removing equipment. Depending on user mood, cooperation and overall session environment, actual driving time varied between 20 and 30 min. This finding, representing approximately 33–50% efficiency in session time utilisation, aligns with literature suggesting that technical barriers significantly impact therapeutic intervention time [6,21]. The substantial proportion of non-driving time identified through stakeholder consultation represents a critical inefficiency that directly reduces therapeutic benefit.

Research outcome 2: integrated technological solutions

Secondly, the integrated technological solution successfully addressed the identified barriers through a coordinated four-system approach. Automated user identification eliminated the need for manual setting selection, while digital range control simplified SCAD adjustment procedures. The contactless sensors removed the previously unrecognised issue of noise distraction, and automated data collection enabled systematic progress tracking. This comprehensive approach demonstrates how multiple technological innovations can work synergistically to address complex clinical challenges.

Research outcome 3: multi-user platform automation

The one-shot learning approach proved particularly suitable for clinical settings where user numbers are limited but personalisation requirements are critical. This approach directly addresses the challenge identified by Griggs [9] regarding the need for user-centred design in wheelchair systems, providing a scalable solution for facilities serving multiple users with diverse needs.

Technical innovation and advancement beyond available research

This research demonstrated several technical innovations that significantly advance the field of powered wheelchair technology beyond existing solutions. While Sanders et al. [10] addressed wheelchair veer control and Langner [11] developed collision avoidance systems, these focused on single-user optimisation. This research uniquely addressed the multi-user platform challenge that has not been systematically tackled in previous literature, representing a fundamental shift from individual to shared-use accessibility solutions. The integration of user identification with automatic setting installation represents a novel contribution to the field, moving beyond single-user optimisation to address the practical realities of shared equipment in clinical settings.

The application of one-shot learning for powered wheelchair user identification represented the first reported use of this approach in this context, offering a solution that balanced accuracy with the practical constraints of limited training data. This innovation directly addressed the limitations of clinical settings where traditional deep learning approaches would require extensive training datasets unavailable in small user populations. The automatic user identification system eliminated the need for manual setting selection between users, a capability not present in previous wheelchair control systems.

The silent input system addressed a previously unreported sensory barrier that emerged only through direct stakeholder consultation, highlighting the importance of user involvement in technology development. While previous research has focused on improving switch responsiveness and accuracy, no prior work identified or addressed the distraction caused by mechanical clicking sounds. This finding demonstrated how stakeholder consultation can reveal barriers invisible to purely technical development approaches.

The integrated approach, combining identification, safety, input and analytics in a unified system, demonstrated how holistic solutions can provide greater benefit than isolated improvements typically seen in wheelchair technology research. Previous studies have addressed single aspects of wheelchair control—either safety, or input methods, or data collection—but not their synergistic integration. The auto-calibration feature significantly reduced caregiver intervention requirements, supporting greater user autonomy than systems requiring manual adjustment. This comprehensive approach represents a departure from traditional component-focused improvements, instead creating a cohesive system where each element enhanced the others' effectiveness.

Limitations and future work

This paper presents system development and preliminary testing with several important limitations that must be acknowledged. The most significant limitation is the lack of systematic quantitative evaluation. While setup time reduction and driving time increases were observed during testing, these improvements were not systematically measured or statistically analysed. The limited number of users who tested the complete integrated system prevents generalisation of findings, and the single-site nature of the study limits external validity. Additionally, no controlled comparison between baseline and intervention conditions was conducted, preventing definitive conclusions about system efficacy. The impact on different user disability types was not assessed, and economic analysis was not performed, both of which are essential for clinical implementation decisions. These limitations reflect the preliminary nature of this work as a development and feasibility study rather than a clinical trial.

Future work will need to address these limitations through rigorous evaluation protocols. Controlled trials with a defined cohort of test users should employ appropriate statistical analysis methods similar to those discussed in Xu et al. [39]. Standardised outcome measures for setup time and driving duration must be established, with baseline measurements enabling meaningful comparisons. User satisfaction should be assessed using validated instruments to ensure acceptability and identify areas for improvement. From a technical perspective, investigation of advanced AI algorithms could enhance system functionality, while expanded application of image processing for movement capture could broaden input options. Development of standardised implementation protocols will be essential for wider adoption, along with comprehensive statistical analysis of time savings and user performance metrics.

Clinical implications

The successful integration of these systems, despite the preliminary nature of testing, suggests significant potential for clinical implementation. Improved session efficiency in multi-user settings could substantially increase therapeutic contact time, potentially enhancing rehabilitation outcomes. The reduced physical burden on caregivers addresses workforce challenges in rehabilitation settings, where staff constraints often limit service delivery. Enhanced user autonomy through automated personalisation aligns with contemporary rehabilitation philosophy emphasising independence and self-management. Furthermore, systematic data collection enables evidence-based progress tracking, supporting more informed clinical decision-making and potentially improving long-term outcomes for powered wheelchair users.

Conclusions

This research presents a novel four-system approach for powered wheelchair platforms used by multiple users. Through stakeholder consultation at Chailey Heritage Foundation, key barriers were identified including excessive setup time, setting adjustment complexity and sensory distractions. The developed systems successfully addressed these challenges through automated user identification, digital control interfaces, silent input mechanisms and systematic data collection.

The systems demonstrated successful technical integration and preliminary testing showed promising results in reducing setup burden and increasing actual driving time. While quantitative efficacy data awaits formal trials, the approach offers a promising direction for improving powered wheelchair accessibility in shared-use settings. The stakeholder consultation methodology proved valuable in identifying real-world challenges often overlooked in purely technical developments.

The time and effort needed to adjust and install user settings were reduced, driving session duration was increased, and users practiced wheelchair driving for longer periods. The collected data will be used to train intelligent systems for predicting future route patterns and assessing users' driving ability. Future work will focus on rigorous quantitative evaluation and multi-site validation.

Author contributions

CRediT: **M. Haddad**: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Software, Validation, Visualization, Writing – original draft, Writing – review & editing; **D. Sanders**: Conceptualization, Investigation, Methodology, Project administration, Supervision; **A. Gharavi**: Conceptualization, Investigation, Writing – review & editing; **M. Langner**: Conceptualization, Investigation, Methodology, Validation.

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Notes on contributors

Dr M. Haddad is an Assistant Professor in Data and Computer Science at Northeastern University London, the Artificial Intelligence and Data Science Level 7 and the Data Science Level 6 Programme Leader.Dr Haddad received a BSc in Electronic Engineering in 2006. He went on to postgraduate study and was awarded a distinction in MSc in Electrical and Computer Engineering in 2007. Finally, he completed a PhD in Intelligent Decision Making applied to Management and Engineering in 2019. Dr Haddad is a Fellow – HEA, a certified Project Manager Professional – PMI, a Chartered Engineer (CEng) – IET and a Senior Member of the IEEE.

D. Sanders is an Emeritus Professor at the University of Portsmouth. He leads research into Systems Engineering and has worked in engineering, manufacturing, assistive technology, energy and Artificial Intelligence (AI) research for 40 years, with established collaborators and a successful research track record. He is an expert in control, AI and sensor fusion and a FIMechE and a FIET.

Dr A. Gharavi is a Lecturer in Energy Data and serves as the Course Director for the Energy System Data Analytics (ESDA) program at the Bartlett School of Environment, Energy, and Resources (BSEER), University College London (UCL). Dr Gharavi holds a PhD from the University of Portsmouth and employed Artificial Intelligence techniques, including machine learning and deep learning, to develop predictive models for identifying potential zones (sweet spots) in unconventional oil reservoirs. Dr Gharavi's professional experience includes roles as a Data Scientist and Data Analyst at Halliburton and Baker Hughes in the UK. In addition Dr Gharavi holds an MSc and a BSc in Petroleum Engineering, as well as a BSc in Genetics.

Dr M. Langner is a resident engineer at Chailey Heritage Foundation. He has been working at the charity since the early 1980s and has developed a range of wheelchair guidance methods. As a research fellow at the University of Portsmouth, Dr Langner has been collaborating with fellow engineers and scientists to develop digital systems that allow young people with the most complex physical disabilities to navigate their environment as independently as possible.

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