NextGen Wheelchair: A Semi-Autonomous Approach for Disabled People Using Head Motion and Digital Twin Technology

Department of Computer Science and Engineering

Evaluation Report

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1. Introduction

NextGen Wheelchair is designed to assist those with physical disabilities that limit their ability to move, like spinal cord injuries or neuromuscular illnesses. Through the use of head movements, it aims to increase the mobility of paralyzed patients and provide them the independence to move around freely. In addition, the system has two more options: voice and manual joystick, which will improve user dependability and functionality. The entire system can be managed by a web server, which will relieve the caregivers' physical labor by allowing them to watch the patients from a distance. To make the system more secure, clever judgments are added to it, such as stopping the system in an emergency case or detecting obstacles.

2. Objectives

2.1 To design and develop a wheelchair that can be controlled using the user's head movements.

2.2 To provide backup control methods, such as the joystick and voice control, to ensure that the user always has a method of control that works for them.

2.3 To be able to halt instantly when an emergency arises.

2.4 To develop and implement efficient decision-making algorithms that can identify obstacles and avoid them.

2.5 To be able to be controlled and monitored via a web interface.

2.6 To conduct rigorous testing and quality control measures to ensure that the wheelchair meets all necessary safety and performance standards.

2.7 To make the wheelchair affordable and accessible to as many people as possible, to improve the quality of life for those who are physically unable to move without assistance.

3. Study Procedure

As we've developed a prototype rather than implementing the system on a wheelchair, the evaluation study was conducted using an agile process to access the functional accuracy and usability of the proposed system in a regular environment. The study procedure involved several steps to ensure a comprehensive evaluation. Firstly, test case scenarios were designed to cover various aspects of system performance and user interactions. Next, the study was conducted with five selected participants who were invited to use the system. Before the evaluation, a brief discussion about the system was given to the participants to explain the objective of the study and provide an overview of the proposed system. During the evaluation, the participants were given the opportunity to interact with the system from their respective points of view for a period of approximately 4 – 5 minutes. They were encouraged to explore the system's features and functionalities and provide feedback on their usability and effectiveness.
After the initial interaction, the participants were assigned a set of tasks to perform using the system. These tasks were designed to assess the system's performance in specific scenarios and evaluate its ability to meet user requirements. Throughout the evaluation process, the participants were encouraged to ask questions and provide their opinions on the system's usability. The

researchers observed and recorded relevant data, such as the number of attempts taken to complete tasks and the time required for task completion. At the end of the evaluation, the participants were asked to provide opinions on the system's usability and effectiveness. They were also invited to share any suggestions they had for improving the system.

4. Data Analysis

Task	Module	Result	Number of Attempts (M±SD) (sec)	Task Completion Time (M±SD) (sec)	Number of Times Asking for Help (M±SD) (sec)
Log In	Software	100%	1±0	12.64±8.02	0±0
System Control with Head Motion	Software	83%	1.25±0.43	20.56±2.75	0.2±0
System Control with Voice Speech	Software	77%	2.6±0.44	17.71±4.28	0±0
System Control with Manual Joystick	Software / Hardware	100%	1±0	10.01±1.94	0±0
Obstacle Detection	Hardware	100%	1±0	0.17±0.02	0±0
Emergency Stop	Hardware	100%	1±0	0.33±0.07	0±0
Speed Control	Hardware	71%	1.4±0.55	2.25±0.55	0±0

The collected data from the evaluation study provides valuable insights into the participants' performance and their interaction with the system. The analysis of the data reveals important findings regarding Task Completion, User Engagement, and Module Performance. The results are analyzed as follows:

4.1. Task Management

4.1.1 The tasks were generated in a predefined manner. With all the control modules, the participants were told to operate the system in four specific directions - left, right, forward, and backward. Additionally, they were also told to stop the system after operating the system in those four directions. We measured the time for the task for each user and calculated the required data. For voice control, the participants were told to attempt the system two times – one in a less noisy place and one in a noisy place.

4.1.2 For obstacle detection, we placed some obstacles in the path of the system while it was operating. We measured the mean and standard deviation times of how much time the system needed to detect the obstacle and make the buzzer alarm active.

4.1.3 To make the emergency halt and speed control, the participants were told to halt and control the speed of the system by pushing the switch buttons available in the system in case of an emergency situation. We measured the time of halting the system.

4.1.4 All tasks were arranged serially and sequentially as per the importance of the modules in the system. We discussed the modules and told the users to complete the tasks according to the sequence.

4.1.5 The participants responded to the tasks actively with effective communication with the researchers.

4.2. Task Completion

4.2.1 All tasks, including log-in, system control with head motion, voice commands and manual joystick, obstacle detection, emergency stop, and speed control were completed successfully by the participants.

4.2.2 There were some loopholes in the system like the system responding to the voice commands lately, sometimes not detecting the obstacle, and the system moving faster than expected. Besides, from the user's perspective, the head motion control can be implemented in a faster and more efficient way than the implemented one. Voice recognition can become more effective and efficient if the system can recognize the voice speech much quicker than the implemented one.

4.3. Number of Attempts

4.3.1 The participants required only one attempt to complete each task.
4.3.2 The standard deviation (SD) for the number of attempts across almost all tasks was 0.4, indicating consistent task completion fluctuating for some participants as they were unable to complete the task within a single attempt.

4.4 Task Completion Time

4.4.1 The average completion time for most tasks was relatively quick, ranging from 1 to 20 seconds (approx.).

4.4.2 The "Head Motion Controlling" and "Voice Speech Controlling" tasks took a slightly longer time, with an average time of 20.56 and 17.71 seconds respectively.
4.4.3 The standard deviation (SD) for task completion time varied across tasks, indicating some degree of variability in task duration.

4.5 Asking for Help

4.5.1 The participants didn't require any assistance or ask for help during the completion of most tasks except the speed control as it was a bit hard for them.

5. Result

The evaluation of the NextGen Wheelchair system yielded promising results. Participants engaged in various tasks, such as login, and controlling the system through head motion, voice commands, and manual joystick. They successfully completed all assigned tasks, showcasing the system's effectiveness and usability. The study was based on an agile process and test case scenarios to measure the functional accuracy and usability of the proposed system. Five participants were encouraged to evaluate the system with these generated test cases. They had the opportunity to use the system for a few minutes, followed by the performance of a set of tasks. The outcomes and findings of the system provided us with some innovative feedback to develop the system more efficiently in the future. Besides, the lack of accuracy and reliability of the system made us motivated to research the system in the future and make it much more error-free and user-friendly to the users.