MILITARY INSTITUTE OF SCIENCE AND TECHNOLOGY
Department of Computer Science and Engineering

CSE 460: Integrated Design Project

SRS

NextGen Wheel Chair

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Contents

1 Preface:

One of the difficulties that stroke or spinal cord injury (SCI) survivors encounter is mobility. These people may benefit from a wheelchair to help them accomplish specific everyday tasks independently. The demand for wheelchairs among elderly people and individuals with paralysis has surged recently. A push wheelchair, however, does not offer comfort or maneuverability for physically challenged people. Electric-powered wheelchairs (EPWs) were developed to preserve users' physical energy and give them greater maneuverability. Though this approach came out in handy for most paralyzed individuals, it could not make it this far for those who cannot even use their hands, ultimately making them dependent on a human assistant. To address several mobility issues, extensive research has lately been done on intelligent wheelchair technology.

The goal of this project is to develop a wheelchair that can be moved by the user's head movements, giving those who are unable to walk or speak a feeling of freedom. To guarantee that the user always has a control method that suits them, the backup control methods of joystick and voice control have also been added.

We believe that this project has the potential to greatly improve the quality of life for those who are physically unable to move without assistance, and we are excited to share our progress with others in the field. Our team is committed to creating a safe, reliable, and easy-to-use wheelchair that can make a meaningful difference in the lives of those who need it.

2 Introduction:

2.1 Purpose:

To increase the mobility and liberty of people who are physically unable to walk or speak, this project is focused on creating a wheelchair that can be operated by the user's head movements. By providing an alternative to traditional joystick controls or human assistance, we aim to empower individuals with physical disabilities to move around with greater freedom and dignity. We made the whole system accomplish some objectives such as:

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

2.1.2. 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.

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

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

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

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

2.1.7. 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.

2.2 Intended Audience:

Almost 10% of the total population of Bangladesh (16 Million) has been suffering or has suffered at some point in life from paralysis due to some disorders like strokes, spinal cord injuries, autoimmune diseases like multiple sclerosis, brain injuries, etc. It is typically caused by damage to the nervous system due to some reasons and signals from the brain cannot communicate to the body. Paralyzed people experience several challenges, such as mobility issues that limit their ability to move on their own. Therefore, they must rely on their family members or other people to take care of them. Our project intends to provide disabled people to maneuver freely which is important to make them independent.

The intended audience for our project includes individuals with physical disabilities who are unable to walk or talk and rely on wheelchairs for mobility, as well as their families and caregivers. We also aim to reach healthcare professionals such as doctors, nurses, and physical therapists who work with individuals with physical disabilities, as well as researchers and engineers in the field of assistive technology.

Additionally, our project may be of interest to funding organizations, non-profit organizations, and government agencies that focus on improving the lives of individuals with physical disabilities. We aim to raise awareness about the importance of mobility and independence for individuals with physical disabilities and promote greater inclusivity and accessibility in our society.

Our project may also be of interest to the wider public, as it highlights the potential of technology to address real-world problems and improve the quality of life for individuals with physical disabilities. We hope to inspire others to pursue innovative solutions in the field of assistive technology and create a more inclusive and accessible world.

The primary audience for a head motion-controlled wheelchair system is people with impairments who have limited or no use of their hands or arms, including individuals who have spinal cord injuries, muscular dystrophy, cerebral palsy, or multiple sclerosis. These individuals have mobility issues that make it difficult for them to move around independently. Our project intends to provide disabled people to maneuver freely which is important to make them independent. A head motion-controlled wheelchair offers an alternative method of operating their mobility equipment. This system will enable people with impairments to access and navigate their environments more freely, enhancing their overall quality of life. It will enable this by detecting and interpreting head motions. Another target group for a Head Motion Controlled Wheelchair system is caregivers who assist individuals with physical disabilities operate their mobility aids. A head motion-controlled wheelchair system may reduce the physical strain on carers and increase the safety of wheelchair operations. These caregivers frequently experience physical strain and damage from prolonged use of manual control systems. The NextGen wheelchair is a head motion-controlled wheelchair that will be controlled through the movements of the head obtained by a USB camera. After that, interaction will be made with a raspberry pi module to translate the head motions into commands which will drive the wheelchair. The system is expected to take intelligent decisions like halting when it will see any obstacle as well while moving. As an alternative, a voice control system will also be added. Additionally, an emergency alarm will be activated in order to ensure the user's safety. Although the system's initial cost is anticipated to be slightly higher, it can be offset by the benefits it will provide in the long run.

2.3 Scope:

The scope of our project is to design and develop a wheelchair for individuals with physical disabilities who are unable to walk or talk. The wheelchair will be controlled using the user's head movements, with backup control methods such as the joystick and voice control. The project will involve the following steps:

- 2.3.1. Research and development of the head-controlled wheelchair system, including the hardware and software components.
- 2.3.2. Design and development of the joystick and voice control backup systems.
- 2.3.3. Design and development of the emergency system
- 2.3.4. Integration of the head-controlled system with the backup control systems and the emergency system, ensuring seamless switching between control modes.
- 2.3.5. Design and creation of a web interface for patient monitoring.
- 2.3.6. Testing and validation of the wheelchair system to ensure safety, reliability, and performance.
- 2.3.7. Cost analysis and optimization of the system to ensure affordability and accessibility

Although there is a huge scope for the handicapped people, the project will have certain limitations, including:

- 2.3.1. The system will be designed for indoor and smooth surface use only, and may not be suitable for outdoor or rough terrain use.
- 2.3.2. The system will be designed for users with specific types of physical disabilities, and may not be suitable for all individuals with physical disabilities.

2.3.3. The system will have certain technical limitations, such as a limited range of motion for the head-controlled system and potential interference with other electronic devices.

Overall, the scope of our project is to develop a safe, reliable, and user-friendly wheelchair system that can be controlled using the user's head movements, providing greater mobility and independence for individuals with physical disabilities.

3 Glossary:

3.1 Real-Time Data:

Real-time data is data that is available as soon as it's created and acquired. Data is sent to customers immediately after it is collected and is instantly available — without any latency — which is essential for supporting live, in-the-moment decision-making. This data is at work in virtually every part of our lives, powering everything from bank transactions to GPS to the many COVID-19 maps that have emerged during the pandemic.

3.2 Data Processing:

Data processing, or computer-aided data manipulation. It includes the conversion of raw data to machine-readable form, the flow of data through the CPU and memory to output devices, and formatting or transformation of output. Data processing can be described as the use of computers to carry out specific operations on data. In the commercial world, the data processing refers to the processing of data required to run organizations and businesses.

3.3 Raspberry Pi:

The Raspberry Pi is an inexpensive, credit-card-sized computer that plugs into a computer monitor or TV, and operates with a regular keyboard and mouse. It is a capable little device that enables people of all ages to explore computing and learn how to program in languages like Scratch and Python.

3.4 HCI (Human-Computer Interaction):

HCI is a field that focuses on understanding how humans interact with technology and improving the design of user interfaces to make them more usable, efficient, and satisfying. It involves research on users' needs, preferences, and behavior, as well as the design and evaluation of software and hardware interfaces. HCI is an interdisciplinary field that draws on psychology, computer science, engineering, and design to create intuitive and accessible interfaces that enhance the user's experience.

3.5 Machine Learning:

The process by which computers learn to recognize patterns, or the capacity to continuously learn from and make predictions based on data, then make adjustments without being specifically programmed to do so, is known as machine learning (ML), a subcategory of artificial intelligence.

3.6 Pattern Recognition:

Pattern recognition is the process of recognizing patterns by using a machine learning algorithm. The classification of data based on previously acquired knowledge or on statistical data extrapolated from patterns and/or their representation is known as pattern recognition.

3.7 P300:

P300 is an important event-related potential (ERP) component that is used to evaluate cognitive abilities like concentration, working memory, and attention. It is primarily triggered by the oddball paradigm and occurs about 300 ms following an infrequent stimulus. The P300 components have been thought of as a potential sign of cognitive impairment. The waveform of the P300 component is described by its amplitude and latency. The

P300 amplitude represents the degree of information processing, which is also associated with the number of attentional resources allocated to a task and the level of superior cognitive function.

3.8 Oddball Paradigm:

An experimental strategy employed in psychology research is known as the oddball paradigm. Infrequent presentation of a deviant stimulus breaks up a chain of repeating stimuli. A recording of the participant's response to this 'oddball' stimulus is made.

4 Requirement Discovery:

4.1 Survey:

A google form was used to conduct an online survey to learn about users' opinions about the system. The form was mostly filled up by the targeted users and their relatives from all around the nation. Besides, some students of medical backgrounds who know about paralyzed people and their disabilities, also filled up the form as they can give some essential information that can be used for the betterment of the system.

40 responses were received from the survey. 32% of them were physically disabled but can move their body parts, 42% of them were the relatives of the patients and 26% of them were medical science students. From the survey, the following information was gathered-

4.1.1. 74% of people felt about the necessity of a wheelchair for the movement of disabled people.

4.1.2. Almost 50% of the patients require an assistant to move around.

4.1.3. Almost 40% of the patients need to use a wheelchair 3-5 times daily.

4.1.4. More than 59% of people need to use a wheelchair for around half an hour straight daily.

4.1.5. Almost 45% of people need to travel around 10-12 meter distances daily with a wheelchair.

4.1.6. Around 66% of people think about using modern technology to control the movement of the wheelchair.

4.2 Interview:

We conducted interviews with medical professionals who specialize in orthopedics and medicine because our study dealt with disabilities in movement and brain function. We spoke with Dr. Abu Sayed from Mitford Hospital, who has been working in this field for about ten years. The following are some crucial insights:

4.2.1. Patients who lose their motor control and body movement are also prone to losing brain functioning in that area since the brain does not get enough feedback from that area of the body.

4.2.2. It is conceivable to have diverse signal patterns for the same movement command since the brain may function differently for different patients.

4.2.3. Training patients as soon as feasible can have a significant impact on the success rate of integrating projects like ours with patients.

4.2.4. EEG is mostly used in the medical field to determine whether or not the entire brain is functioning. It is not utilized to identify a specific body part malfunction.

4.3 Literature Review:

Patil et al.(2020) designed a system that was operated with the help of a tilt of the head movements[1]. The system was designed and developed using tilt sensors and wireless modules and can bear a capacity of up to 100 kg and be implemented practically. One of the main objectives of implementing a low-budget system with a better accuracy rate was achieved through this project. A semi-autonomous head-motion controlled wheelchair is proposed for quadriplegic patients by *Kader et al.(2019)*. A 3-axis accelerometer sensor was used to detect the head movement and two DC motors were used to navigate the wheelchair[2]. Two sonar sensors were used to detect the obstacles in the front and back directions of the wheelchair. An SMS system was integrated with the system through a GSM modem with location information to inform the family member about any collision or accident. However, a machine-learning-based approach can be implemented in the future to detect the head motion for controlling the wheelchair more precisely and ensuring a better accuracy rate. Also, the authors have suggested working on IoT based health monitoring system to continuously monitor the physical condition of the patient. *Hassani et al.(2019)* developed an interface for disabled people to control the standard electric wheelchair with head gestures[3]. They developed the system based on the principle of acceleration and rotation rate of the patient's head which was detected using an accelerometer and gyroscope sensors embedded with MPU6050. Overall performance was evaluated in an indoor environment with a healthy object. However, the system was limited to the X and Y axis of the user's head angles, which limits the movement of the wheelchair in some defined directions. Future work can be implemented on driving the wheelchair on diagonal regions and the Z - axis, which can make the system more reliable and efficient. *Bakouri et al.(2022)* developed and implemented a voice control algorithm to control a smart robotic wheelchair (SRW) using the neural network technique[4]. Network In Network (NIN) and Long Short Term Memory (LSTM) structures were integrated into the system with a built-in voice recognition algorithm. A Wi-Fi hotspot was used to connect the hardware and software parts of the system with a configured mobile application. Five voice commands were employed with the Raspberry Pi and DC motors in the system to navigate the wheelchair. The system was implemented in both indoor and outdoor environments which resulted in an accuracy rate of 98.2% for the proposed five voice commands - left, right, yes, no, and stop. Though, the authors have suggested enhancing the system with GPS technology which can allow the users to design their routes for future work. Besides, adding safety measurements like integrating ultrasonic sensors, integrating more voice commands with the system, and controlling the wheelchair with brain signals can be a great addition. So, future research is needed to implement these proposals which can make the system multi-operational, more accurate, and reliable. Artificial neural networks were trained through the user's voice commands based on neural networks and a backpropagation algorithm by *Karande et al.(2022).* The proposed prototype was trained using five voice commands - Forward, Backward, Left, Right, and Stop[5]. The commands were written on target hardware wirelessly by using a Bluetooth module for the motion of the DC motors. The overall prototype was designed on MATLAB R2020a and Arduino UNO. To make the system more efficient and less costly, the authors suggest future work like deploying the whole MATLAB code directly to the target hardware. *Karim et al.(2022)*, constructed the wheelchair using a microcontroller and other electronic devices to control the motors and process the voice commands[6]. The system was designed in such a way that it remains cost-effective and can be commercialized for needy users. *Rulik et al.(2022)* designed a multimodal control method for robotic self-assistance that can assist patients with disabilities in performing self-tasks daily[7]. Two interchangeable operating modes- chin and finger joystick control frameworks were developed to control the movements of the assistive robot. The system was tested by performing some daily activities such as picking up and placing items which resulted in a completion time of less than 1 minute for each task. The absolute position accuracy was spotted at approximately 5 mm. However, to pick up heavy objects, the system needs high torque and the performance of the system becomes low also. So, the authors should work on this area to make the system more efficient. *Kulkarni et al.(2022)* developed a "signal-controlled wheelchair" that can be controlled with a small motion of the hand[8]. The proposed system was implemented with Arduino grounded predispositions which is similar to the Arduino NANO and UNO microprocessors. The system was developed to address the challenges of using joysticks to control a wheelchair. The authors proposed a mixed optic indicator to detect the retina to move the wheelchair for future research. Besides, GSM technology can also be used to transmit messages in an emergency.

As a goal of developing a wheelchair with control methods of head motion, voice, and wireless control that is specially tailored to quadriplegic as well as other disabled patients, is a good starting approach. This system is proposed to develop of a wheelchair that can be controlled via the head motion of the user, as well as with voice and joystick modules as two other alternatives. A web interface is also developed for continuous monitoring of the system as well as controlling the system through that web interface. Besides, the caregivers can control the system from a far distance which can reduce the physical strain that they experience while being with the patients.

5 User Requirement:

5.1. The wheelchair shall be operated as intended by the user.

5.2. The system shall be accurate enough to operate according to the user commands within the shortest amount of time.

5.3. The system shall have an alarm system for both unexpected system failure and patient emergency circumstances.

5.4. User shall alternatively use their voice and a joystick to operate the system as well.

5.5. The system shall have enough power to operate for at least three hours.

5.6. The system should not malfunction on any type of road while moving.

5.7. The system should be suitable and flexible for all intended users.

5.8. The system should ensure the safety of the user.

5.9. The system should be cost-effective.

Sl no.	User Requirements	Functional	Non-Functional
1	Head Movement Detection	✓	✗
2	Command Extraction	✓	✗
3	System Durability	✗	✓
4	Comfort	✗	✓
5	Accuracy	✗	✓
6	Processing data using ML	✓	✗
7	Emergency alarm	✓	✗
8	Backup System	✓	✗
9	Set Threshold Point	✓	✗
10	Safety	✗	✓

Table 1: User requirements specification

6 System Architecture:

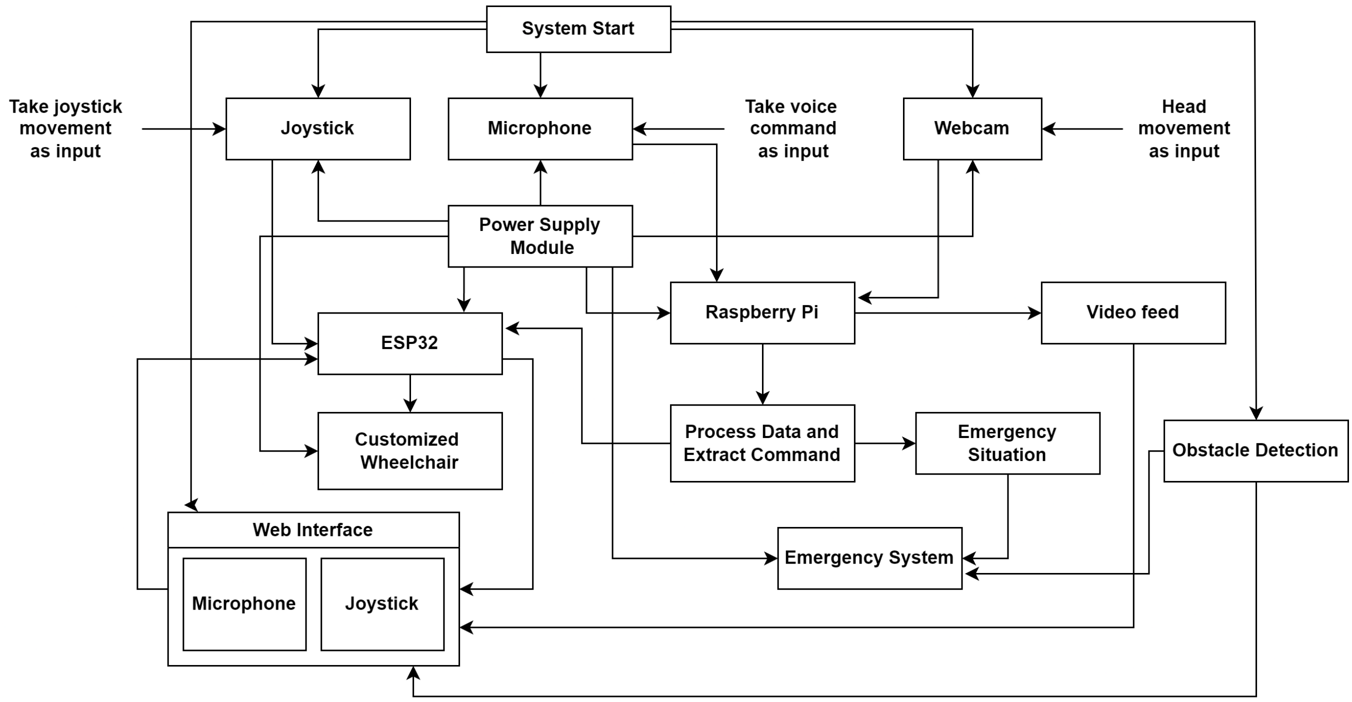

Fig. 1: System architecture of NextGen Wheenchair

The system of NextGen Wheelchair includes-

6.1. One of the three control methods (head movement, voice command and joystick) will be chosen by the user when the system launches.

6.2. The system will be instructed by the user using a joystick, microphone, or head movement.

6.3. Input data from the microphone or the head movement captured via camera will be sent to the Raspberry Pi if a voice command or brain signal is the chosen control method so that Raspberry Pi can decode the command from the input data.

6.4. If a system fails during the decoding process of the movement commands, the emergency system will be activated.

6.5. Then, the Arduino micro-controller will be given the command extracted from the input data and the wheelchair will be moved.

6.6. Every system component that requires electricity will be supplied to it by a power supply module.

7 System Requirements:

7.1. The system shall take video feed of patient via a webcam, then transmit those signals to the processor
- (7.1.1) The user's head motion should be extracted from the video feedback.
- (7.1.2) The video feed should be sent to the processor (Raspberry Pi) and from the processor the feed should be sent to the caregiver.

7.2. Custom modifications shall be made to the wheelchair in order for it to respond to received commands
- (7.2.1) For the wheelchair's controlled movement, two high-torque motors shall be integrated.
- (7.2.2) The wheelchair shall also have other hardware resources installed in order to increase user reliability.

7.3. Collected data shall be processed and the desired command shall be carried out
- (7.3.1) The processor shall make the appropriate decisions by applying machine learning algorithms to recognize patterns of the signals

7.4. According to the retrieved instructions, the custom wheelchair shall be moved.

7.5. The accuracy of the system shall be more than 85%

7.6. The system shall be reliable for the targeted audience

7.7. The time that elapses between receiving head movement and carrying out intended instructions should be as short as possible.

7.8. An emergency buzzer shall sound in case of system malfunction

(7.8.1) When the user's brain signal is discovered to be anomalous, the system shall alert via a buzzer.

(7.8.2) In case of unexpected system failure, the system shall alert via a buzzer.

7.9. As a backup control system, the system shall be integrated with a voice-controlled system

(7.9.1) The user's voice command shall also be used to operate the system.

(7.9.2) There shall initially be five voice commands: "left", " right", "forward", "stop", and "start".

7.10. To reach a wider user base, the system should be cost-effective.

7.11. The entire procedure shall be monitor-able by the caregiver using a web interface.

(7.11.1) A web interface that contains all the information needed to monitor whether the system is operating well or not shall be developed and implemented.

(7.11.2) The web interface shall display the user's live video feed and shall contain control access of the wheelchair.

Sl no.	**System Requirement Description**	**Functional**		**Non-functional**
		Input	**Output**	
1	Taking video feed using webcam	Head movement	Movement direction	✗
2	Custom Wheelchair	Wheelchair and hardware equipment	Customized wheelchair	✗
3	Wheelchair movement	Commands	Movement of wheelchair	✗
4	Accuracy	✗		✓
5	Reliability	✗		✓
6	Propagation delay	✗		✓
7	Emergency system	System malfunction	Alert via buzzer	✗
8	Backup Control System	Voice command	movement of wheelchair	✗
9	Cost-efficient system	✗		✓
10	Real-time feed in Web	User's real-time status	Real-time monitoring	✗
11	Web interface	✗		✓

Table 2: System requirement specifications

8 System Model:

8.1 Context Diagram:

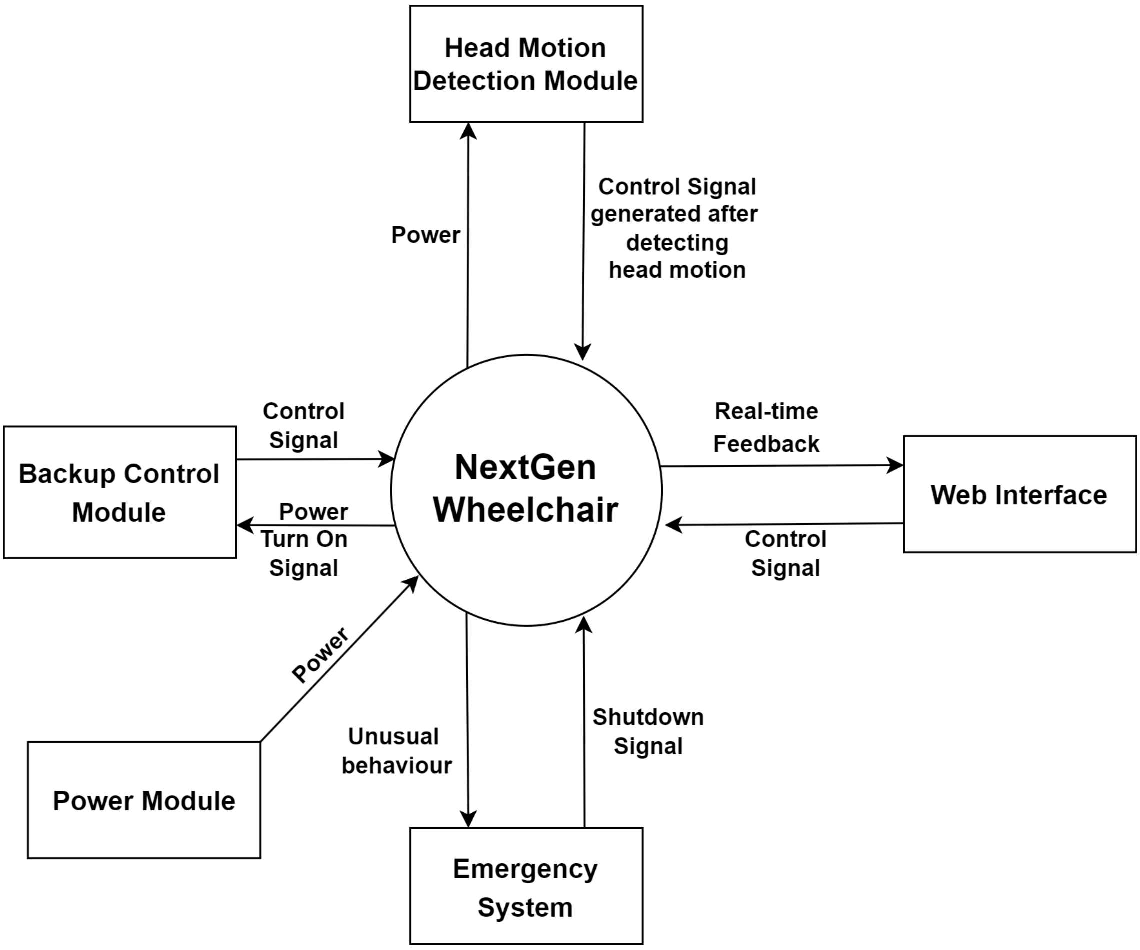

Fig. 2: Context diagram of NextGen Wheenchair

The 5 components in the NextGen Wheelchair are:

8.1.1 Head Motion Detection Module:

The main control module of the system. It will (a)gather the user's head motion, (b) analyze those motions and gather pertinent information from them, and (c) deliver the control signal to the wheelchair.

8.1.2 Power Module:

This module will distribute power to the whole system according to different components requirement.

8.1.3 Backup Control Module:

This module is activated when the head motion module is unable to process data or when the user wants to control the wheelchair using alternative options. The module will interpret voice commands or joystick movement and then send control signals to the wheelchair accordingly. This module is also usable by the caregiver through the web interface.

8.1.4 Emergency system:

In the event of an emergency (e.g.: low battery, patient's unconsciousness), this subsystem will notify the caregiver and request assistance.

8.1.5 Web Interface:

The web interface will receive real-time data feedback(video) from the patient. Through the web interface, the backup control modules are also usable if needed.

8.2 Activity Diagram:

8.2.1 Activity diagram of Control System:

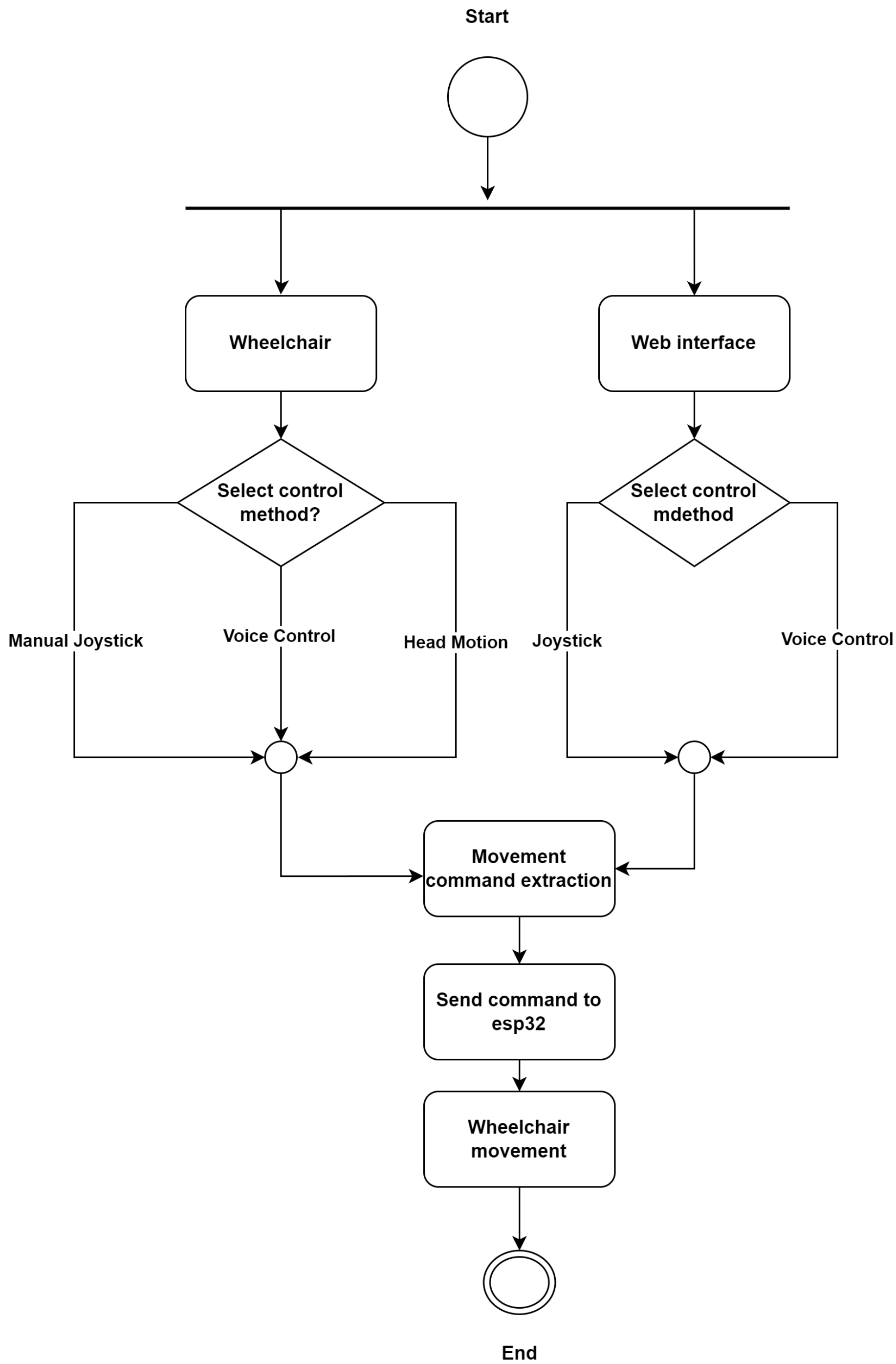

Fig. 3: Activity diagram of control system

8.2.2 Activity diagram of Emergency Module:

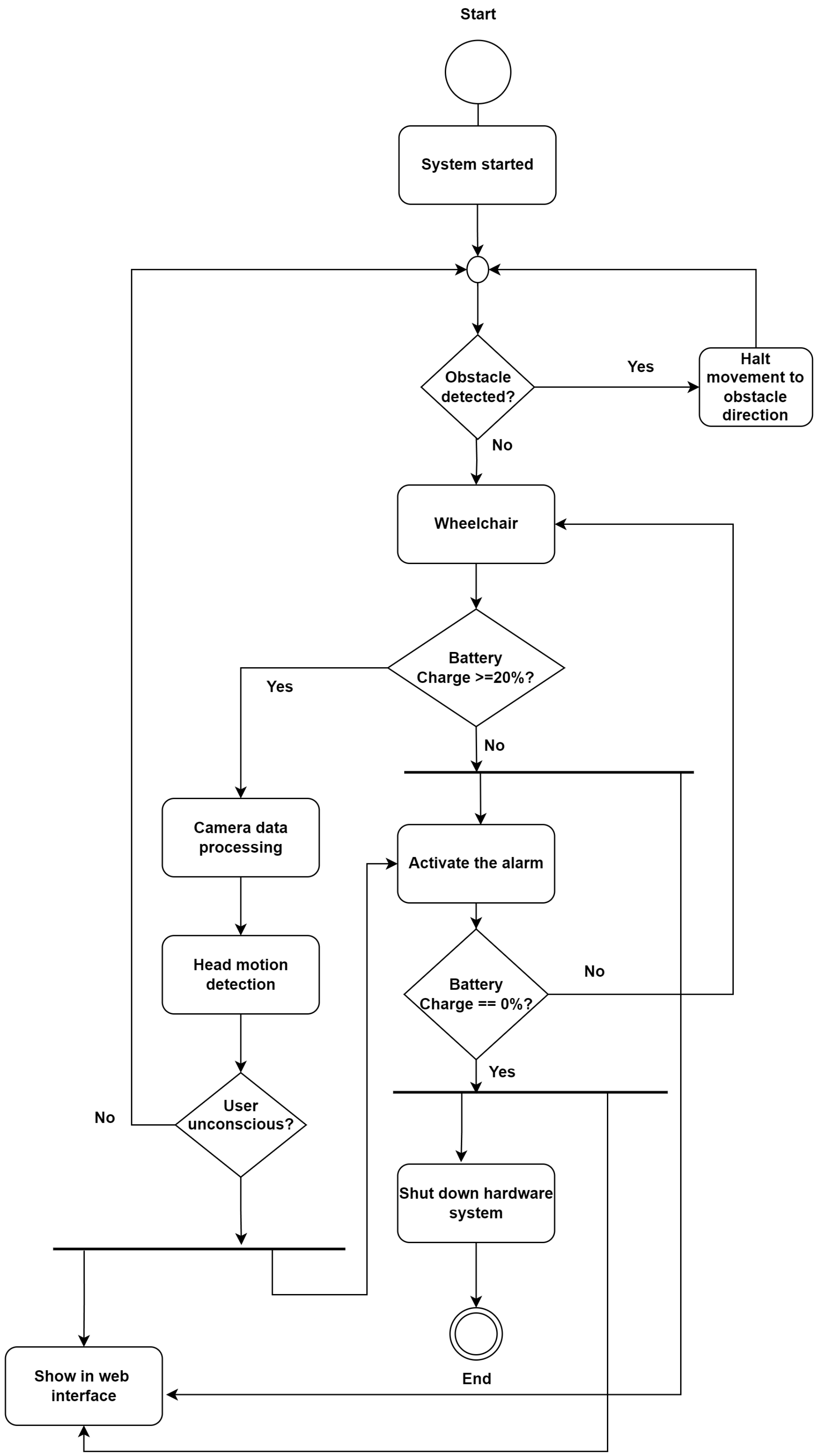

Fig. 4: Activity diagram of emergency module

8.3 Use-case Diagram:

8.3.1 Head-motion Processing Module:

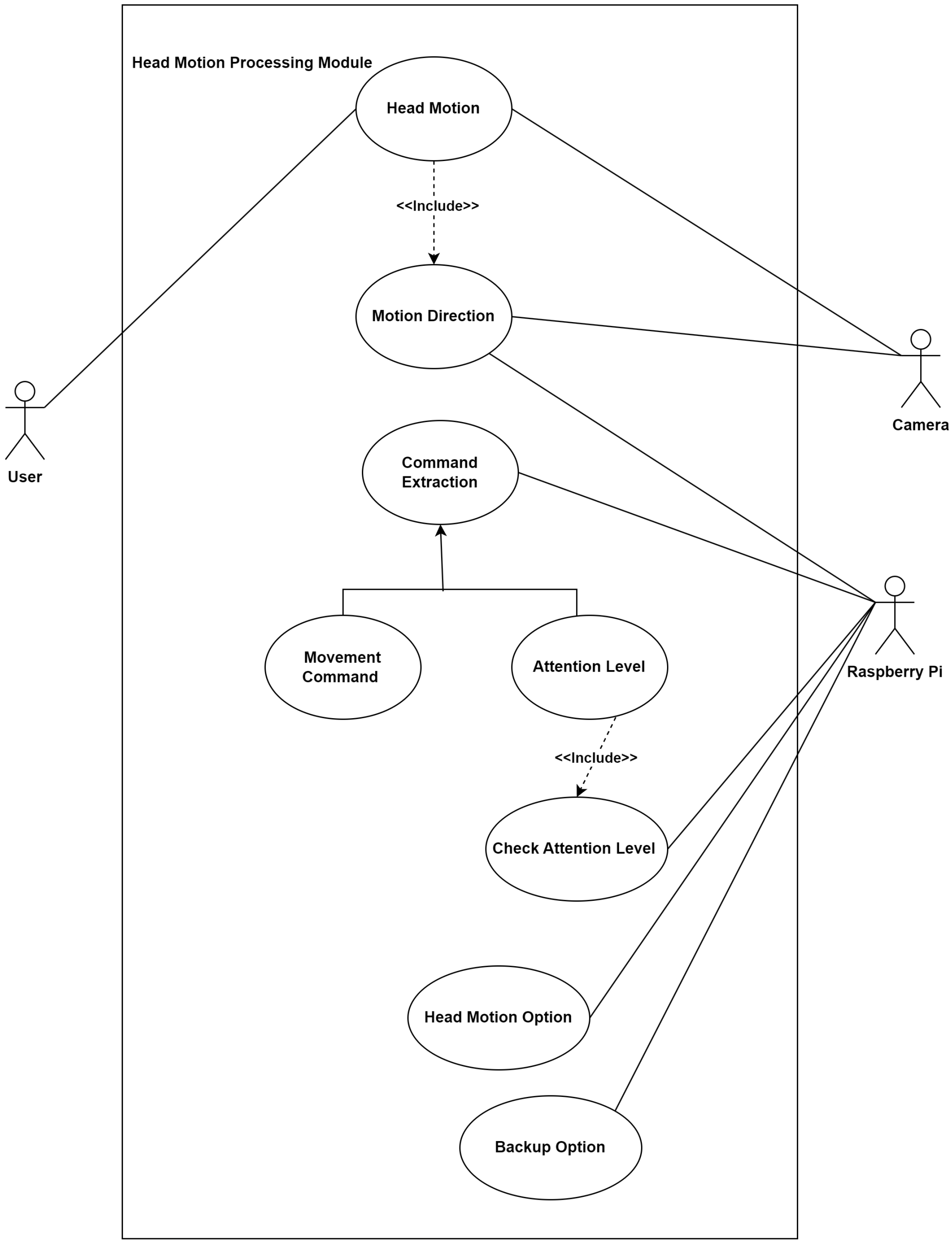

Fig. 5: Use-case diagram for head motion processing

Head-motion Processing Module	
Actors	User, webcam, raspberry pi
Description	The webcam will receive video feed input from user. After that, the video feed will be analysed by Raspberry Pi to determine the intended direction of commands.
Data	User's video feed
Stimulus	User head-motion video sent to Raspberry Pi.
Response	Extracts direction command.
Comments	In order to activate head-motion control, a clear video feed from eye level has to be ensured.

8.3.2 Power Module:

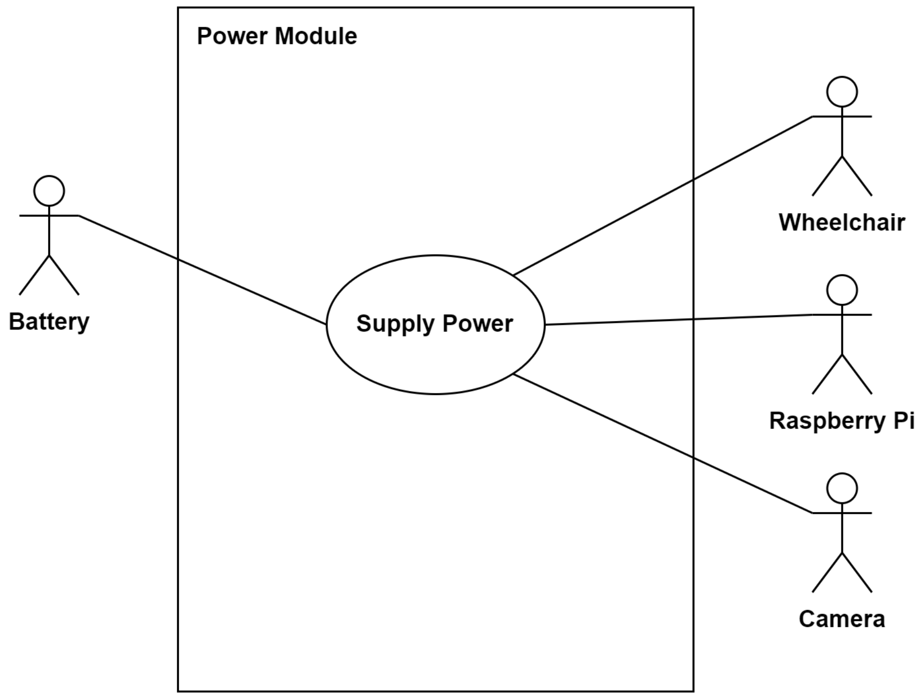

Fig. 6: Use-case diagram for power module

Power Module	
Actors	Battery, wheelchair, raspberry pi, camera
Description	The system as a whole will be powered by the battery.
Data	Battery power
Stimulus	Battery supplies the power
Response	Runs the whole system
Comments	The battery needs to function properly in order for the system to run.

8.3.3 Emergency System :

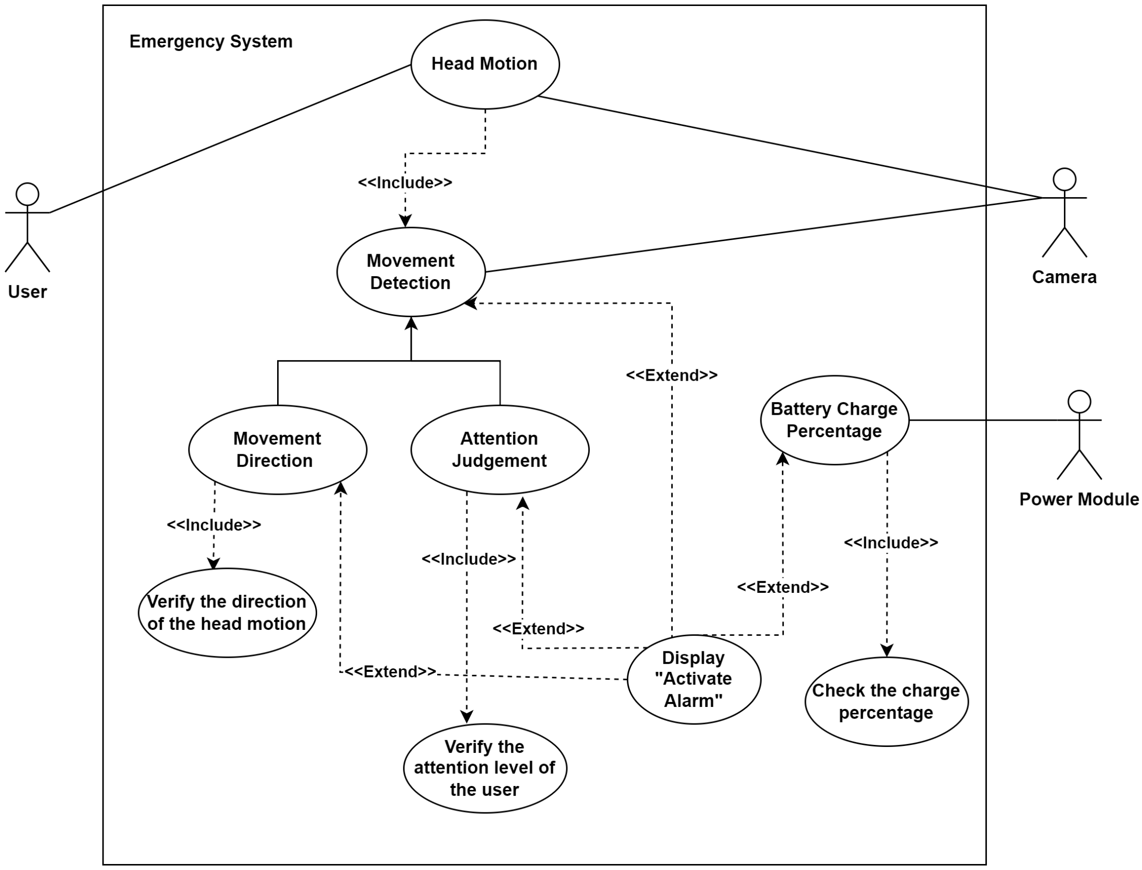

Fig. 7: Use-case diagram for emergency system

Emergency System	
Actors	User, camera, power module
Description	Users video feed is given input into the system, which is then transmitted to the raspberry pi. The pi processes the video and extracts a direction command. An emergency alarm is triggered by the system if EAR falls below a predetermined threshold. Additionally, a power module is utilized to display the battery level and instruct the system to perform the appropriate measures in response. A Raspberry Pi, and a Single Board Computer will be used to perform all of these calculations or choices.
Data	Users' live video feed
Stimulus	User uploads his live video feed.
Response	Successfully sets off an emergency alarm.
Comments	In order to activate the device, the user must be able to send live video feed.

8.3.4 Backup Control:

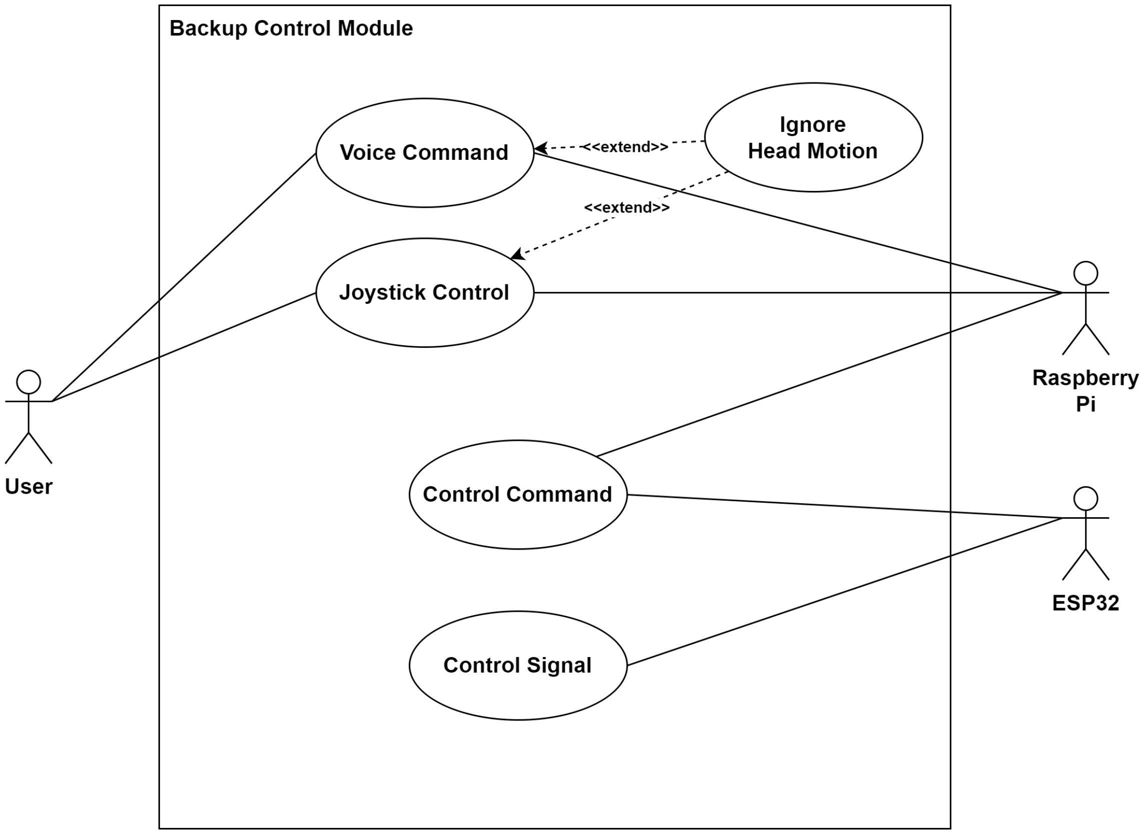

Fig. 8: Use-case diagram for backup control systems

Backup Control Module	
Actors	User, raspberry pi, ESP32
Description	The use gives voice command or moves joystick rather than using head-motion. If the system detects voice command, then it will use voice recognition in order to extract necessary instructions from the voice command, then it'll send those instructions to Arduino (microcontroller). If the user uses the joystick then the input from the joystick will be fed through Raspberry Pi to Arduino. After getting control instructions, Arduino will generate the control signal for the system which will drive the wheelchair.
Data	Voice command or Joystick input from user
Stimulus	User selecting voice or joystick mode
Response	Acting upon the voice commands or joystick control rather than following user's brain signals
Comments	Turning on or off the backup control module will be controlled by a switch.

8.3.5 Web Interface:

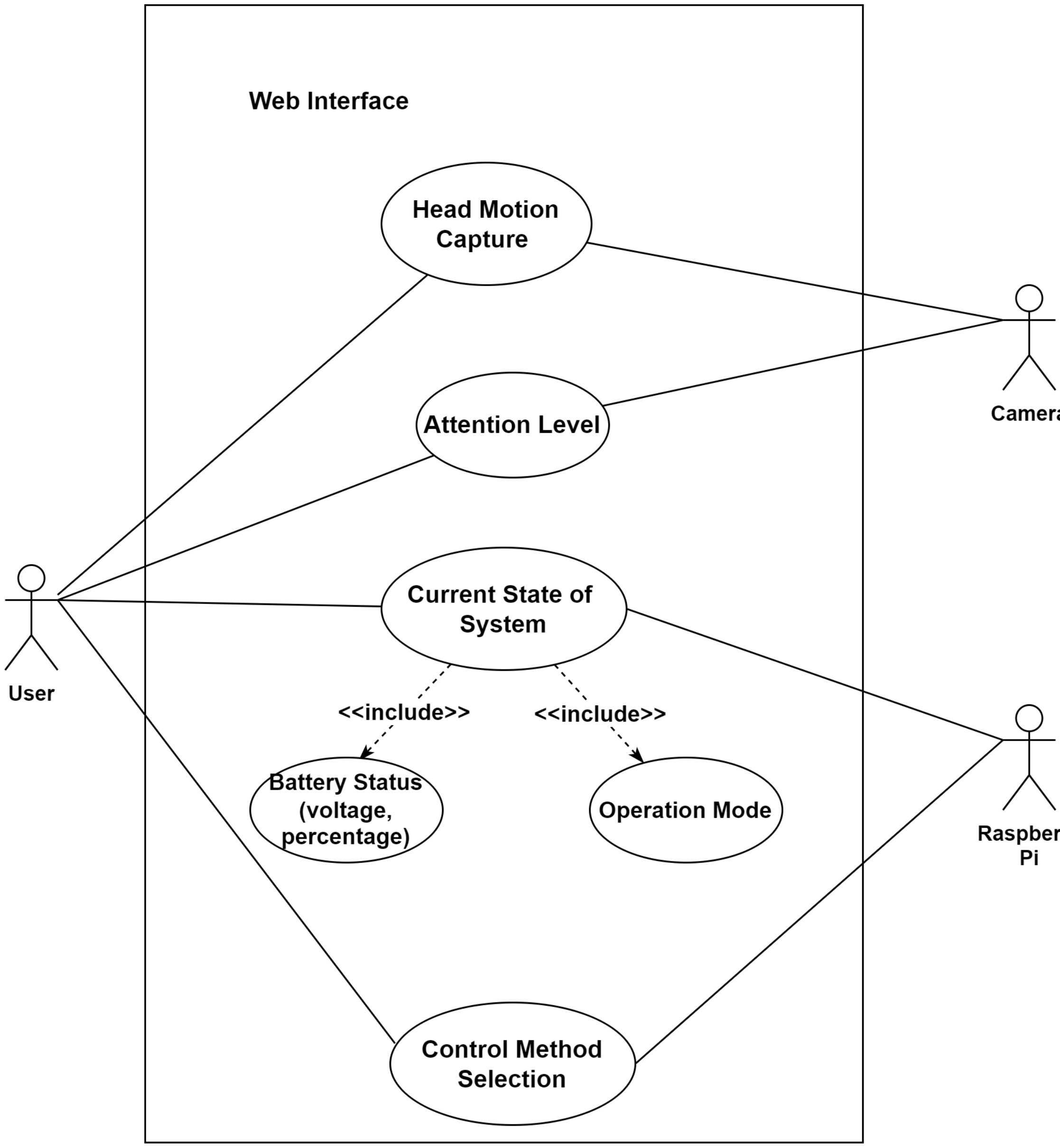

Fig. 9: Use-case diagram for web interface

Web Interface	
Actors	User, Camera Raspberry Pi
Description	Web interface will show the camera feed received from the user. It will also show info about the patient's status and warn if needed. The current status of the system will be shown which will include battery percentage, battery voltage, operation mode, etc. The user will be able to select from the two backup control methods using the web interface.
Data	Brain Signal, attention Level, current system status, control method selection
Stimulus	Powering on of the system
Response	Showing live video feed, the status of the whole system.

8.4 Sequence Diagram:

8.4.1 Emergency System:

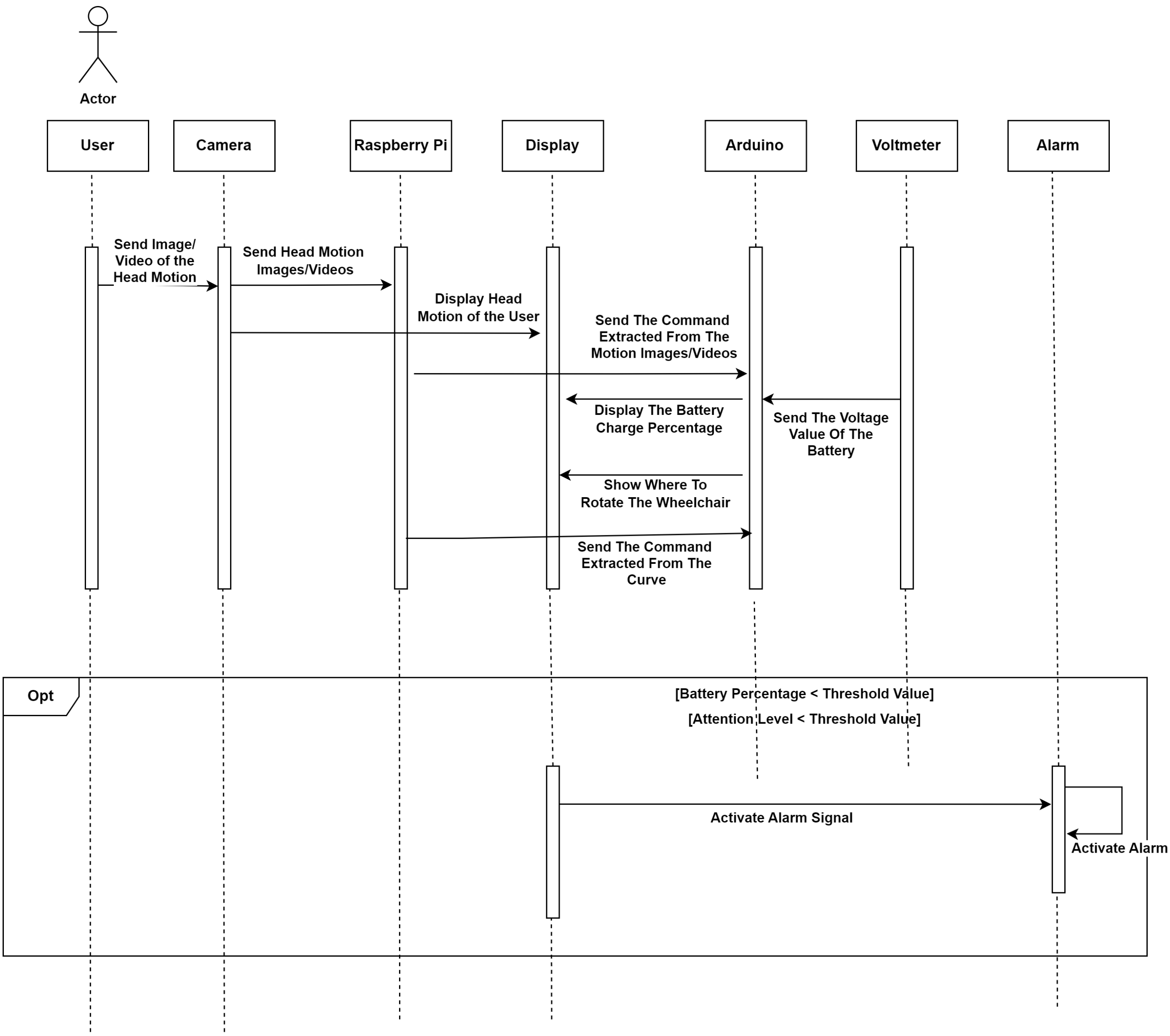

Fig. 10: Sequence diagram of emergency system

8.4.2 Backup Control Module:

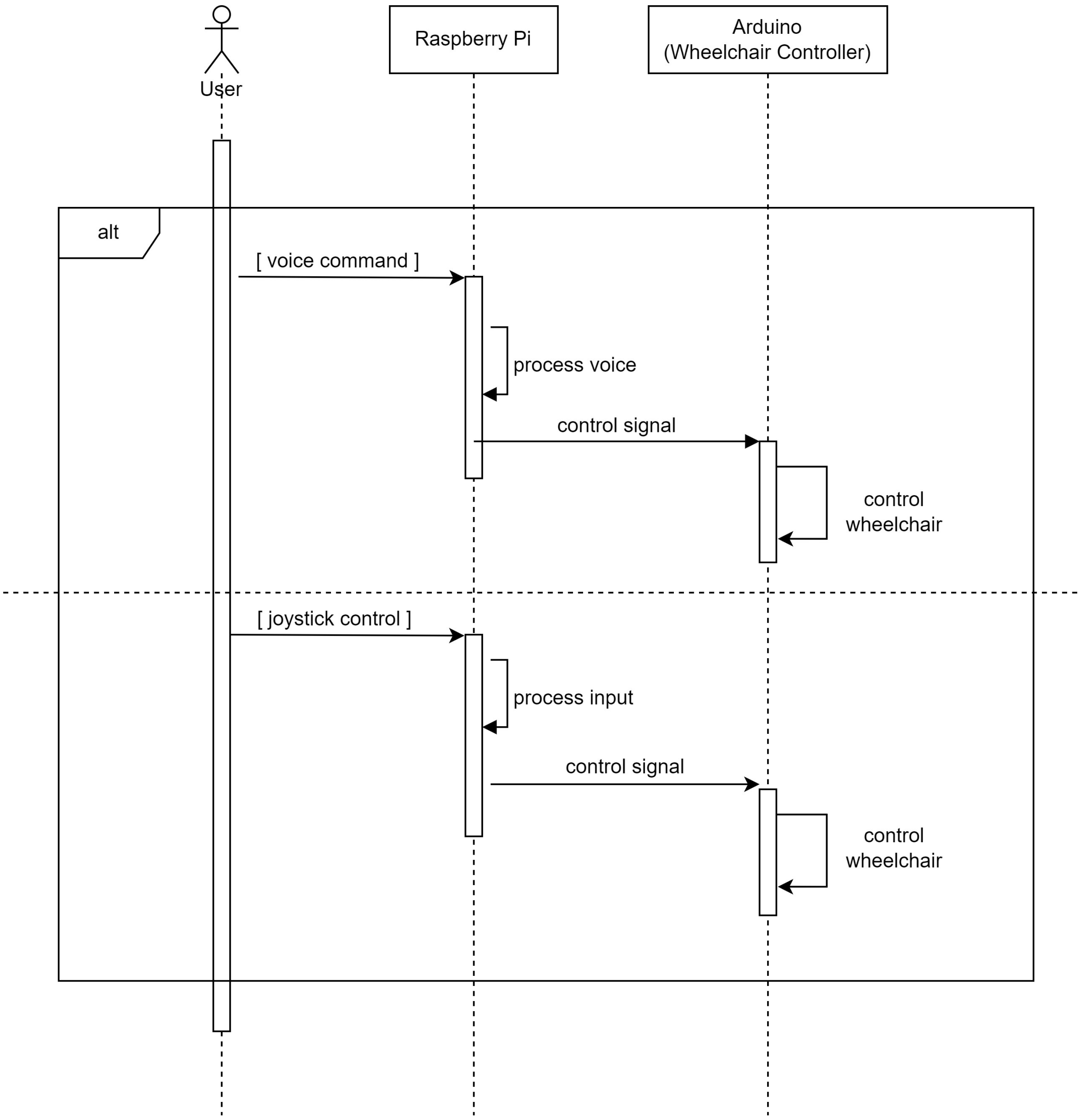

Fig. 11: Sequence Diagram of backup control module:

8.4.3 Power Module:

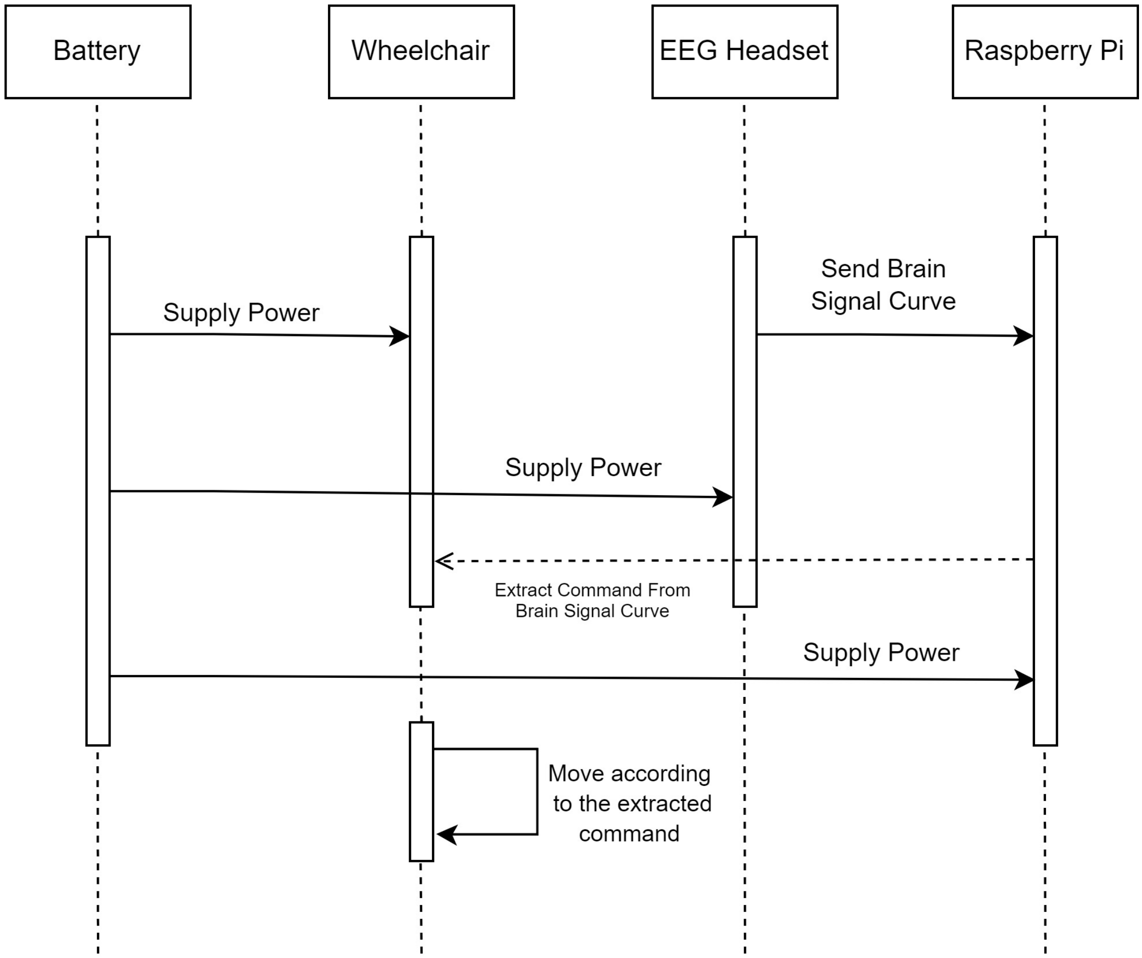

Fig. 12: Sequence diagram of power module

8.5 State Diagram:

8.5.1 Wheelchair Movement methodology:

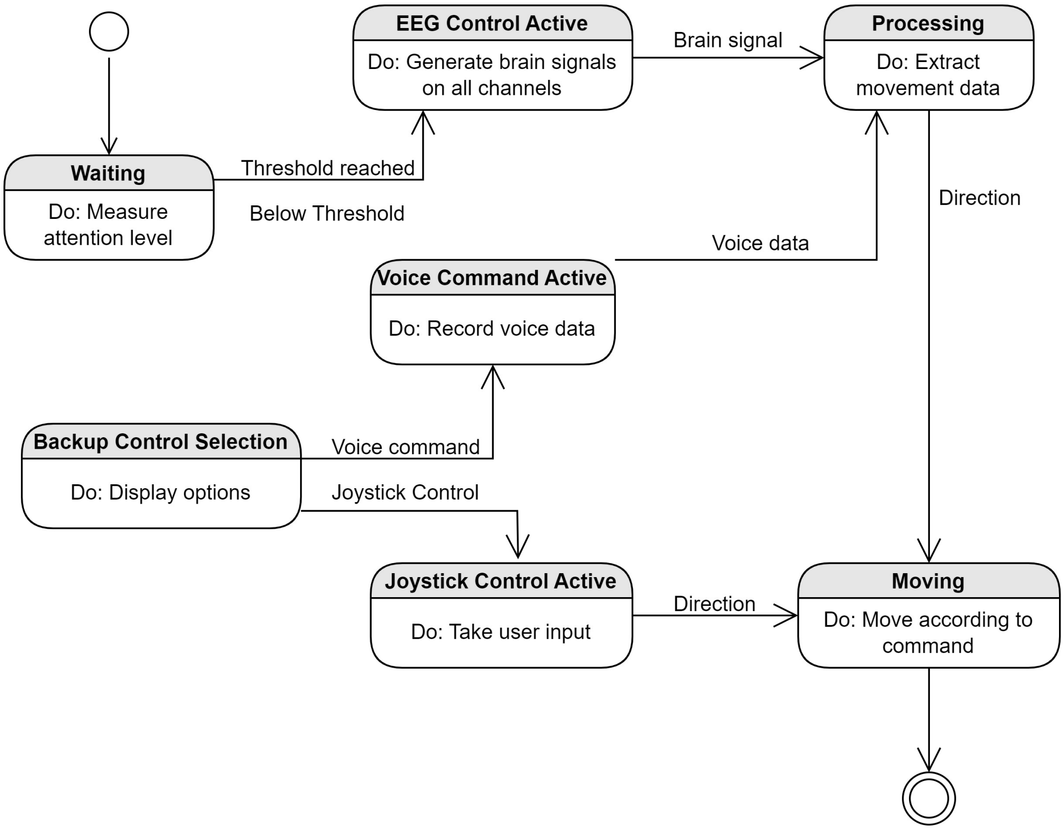

Fig. 13: State diagram of wheelchair movement methodology

8.5.2 Emergency System:

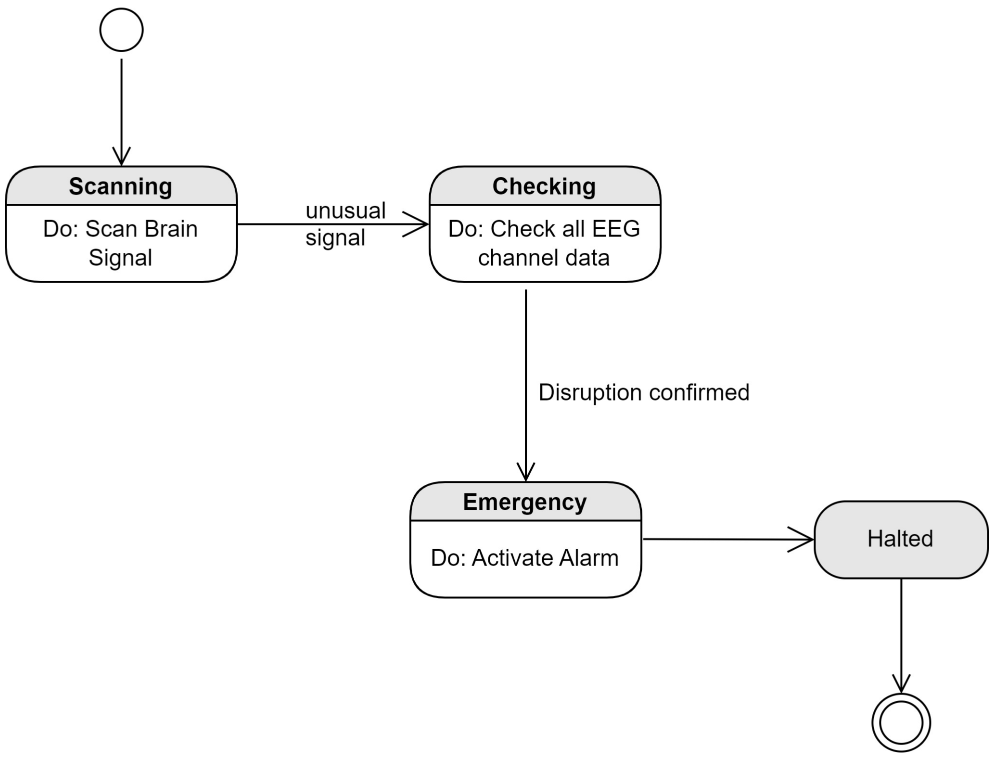

Fig. 14: State diagram of emergency system

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Survey Questionnaire:

The following questionnaire was set for conducting the survey:

1. Are you a medical science student?
2. Are you a paralyzed patient? If not, then do you have any paralyzed patients in your house or in your locality?
3. Do the patients use wheelchairs for their movement?
4. How many times in a day the patient requires to use the wheelchair?
5. Can the patient control the wheelchair by himself/herself?
6. How long does the patient needs to use the wheelchair continuously in a day?
7. How long distance does the patient need to cover using the wheelchair daily
8. Can the patient give the necessary commands to move the wheelchair according to his/her needs the assistant?
9. Will the patient feel comfortable using modern technology which can be used to control the wheelchair according to his/her commands?