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A Real-Time Sensor Based Hand Gesture Controlled Robotic Wheelchair for Assisting People with Disabilities

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Abstract**—**Currently, thousands of people are suffering from paralysis. They have difficulties with speaking and walking. So we've developed a new kind of robot that can help those people who can't walk or speak. By utilizing this robot (hand gloves or wheelchair handle) and gesture-based regulators, people with physical disabilities will improve their quality of life. The robot of the proposal has two components, one is the controller of the motion, and the other is the Robotic Wheelchair (RW). Where one can easily interact with the robotic-base wheelchair-using sensor-based hand gesture. With this human-robot interaction, a patient can quite easily control the robot and can move freely. In addition, the required patients may use gestures (hand gloves or wheelchair handle) to express their needs. Furthermore, we will reduce the effort to regulate the RW and hand movements with this device, that's really difficult for disabled or dumb people. Our device can run with approximately 94% accuracy and very minimal delay.

Index Terms**—**Wheelchair, Controller, Sensors, voice, Gestures, Dumb, Accuracy, Response Time, and Time Delay.

I. Introduction

IN the world we live in a vast number of aged, impaired, dumb peoples who can not speak and walk properly. Numerous electric wheelchairs and hand signals [1] have been quickly conveyed for the last two decades to boost the quality of their lives [2] [3]. They offer functional mobility to those with lower and upper extremity impairments. According to the [4], there are 466 million individuals with crippling deafness and ignorance. This represents 6% of the world's population and requires a wheelchair for 75 million people. This constitutes 1% of the population in the world. In addition, according to the CCD [5], 16 million people in Bangladesh are projected to be living with a disability, getting little to no support and excluded from everyday life. Furthermore, within the United States over than 200,000 individuals utilizing EPWs as their essential implies of portability. Most of these EPWs are operated by a joystick but some patients are still facing to move from one place to another place using this technology. People with mobility disorders are living at 5.1% and, 2.1% has a communication disorder as per the World Health Organization (WHO) [6].

There are several common disabilities in the present word which are shown in Fig. 1. Where walking difficulties in 30.6 million are reached. In addition, a person's need assistance is 12 million. The author's goals are to build an RW where a disabled person can move safely using sensors based gloves or sensors based on wheelchair handles. In addition , the author also designs a sensor system that helps people who can't speak or express their basic needs with the dumb impairments.

Many times, several researchers have presented various types of robotic wheelchairs. Also, they have designed a voice-command-based system for dumb impairments. In addition, most of the studies have indicated the physical impairment challenges. From the above premises, the author try to design a system that assists to survive the elderly (requiring assistance), disable (walking difficulties), paralyzed (using wheelchair), and dumb impairments peoples.

However, the controller and robot have different methods of communication. But Bluetooth and WiFi are the most common communications media [7] [8]. Disabled people can comfortably travel via a robot wheelchair using these technologies and express their need using hand gesture sensors [9] [10].

This paper summarizes the principal contributions as follows:

- The proposed RW is built with easy and minimally expensive hardware.

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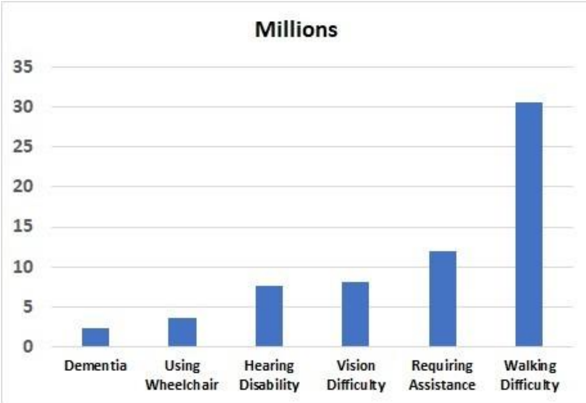

Fig. 1: Common Disabilities

- It executes more rapidly and with greater precision based on specific commands.
- It will help the elderly, impaired, crippled, deaf and dumb communities to survive.
- Also, To make it more accurate and more stable by-errors.

We are attempting to build a system that can manage any robot wheelchair through hand movements (left and right) with certain infrared and flex sensors which can change lives for the aged, the disabled, and the dumb, respectively. We have also built a robot wheelchair, rather than a joystick, creators have fabricated a hand-signal regulator (wheelchair and hand-gloves), by using the wheelchair disable people able to travel safely and quickly using Right-hand sensors which shown in Fig. 7 and express their needs using Left-hand sensors which shown in Fig. 8. Moreover, The disable people able to travel using the controller using Right-Hand sensors shown in Fig. 7 and use the left-hand sensors shown in Fig. 8 to express their needs. In every aspect of the system, we have also tried to reduce the cost so that RW can be easily accessible to the aged, physically challenged and handicapped.

Paper Organization: Related works are presented and described in section II. Then, system design is presented in section III where we have introduced a Robot Wheelchair for disable people and described the system design. In addition, authors in section IV demonstrate the consistency of the system, response time, and time delay. Finally, the authors have concluded the paper in section V.

II. RELATED WORKS

In the current years of assisting people with disabilities a major research initiative has been found.

Hossain et al. [11] have been developed an AI-based intelligent robot for autistic children that can talk and detect people. Moreover, it can move and communicate with other peoples. They also have evaluated the performances of the AI Robot using various parameters. Then, A multi-sensor based wheelchair has been presented by Gomez-Donoso et al. (2017). Authors have used various interactions for disable peoples.

Shayban et al. [12] later proposed a head gesture device using a sensor for the acceleration where the wheelchair is regulated by a joystick which is hard to control for people with disabilities. By changing the head, data is transmitted wirelessly to the micro-controller, and the wheelchair controls movement. In addition, an electronic wheelchair based on android [13] has been suggested for physically disabled people where the smartphone gives voice commands, and voices are translated to text. The microcontroller then receives texts with the aid of the DC motor, using the Bluetooth module.

In another paper Vu et al. (2017) has provided a new algorithm for disabled people to monitor their orientation. They used 25 items that were disabled, and they sought to enhance their findings through various experiments. This was accompanied by a number of research including gesture on hand, head motion, head gesture (jackowski et al., 2017). Then Jesse Leaman et al. (2017) systematically addressed Smart Wheelchair (SW): current, past, and future research initiatives and attempted to explain which types of wheelchairs are suitable for people with disabilities. Very recent study has attempted to incorporate the (hansen et al.,2018) (zhang et al., 2019) of head and glance and not many studies on that work have been done.

Moreover, several works [14] [15] [16] have been conducted for development of robotic wheelchair in recent years. They also described the challenges and issues on that [17] [18] [19].

Furthermore, Mahbuba Alam et al. [20] have also suggested a wearable gesture controlled robot for people with physical difficulties and disabilities where the hand movements are detected by motion sensors. They also have applied machine learning to classify hand gestures accurately. Later, An intelligent [21] wheelchair have introduced for Quadriplegic Patients that have abilities to navigate, detecting obstacles and moving automatically using sensors. After that, Prannah et al. [22] have proposed a navigation based smart wheelchair-using head gesture. It used an accelerometer sensor for moving wheelchair-using head gestures. It also used ultrasonic sensors for detecting obstacles and solar panels for green energy. Moreover, Gyroscope [23] controlled wheelchair have introduced for disabled people that is operated by the head motion signals and proposed system used brain-based gyroscope which consists of an EMOTIV. Furthermore, For disable and elderly people a RoboChair has been built by the Gray et al. [24]. Another paper for RoboChair [24] which controls the RoboChair motion utilizing DSP movement regulator has been published. The fundamental reason for this exploration was to make an easy to understand environment for old individuals and individuals with incapacities.

However, several researchers presented various types of robots through various interactions like a hand, voice, gaze, body pose, touch, head motion, and so on. But it is impossible to generate voice commands who cannot speak (dumb). Then, it is so difficult to move from place to another using body interactions whose body are fully disabled. After that, head motions are another problem for paralyzed people who can only move their hands. Furthermore, many researchers have been presented wheelchairs where most of them used joysticks for controlling the wheelchair. But sometimes it is not possible to use a joystick for a physically disable peoples. So, the author’s goal is to design a system that provides multiple solutions for paralyzed, dumb, and elderly people who cannot speak and walk. In addition, the author tries to design a robotic RW that can reduce costs.

From the above premises, the author has analyzed all above the research efforts and try to address the research challenges and designed a Robotic Wheelchair which goal is to develop a hand gesture-based controller with low computational costs.

III. System Design

We have included two sections in the design part, one designs the controller and the other designs the robot shown in Fig. 2.

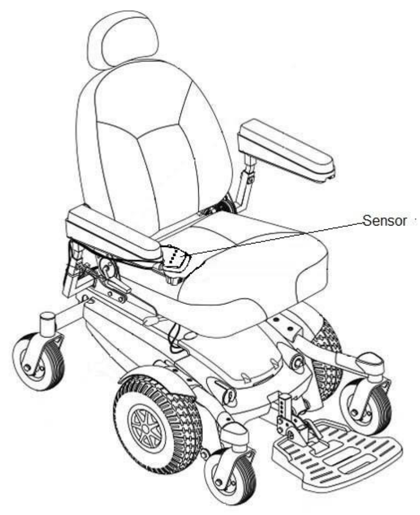

Fig. 2: The Robot Wheelchair

A. Block Diagram

In addition, we've added two sender and receiver units. Using a Bluetooth driver, both the sender and the receiver will connect to a wireless system. The transmitter has an infrared array device that records the motions. Bluetooth is used for communication purpose that receives and sends the data properly. It controls four engines using two L298N motor drivers, an storage device is used to store the data. Moreover, the authors have used a power supply for Arduino-Mega. Fig. 3 shows a Robot Wheelchair structure diagram.

B. Functional Block Diagram

Authors have used infrared sensor-based hand-gesture that receives the signal, encoded the data by the encoder. Then it transmits to the robot. After receiving the data Robot decodes the information. The decoded data is then translated into the corresponding operation shown in Fig. 4. In addition, Fig. 5 displays the device circuit diagram, where four infrared sensors and four Flex sensors are connected to the Arduino-Mega which are also connected to a motor driver.

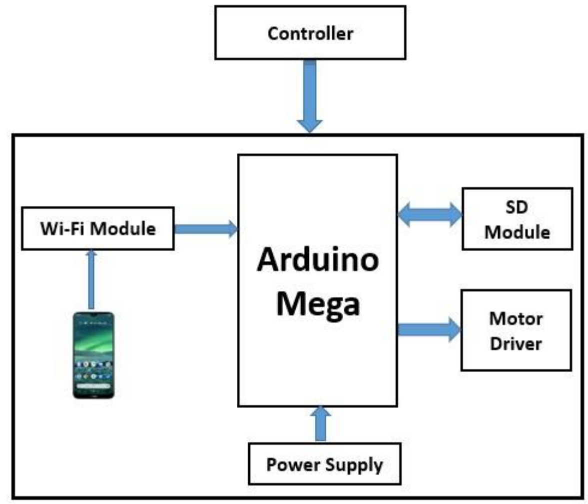

Fig. 3: The RW Structure Diagram

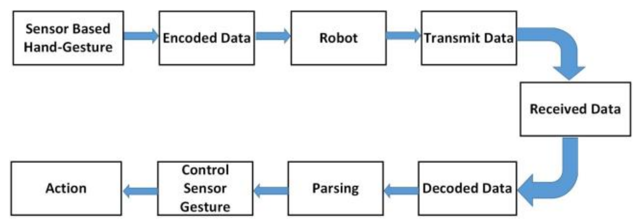

Fig. 4: Functional Block Structure Diagram

C. Training Scenarios

The four infrared sensors are shown in Fig. 6. Initially, the red color for no movements is all sensors. If the hand action (right-hand finger pressing with palm) is done by disabled people using a sensor wearing a glove suggested by pressing only the first sensor, the wheelchair moves left. Fig. 7 shows the wheelchair various movements for Right-hand fingers that are connected with the infrared sensors. If a disabled person wants to move forward, his/her little and ring fingers must be touched to his/her palm. Moreover, Fig. 7 shows all of the movements. On the contrary, Fig. 8 shows the various

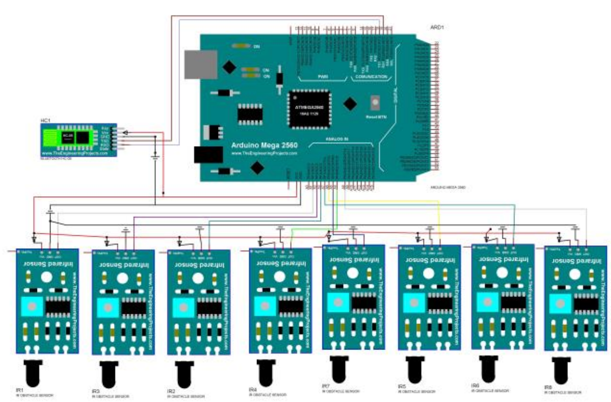

Fig. 5: The System Circuit Diagram

voices are generated for the Left-hand fingers which are also connected to the Flex sensors. Disable people can easily express their needs. If a disabled people want water, his/her little finger must be touched to his/her palm.

Furthermore, Fig. 9 likewise shows an exhibit of our system that can move (Left, Right, Forward and Backward) and produce voices (Hungry, Feed Me, Medicine, and Water) using infrared sensors with a hand motion. Table I shows the types of participants and no. of the sample that are taken by the system.

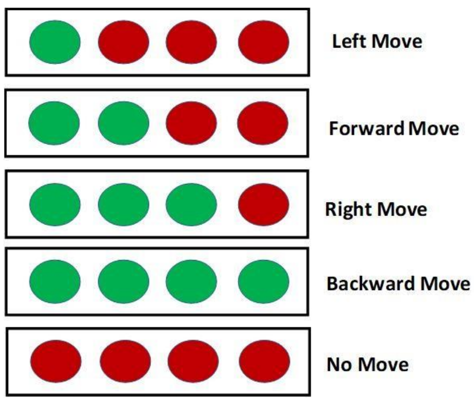

Fig. 6: Workout Scenarios

IV. Result and Discussion

A. Performance Measurement Parameters

For evaluating the performance of the proposed system, we have used two criteria: accuracy and response time.

The equation Eq.(1) can be used to calculate the accuracy:

$$\text{Accuracy} = \frac{TP}{N} * 100 \qquad (1)$$

Where, TP= Accurately Identified Values and N= Total no. of Values

The average time it takes for a device to respond to a service request is known as response time.

TABLE I: PARTICIPANTS (HAND GLOVES BASED & WHEELCHAIR HANDLE BASED)

Type of participants	Number of samples taken
Paralyzed (hand gloves)	10
Paralyzed (Wheelchair handle)	10
eldest (hand gloves)	10
eldest (Wheelchair handle)	10
Difficulty Walking (hand gloves)	10
Difficulty Walking (Wheelchair handle)	10
Using Wheelchair (hand gloves)	10
Using Wheelchair (Wheelchair handle)	10
Require assistance (hand gloves)	10
Require assistance (Wheelchair handle)	10
Total=10	100

B. Wheelchair movements (Wheelchair Handle and Hand Gloves)

1) Confusion Matrix for various movements: Table II and Table III The handle for the wheelchair and protective gloves for hands for different movements. Table II shows that it can identify 95% percent accurately for left move and no operation at 5%, 97% can be understood correctly for forwarding movement, but 3% identify as a left movement because often physically disabled people can not push two sensors at that same time.In addition, 85% can be correctly classified for the right movement, but 15% identify it as a forward movement since it is very complicated for a disabled person to push 3 sensors with 3 fingers at that same time and it can effectively detect 96% for backward movement but no move for 4%. It has no incorrect identity, since pressing 4 sensors with 4 fingers at a time is relatively simple.

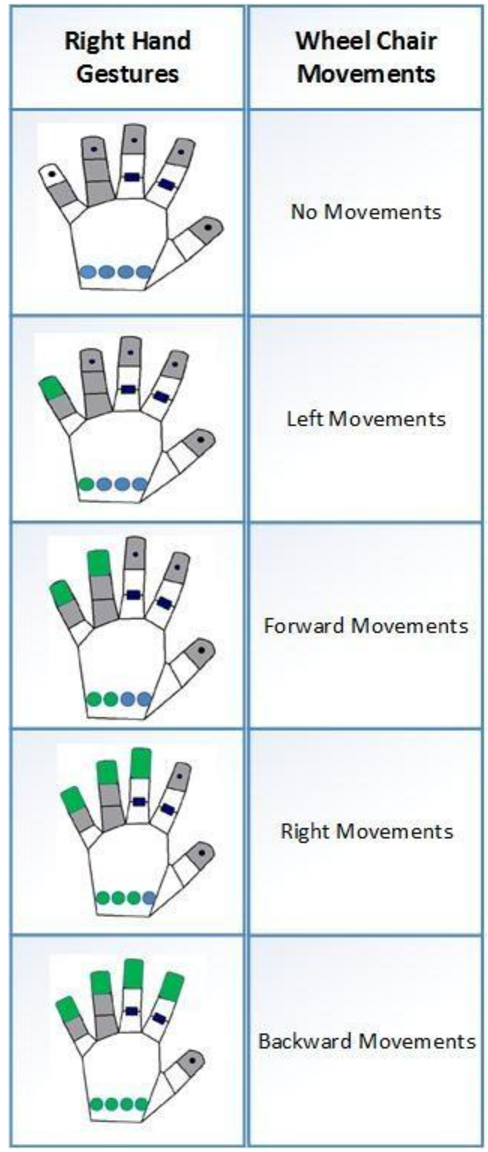

Fig. 7: Sensors Response and Wheel Chair Movements

On the contrary, Table III indicates that it can identify 93% accurately for the left move and no operation for 7%, 95% can be correctly identified for forwarding movement, but 5% identify as a left movement since many people with disabilities can not touch two sensors with two fingers at that same time. In addition, it can accurately identify 83% for the right

Fig. 8: Sensors Response with Different Voices

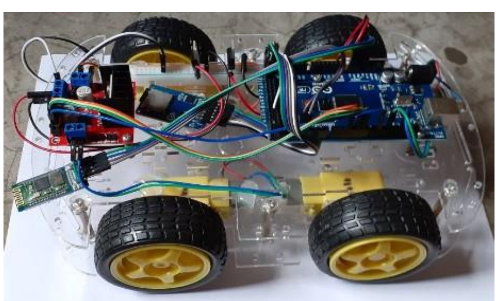

Fig. 9: The Systems Prototype

move but is relatively lower than a forward movement that recognized 17% as a wrong movement rather than the Right movement. Moreover, 93% Backward movement is correctly identified by the system but unfortunately for 7% system can not recognize anything because it is often extremely challenging to touch four sensors at that same time using fingers to people with disabilities.

From the above observation it is seen that the controller based on the wheelchair handle is much easier to manage opposed to the controller based on the hand-gesture.

TABLE II: CONFUSION MATRIX (WHEEL CHAIR HANDLE)

	Left	Forward	Right	Backward	Stop	No Action
Left	95		-	-	-	5
Forward	3	97	-	-	-	-
Right	-	15	85	-	-	-
Backward	-	-	-	96	-	4
Stop	-	-	-	-	100	-

TABLE III: CONFUSION MATRIX (HAND GLOVES)

	Left	Forward	Right	Backward	Stop	No Action
Left	93		-	-	-	7
Forward	5	95	-	-	-	-
Right	-	17	83	-	-	-
Backward	-	-	-	93	-	7
Stop	-	-	-	-	100	-

2) Response time for various iterations: Table IV shows the response time for handle based Wheelchair. The authors have used 10 iterations for the system (Left, Right, Back, and Forward) respectively. For Left, Right, Back and Forward movement average response times are 0.66s, 0.54s, 0.68s, and 0.72 respectively. It is clearly shown that for forwarding movement normal respond time is the most elevated and the Right movement respond time is 0.54 which is the lowest among the movements.

Then again, Table V displays the hand-glove-based respond time. The authors also have used 10 iterations for the system (Left, Right, Back, and Forward) respectively. For Left, Right, Back and Forward movement average response times are 0.61s, 0.50s, 0.63s, and 0.68 respectively. It is clearly shown that for forwarding movement normal reaction time is the most elevated and the Right movement response time is 0.54s which is the lowest among the movements. But hand glove based sensors performance better than Wheelchair handle based sensors.

TABLE IV: RW MOVEMENT RESPONSE TIME (WHEEL CHAIR HANDLE)

Iteration	Left(s)	Right(s)	Backward(s)	Forward(s)
1	0.63	0.84	0.62	0.54
2	1.53	0.45	1.06	0.32
3	0.76	0.35	0.83	0.65
4	0.56	0.54	0.93	0.96
5	0.96	1.24	0.63	0.97
6	0.42	0.36	0.56	0.58
7	0.33	0.47	1.03	0.36
8	0.37	0.75	0.52	0.64
9	0.80	0.54	0.45	1.01
10	0.67	0.35	0.59	1.61
Average	0.66	0.54	0.68	0.72

3) System accuracy and delay time for various movements: Table VI and Table VIII display the accuracy of the method and the delay time(s) for various moves. The wheelchair

TABLE V: RW MOVEMENT RESPONSE TIME (HAND GLOVES)

Iteration	Left(s)	Right(s)	Backward(s)	Forward(s)
1	0.65	0.74	0.56	0.44
2	1.47	0.49	1.04	0.35
3	0.72	0.34	0.76	0.67
4	0.48	0.45	0.82	0.80
5	0.87	1.26	0.64	0.96
6	0.44	0.27	0.45	0.46
7	0.34	0.47	1.06	0.34
8	0.25	0.65	0.54	0.66
9	0.75	0.57	0.46	1.04
10	0.67	0.35	0.44	1.55
Average	0.61	0.50	0.63	0.68

handle regulator's average precision is 94.6% which is significantly higher than the overall accuracy based on hand-gesture (92.8%). In addition, average delay time (642ms), it is so much better than the handle-based controller for hand-gesture-based controllers.

TABLE VI: SYSTEM ACCURACY (%) AND TIME DELAY(MS) (WHEEL CHAIR HANDLE

Movement	Accuracy(%)	Delay time(ms)
Left	95	660.5
Forward	97	540.6
Right	85	680.3
Backward	96	660.1
Stop	100	670.6
Average	94.6	642.2

TABLE VII: SYSTEM ACCURACY(%) AND TIME DELAY(MS) (HAND GLOVES)

Movement	Accuracy(%)	Delay time(ms)
Left	93	680.4
Forward	95	550.2
Right	83	690.1
Backward	93	680.5
Stop	100	670.3
Average	92.8	654.5

C. Various voices (Wheelchair Handle and Hand Gloves)

TABLE VIII: PARTICIPANTS (HAND GLOVES BASED & WHEELCHAIR HANDLE BASED)

Type of participants	Number of samples taken
Dumb (Hand gloves)	10
Dumb (Wheelchair handle)	10
Autism (Hand gloves)	10
Autism (Wheelchair handle)	10
Oldest (Hand gloves)	10
Oldest (Wheelchair handle)	10
Difficulty of speaking (Hand gloves)	10
Difficulty of speaking (Wheelchair handle)	10
Hearing impairments (Hand gloves)	10
Hearing impairments (Wheelchair handle)	10
Total=10	100

1) Confusion matrix for various voices: Table IX and Table X displays the confusion matrix for various voices (Hungry, Feed Me, Food , Water, and No Action) based on the wheelchair handle and the hand gloves. Table IX indicates that for Hungry, 98% and no 2% movement can be correctly identified. For Feed me voice, 95% can be identified accurately but 2% identify as Hungry because often people with physical disabilities could not touch two sensors at that same time. In addition, it can appropriately recognise 89% for the medicine speech, but 4% identify a speech as a feed me. Since it is rarely difficult for a disabled person to touch 3 sensors with 3 fingers. At that same time it can be accurately defined for water voice 90% but no response for 10%. It has no incorrect identity, since pressing 4 sensors with 4 fingers at that same time is relatively simple.

On the other hand, Table X demonstrates that Hungry can identify 95% accurately and no 5% operation. For Feed me voice it can identify 93% properly but 4% identify as Hungry since most people with disabilities could n't touch two sensors with two fingers at that same time. In addition, it can accurately identify 86% for the medicine speech but it's substantially slower than Feed me a speech that remembered 10% as Feed me and it can correctly classify 91% for water speech activity but no 9% action since it is often really hard to touch four sensors at that same time using disabled people's fingertips. From the above evaluation it is clearly seen that how the controller based on the wheelchair handle is much easier to manipulate opposed with the controller based on the hand-gesture.

TABLE IX: CONFUSION MATRIX FOR THE VARIOUS VOICE (BASED ON WHEEL CHAIR HANDLE)

	Hungry	Feed Me	Medicine	Water	No Action
Hungry	98	-	-	-	2
Feed Me	2	95	-	-	3
Medicine	-	6	89	-	5
Water	-	-	-	90	10

TABLE X: CONFUSION MATRIX FOR THE VARIOUS VOICE (BASED ON HAND GLOVES)

	Hungry	Feed Me	Medicine	Water	No Action
Hungry	95	-	-	-	5
Feed Me	4	93	-	-	3
Medicine	-	10	86	-	4
Water	-	-	-	91	9

TABLE XI: RW VOICE RESPONSE TIME (BASED ON WHEEL CHAIR HANDLE)

Iteration	Hungry	Medicine	Feed Me	Water
1	1.8	2.0	1.9	2.0
2	2.7	1.4	1.6	1.9
3	1.7	1.5	1.6	1.9
4	1.8	1.8	1.8	1.6
5	1.3	1.6	1.4	1.8
6	1.6	1.6	1.9	1.8
7	1.4	1.9	2.0	1.7
8	1.8	1.4	1.7	1.9
9	1.5	1.6	2.2	1.8
10	2.8	1.3	1.2	1.9
Average	1.84	1.61	1.73	1.83

TABLE XII: RW VOICE RESPONSE TIME (BASED ON HAND GLOVES)

Iteration	Hungry	Medicine	Feed Me	Water
1	1.6	1.8	1.7	1.7
2	2.0	1.1	1.4	1.5
3	1.5	1.3	1.3	1.6
4	1.5	1.6	1.5	1.4
5	1.0	1.4	1.3	1.7
6	1.5	1.5	1.5	1.6
7	1.3	1.5	1.7	1.5
8	1.3	1.0	1.4	1.5
9	1.4	1.3	2.0	1.4
10	2.4	1.0	1.0	1.6
Average	1.42	1.35	1.48	1.55

TABLE XIII: SPECIFIC VOICE SYSTEM ACCURACY (WHEEL CHAIR HANDLE BASED)

Movement	Accuracy(%)	Delay time(ms)
Hungry	98	1840
Feed Me	95	1780
Medicine	89	1650
Water	90	1690
Average	93	1740

2) Response time for various voices: The wheelchair handle and hand gloves dependent on response time (seconds) are appeared in Table XI and Table XII for different voices (Hungry, Feed Me, Medicine and Water) using various iterations. Table XI and Table XII displays the response time (seconds) for various voices (Hungry, Feed Me, Medication and Water) based on wheelchair handles and hand gloves, using different iterations. Using 10 iterations, for wheelchair- based Hungry controller behavior, the average respond time is 1.84s, for Medicine actions (1.61), which seems to be the maximum average response time and the response time is smaller than for others. Then again, the normal hand-held regulator response time is more modest than the wheelchair-

TABLE XIV: SPECIFIC VOICE SYSTEM ACCURACY (HAND-GLOVES BASED)

Movement	Accuracy(%)	Delay time(ms)
Hungry	95	1750
Feed Me	93	1710
Medicine	86	1610
Water	91	1670
Average	91.25	1685

TABLE XV: FAILURE RATE

System	Moves		Voice	
	Wheelchair Handle Based (%)	Hand Glove Based (%)	Wheelchair Handle Based (%)	Hand Glove Based (%)
Proposed System	6.75	9	7	8.75

TABLE XVI: COMPARISON TABLE

System	Moves		Voice	
	Acc.(%)	Delay (ms)	Acc.(%)	Delay (ms)
Proposed System	93.7	648	92.12	1712.5
System 1 [25]	88	852.5	N/A	N/A

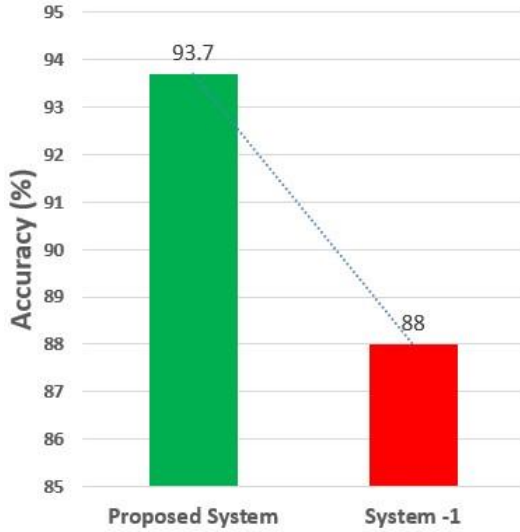

Fig. 10: Accuracy Comparisons

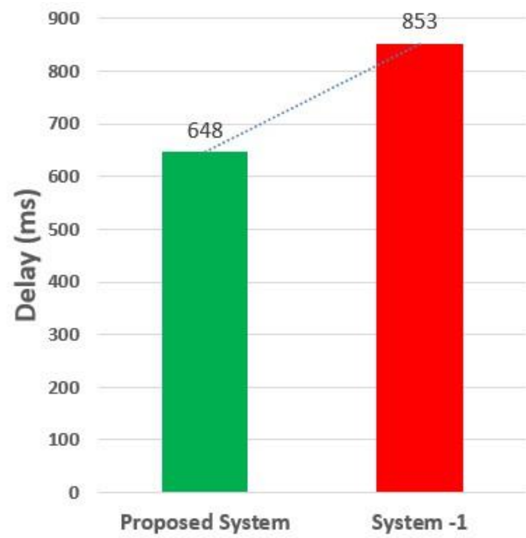

Fig. 11: Comparisons on Delay (ms)

based handle regulator. where the average response time for Hungry actions is 1.42 which is the maximum and the average response time for Medication activity is 1.35s which is the lowest average response time.

3) System accuracy and delay time for various voices: Table XIII and Table XIV display the accuracy and time(s) of the method for various voices (Hungry, Feed Me, Food , and Water). The average accuracy of the wheelchair handle controller is 93% which is significantly higher than the overall accuracy based on hand-gesture (91.25%). In comparison, average delay time (1740ms) for the hand gesture-based controller is so much greater than the handle-based controller (1685ms). In addition, the Table XV indicates the failure rate of the suggested method.

Fig. 10 and Fig. 11 present the results of our system's contrast with the System-1 [25] developed using gyroscope sensor.

Fig. 10 and 11 present the outcomes of our framework's

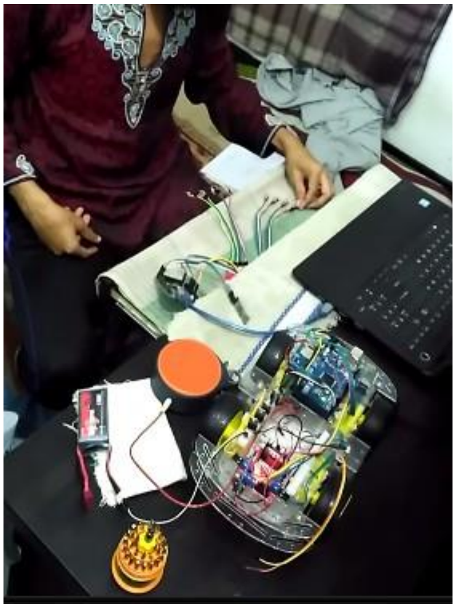

Fig. 12: Hardware Configuration and RW Fine-Tuning

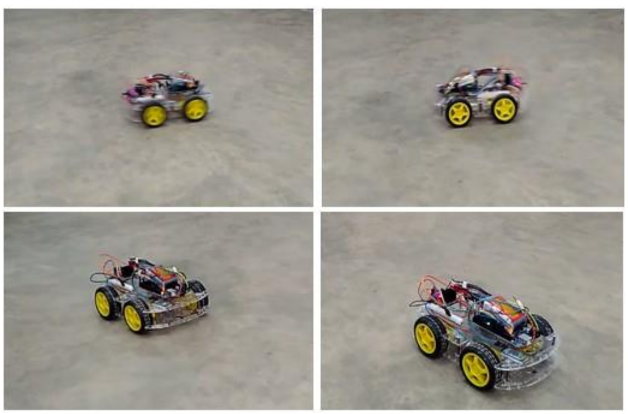

Fig. 13: Example Experimental snapshot of the developed model for multiple directions

differentiation with gyroscope sensor based System-1 [25]. Only for going in opposite directions were both systems carried out. Moreover, Table XVI shows both moves and voice comparison with respect to System-1. In addition, the experimental setup was shown by the authors in Fig. 12. In addition, in Fig. 13, the authors also demonstrated screenshot examples for various directions of the suggested model.

V. CONCLUSION

This study is really useful for those disabled, dumb and physically disabled people who have difficulty walking or communicating. It is an advanced RW which can allow people with disabilities and the elderly to walk and communicate their essential necessities. Also, for them this study will change their lives. The device gave is very valuable and simple to utilize. It tends to be really inexpensive and will reassure consumers. We've employed a small range of movements dependent on sensors. The proposed device could be enhanced in the future and can be operated using some kind of sensor-based gestures. In addition, the device can be enhanced and will be regulated utilizing AI or image processing technology based hand gestures. In addition, we 'd include some sensor that can track the patient's health status The system can alert the family member or the doctor through SMS or e-mail in case of any emergency situation. We would also like to incorporate GPS into the device so that other individuals can easily locate it when the patient has an emergency problem.

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