Original Article

Comparative Analysis on EEG Controlled Wheelchair using Raspberry Pi and ATMEGA-328 Microcontroller

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Abstract

Aim: The aim of this research work is to analyze the accuracy of the ATMEGA-328 Microcontroller, used in Electroencephalogram(EEG) controlled wheelchairs, and to compare the accuracy rate between ATMEGA-328 and Raspberry Pi microcontroller.
Materials and Methods: Data collection containing innovative wheelchair control movement output from the hardware designed was used in this research.samples were considered as (N=20) for ATMEGA-328 microcontroller , and (N=20) for Raspberry Pi microcontroller in accordance to total sample size calculated using clinical.com by keeping the alpha error threshold by 0.05, enrollment ratio as 0:1,95% confidence interval , power at 80%.
Result: Comparison of accuracy rate is done by independent sample test using IBM-SPSS software.There is a statistical indifference between the output obtained from ATMEGA-328 (65.4%) showed higher results in comparison to Raspberry Pi (58.4%) with (p=0.080;p>0.05).
Conclusion: EPOC headset appears to give better sensitivity than Neurosky mindwave portable headset in processing the EEG signals in an EEG controlled wheelchair.

Keywords: Innovative Wheelchair Control, Raspberry Pi microcontroller,ATMEGA-328 Microcontroller, Electroencephalogram(EEG), BCI, Accuracy, Artificial Intelligence.

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INTRODUCTION

The ability to move around influences a person's perception of importance and self assurance(Campbell and Shah 2016).People lose their ability to move outmoded wheelchairs due to neural disorders, such as Amyotrophic lateral sclerosis (ALS) and Parkinson's disease which resists their ability to move by paralyzing the muscles and by malfunctioning the neural networks in our body (nerves) which play a prime role in movement of an individual (Wickramasinghe and Bodendorf 2019). This study explores a revolutionary method for controlling an innovative wheelchair control using the microcontroller ATMEGA-328 to provide movement to the immovable individual (Munifah, Wiendartun, and Aminudin 2019). The Electroencephalogram(EEG) is a technique for recording the brain's bioelectric activity using electrodes placed on the scalp (Tamura and Chen 2017). This method is highly effective as it can be coupled with a control system by using various algorithms to be implemented in various medical diagnostic devices which also help in assistance such as EEG controlled wheelchairs (Zgallai 2020).Various control methods have been reported, such as breathing pressure causing the wheelchair to move (Mahle and Ward 2018), and another method proposed is uses tracking of eye movement, detection of blinks, and detection of eye gaze tracker, which tracks the eyes and causes the wheelchair to move in response to its motion (Vicente et al. 2019). In such devices it is not necessary to use a coupling medium to extract signals (Chaidaroglou et al. 2021).The user's cognitive skills collaborate with his/her head movement tracking to pick the desired migration command(Klugman et al. 2014). A headset is used to trail the brain wave signals for the movement of the wheelchair (Madona, Mujiono, and Wijaya 2019).

Around 143 articles were referred from Google Scholar and 94 articles from ScienceDirect which explained in detail about the updated microcontroller models and developed neural networks like ATMEGA328 and deep learning and machine learning algorithms like Random Forest Network, autoregressive neural networks in various experiments in order to evaluate Electroencephalogram (EEG) signals for wheelchair movement or to record and process them more accurately. This paper focuses on obtaining a better accuracy rate than previous studies regarding the movement of innovative wheelchair control determining the mental commands (Fereidouni et al. 2020) has proposed that leap motion sensors can be used to detect the hand gestures with the help of the embedded cameras to pass reliable commands to the wheelchair's processing unit, this method provides more flexibility to the innovative wheelchair control. It has resulted in reduced delay and detection errors, independence from internet connection, high resolution and less movement constraints (Nataraj et al. 2020)**.** This study proposes a cross-correlation method to obtain the coefficients in the frequency domain from consecutive frame samples to process the output to the control system using a machine learning algorithm for the movement of the wheelchair. The results indicated that the μ (*r*) feature set based on cross-correlation signals had the best performance with a recognition rate of 55%.another paper proposed by (Lahane et al. 2018) uses Body-Computer Interface (BCI) as an innovative approach to control the movement of the wheelchair for the disabled and paralyzed without any assistance.Our team has extensive knowledge and research experience that has translate into high quality publications(Bhansali et al. 2021; Jayanth et al. 2021; Sudhakar, Ravel, and Perumal 2021; Sathiyamoorthi et al. 2021; Deepanraj et al. 2021; Raju et al. 2021; Arun Prakash et al. 2020; Kamath et al. 2020; Shanmugam et al. 2021; Rajasekaran et al. 2020; Adhinarayanan et al. 2020; Rajesh et al. 2020; Aurtherson et al. 2021)

Unaccomplished accuracy rate of Electroencephalogram (EEG) controlled wheelchair movements which makes it unreliable for use by the disabled is the major key point that motivated the work on this project to accomplish the nearest accuracy rate of EEG controlled wheelchair movement for the disabled and paralyzed. The authors are expertized in the field of electronics and communication and were able to conduct studies in comparison between ATMEGA-328 microcontroller and Raspberry Pi microcontroller in the biomedical aspect.The main aim is to attain maximum accuracy of the EEG controlled wheelchair movement to make it reliable for the disabled and paralyzed individuals.

MATERIALS AND METHODS

This research work was carried out at the Electronics laboratory, Saveetha School of Engineering, Chennai. The sample size calculation was done using previous study results using clinical.com by keeping the alpha error threshold at 0.05, enrollment ratio as 0:1,95% confidence interval , and power at 80%. Group 1 was the output data of the ATMEGA -328 microcontroller (N= 20 study group) and group 2 was the output data of the Raspberry Pi microcontroller (N= 20 control group). The total sample size was 40. The wheelchair output used in our study were from two datasets, one is from study report using Raspberry Pi Microcontroller ,called dataset 1,and the other one is real time output from wheelchair designed with ATMEGA-328 microcontroller called dataset 2(Al-Haddad et al. 2012).

The ATMEGA328P-PU is a low-power CMOS 8-bit microcontroller based on the AVR enhanced RISC architecture. By executing powerful instructions in a single clock cycle, the ATmega328P-PU achieves throughputs approaching 1 MIPS per MHz allowing the system designer to optimize power consumption versus processing speed.The AVR core combines a rich instruction set with 32 general purpose working registers. All the 32 registers are directly connected to the Arithmetic Logic Unit (ALU),allowing two independent registers to be accessed in one single instruction executed in one clock cycle. The resulting architecture is more code efficient while achieving throughputs up to ten times faster than conventional CISC microcontrollers.The ATmega328P-PU AVR is supported with a full suite of program and system development tools including: C Compilers, Macro Assemblers, Program Debugger/Simulators, In-Circuit Emulators, and Evaluation kits.

Brain control is considered as the primary control of the wheelchair using Artificial Intelligence. It involves the EEG data acquisition using a Mindwave mobile headset. A bluetooth module HC-05 is the platform which is used to receive and transmit the Electroencephalogram(EEG) data transmitted from the wireless headset. There are two DC motors attached to the wheels of the wheelchair which serves as the wheel control system . one DC motor is responsible for the control of forward and backward movement. Another DC motor is responsible for the control of right and left movement.

The experiment setup is arranged and 5 users/individuals are involved. The EEG headset is placed on the forehead of the user and their brain signals are detected and processed using BCI which uses neural networks such as Random forest neural network which is a deep learning and machine learning algorithm are the concepts in Artificial Intelligence which reads and processes the Electroencephalogram (EEG) signals into a machine's microcontroller to provide the necessary movement as output. The deep learning and machine learning algorithms are implemented in the laptop which serves as the interface between the brain of the user and the wheel control system using the software Arduino IDE. The predicted output is obtained and its sensitivity and accuracy is compared between both the EEG headsets.

STATISTICAL ANALYSIS

The statistical software used is IBM SPSS V 28.0.0.0 (190) software.There is only one Independent variable and there is no dependent variable present. Analysis for the accuracy rate was performed by an independent sample T test.As the variables are independent of each other an independent sample T-test was carried out to find the mean values of accuracy between two groups, and performance comparison between the two groups is performed. The independent variable present is accuracy (Al-Haddad et al. 2012).

RESULTS

In this research work of obtaining greater sensitivity and higher accuracy rate of EEG headsets used in EEG controlled wheelchair, both the models appear to produce same variable results with accuracy ranging from 88.3% to 86.9%.It is observed from Fig. 1.The mean accuracy of ATMEGA-328 microcontroller is better when compared to Raspberry Pi microcontroller.

The wheelchair using the ATMEGA-328 microcontroller has the highest accuracy (65.4%),in comparison to the wheelchair using a Raspberry Pi microcontroller of accuracy (58.4%). The descriptive analysis in Table 1 shows the output of wheelchair experiment subjected to 5 individuals and shows accuracy of ATMEGA-328 microcontroller using wheelchair and Table 2 shows the output of wheelchair subjected to 5 individuals and shows the accuracy of Raspberry Pi microcontroller using wheelchair. Table 3 shows the comparison of all the samples collected using both the methods. Table 4 shows the Comparison of mean accuracy using ATMEGA-328 microcontroller and Raspberry Pi microcontroller using wheelchair. There appears to be a statistically insignificant difference (P=0.080:P>0.05) in ATMEGA-328 microcontroller and Raspberry Pi microcontroller methods using independent sample T-test as shown in Table 5

DISCUSSION

There appears to be a statistically insignificant difference (P=0.080: P>0.05) in the ATMEGA-328 microcontroller and Raspberry Pi microcontroller methods using independent sample T-tests as shown. In this research work of obtaining higher sensitivity of EEG controlled wheelchair using ATMEGA-328 microcontroller had highest accuracy (65.4%) in comparison to EEG controlled wheelchair using Raspberry Pi microcontroller (58.4%).There appears to be slight increase in the significant difference but not statistically significant.

A recent study conducted by (Tiwari et al. 2020) proposed that electroencephalography can be used to maneuver a miniature wheelchair using a sensitive Brain-Computer Interface along with a microcontroller to provide higher accuracy. Another study by (Al-Haddad et al. 2012) states that wheelchairs can be controlled using eye gaze and eye blinks based on point bug algorithms.A paper proposed by (Madona, Mujiono, and Wijaya 2019) states that Raspberry Pi microcontroller can be used to control the direction of the wheelchair based on the brain signals obtained from EEG headset.

Some of the studies have varied the microcontrollers, EEG headset and used different deep learning and machine learning neural networks are the concepts of Artificial Intelligence to obtain the accuracy and produce a reliable product which when proposed will clear the safety tests and get approved by Food and Drug Administration (FDA) and be available as an product in the market to help the disabled and paralyzed to be independent.

The factors affecting the study might be the inability of the EEG headset to sense the EEG signals which leads to undesired or inaccurate movement of the wheelchair which is irrelevant to the input .The aspect ratio of the accuracy of microcontroller and sensitivity of EEG headset are the important parameters of this research work.

Although it is demonstrated to provide greater accuracy than the other proposed methods for the movement of EEG controlled wheelchairs,it is limited from obtaining the 100% accuracy which is necessary to introduce this research work as a product in the market (Al-Haddad et al. 2012).

In the near future, better EEG headset will be researched and applied to provide higher sensitivity and by using further advanced neural networks and well trained learning algorithm for deep learning and machine learning which can recognize and identify the pattern which helps in attaining a much higher efficiency and accuracy of the movement of EEG controlled wheelchair to be utilized by disabled and paralyzed individuals. EEG controlled wheelchairs can be used in the healthcare sector and how they can help with more accurate and efficient movement of the disabled and paralyzed individuals without any assistance by detecting their brain signals .

CONCLUSION

In this study of attaining higher accuracy in an EEG controlled wheelchair, The ATMEGA-328 microcontroller (65.4%) controlled wheelchair appeared to give better results when compared to Raspberry Pi microcontroller (58.4%).

DECLARATION

Conflict of interest

No conflict of interests in this manuscript.

Authors contribution

Author KP was involved in conceptualization, data collection, data analysis and manuscript writing. Author SJ was involved in guidance and critical review of the manuscript.

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TABLES AND FIGURES

Table 1. Test Result For Mental Command Detected By Raspberry Pi microcontroller. It consists of the output sensitivity obtained from the EEG controlled wheelchair using Raspberry Pi microcontroller to process the EEG signals from the brain .The accuracy was calculated from the output obtained from 5 users at 5 different time intervals based on the accuracy of the movement of the wheelchair.

Command/User	**1**	**2**	**3**	**4**	**5**	**Total**
Forward	3/5	3/5	4/5	3/5	1/5	15/25
Backward	3/5	3/5	4/5	3/5	3/5	19/25
Left	2/5	2/5	3/5	4/5	3/5	14/25
Right	4/5	1/5	2/5	4/5	3/5	14/25
Total	60/100	45/100	65/100	70/100	50/100	Total Accuracy:58 /100

Table 2. Test results For Mental Command Detected By ATMEGA -328 microcontroller. It consists of the output sensitivity obtained from the EEG controlled wheelchair using ATMEGA-328 microcontroller to process the EEG signals from the brain .The accuracy was calculated from the output obtained from 5 users at 5 different time intervals based on the accuracy of the movement of the wheelchair.

Command/User	1	2	3	4	5	Total

Forward	4/5	3/5	5/5	2/5	1/5	15/25
Backward	3/5	2/5	4/5	4/5	2/5	16/25
Left	4/5	2/5	3/5	3/5	5/5	17/25
Right	4/5	4/5	2/5	4/5	4/5	18/25
Total	75/100	55/100	70/100	65/100	60/100	Total Accuracy: 65/100

Table 3. EEG Controlled Wheelchair Movement Dataset Processing The Eeg Signals Using Raspberry Pi Microcontroller And Atmega-328 Microcontroller

Samples	**Raspberry-Pi Microcontroller (Accuracy %)**	**Atmega-328 Microcontroller (Accuracy %)**
1	60.13	75.45
2	60.23	75.99
3	60.36	75.27
4	60.09	75.91
5	45.79	55.03
6	45.39	55.56
7	45.77	55.28

8	45.07	55.74
9	65.23	70.03
10	65.02	70.36
11	65.05	70.04
12	65.08	70.47
13	70.87	65.98
14	70.47	65.09
15	70.98	65.00
16	70.86	65.84
17	50.88	60.37
18	50.03	60.58
19	50.00	60.93
20	50.93	60.33

Table 4. Comparison Of Mean Accuracy using Raspberry Pi microcontroller and ATMEGA-328 microcontroller

GROUP STATISTICS

Parameter	Group	N	Mean	Std.deviation	Std.Error mean
Accuracy	Raspberry-Pi Microcontroller	20	58.4115	9.52972	2.13091
	Atmega-328 Microcontroller	20	65.4625	7.28849	1.62976

Table 5. Independent Sample T-Test In Predicting The Accuracy Of Atmega-328 And Raspberry Pi Microcontroller. There Appears To Be A Statistically Insignificant Difference (P>0.05)In Both The Methods.

INDEPENDENT SAMPLE TESTS

		Leven's test for equality of variance		T-test for equality of variance					95% of confidence interval of difference	
		f	sicg	t	df	Sig (2-tailed)	Mean diff	Std.error diff	lower	upper
Accuracy	Equal variances assumed	3.239	.080	-2.628	38	0.012	-7.05100	2.682	-12.481	-1.627
	Equal variances not assumed			-2.628	35.561	0.013	-7.05100	2.682	-12.481	-1.607

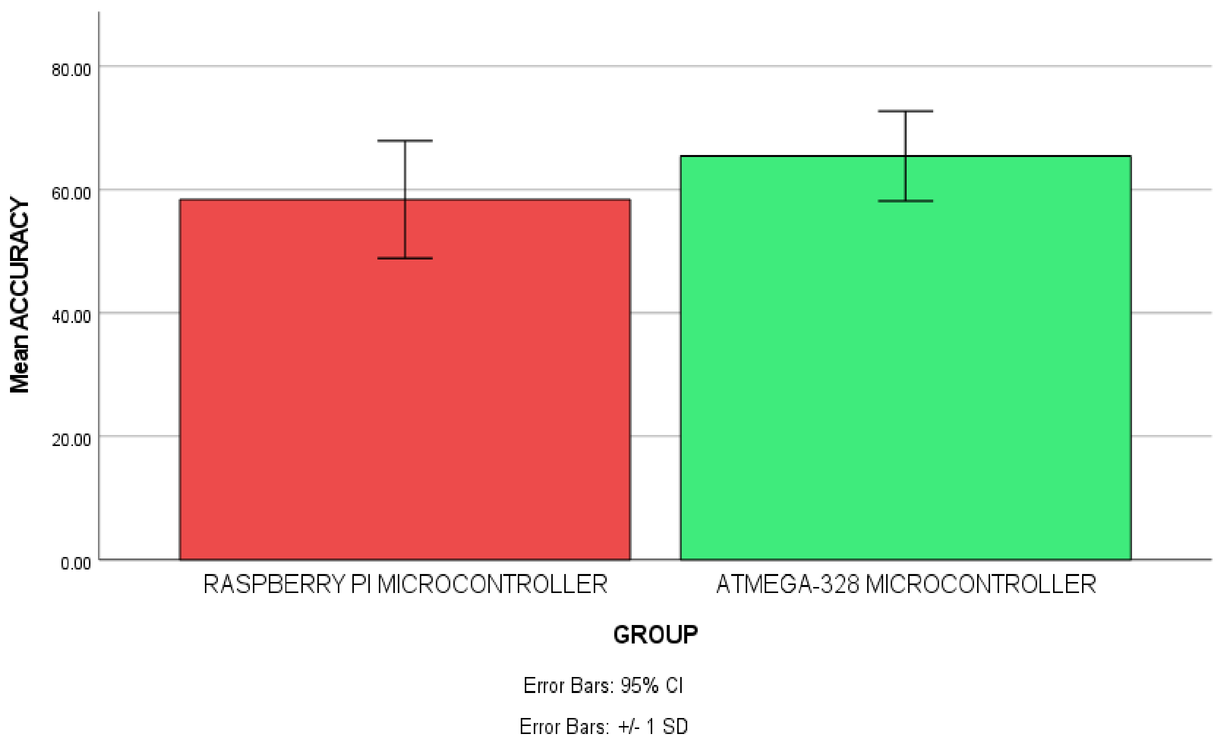

Fig. 1. Mean accuracy using ATMEGA-328 AND Raspberry Pi microcontroller.The Bar chart representing the comparison of mean accuracy of Raspberry Pi microcontroller and ATMEGA-328 microcontroller. The ATMEGA-328 microcontroller appears to produce the most consistent result in accuracy with minimal standard deviation when compared to theRaspberry Pi microcontroller. X axis:Raspberry Pi microcontroller Vs ATMEGA-328 microcontroller, Y Axis: mean accuracy of detection ± 1 SD.