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GLADIATOR (GLOVE FOR DEAF TRANSLATOR): WEARABLE FLEX SENSOR GLOVE FOR BREAKING COMMUNICATION BARRIERS THROUGH SIGN LANGUAGE TRANSLATION

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ABSTRACT

Communication barriers experienced by deaf and speech-impaired individuals in Indonesia continue to limit social, educational, and employment opportunities. Existing sign language translation technologies are often expensive and complex, reducing their accessibility. This study introduces GLADIATOR (Glove for Deaf Translator), an Arduino-based smart glove that uses flex sensors to translate sign language gestures into text or speech in real time. The system was designed to be affordable, simple, and easily replicated for wider community use. Performance evaluation was conducted by testing each letter and predefined word through 30 repeated trials. The results achieved 90.7% recognition accuracy, demonstrating the reliability of the proposed system in recognizing the tested gestures. GLADIATOR offers a low-cost and effective assistive technology that can help bridge communication gaps between deaf and hearing individuals while promoting more inclusive communication.

ABSTRAK

Hambatan komunikasi yang dialami oleh penyandang disabilitas rungu dan wicara di Indonesia terus membatasi peluang sosial, pendidikan, dan pekerjaan. Teknologi penerjemah bahasa isyarat yang ada saat ini sering kali mahal dan rumit, sehingga mengurangi aksesibilitasnya. Penelitian ini memperkenalkan GLADIATOR (Glove for Deaf Translator), sebuah sarung tangan pintar berbasis Arduino yang menggunakan sensor fleksibel untuk menerjemahkan gerakan bahasa isyarat menjadi teks atau ucapan secara waktu nyata (*real-time*). Sistem ini dirancang agar terjangkau, sederhana, dan mudah direplikasi untuk penggunaan oleh masyarakat luas. Evaluasi kinerja dilakukan dengan menguji setiap huruf dan kata yang telah ditentukan melalui 30 kali percobaan. Hasilnya menunjukkan tingkat akurasi pengenalan sebesar 90,7%, yang membuktikan keandalan sistem yang diusulkan dalam mengenali gerakan-gerakan yang diuji. GLADIATOR menawarkan teknologi bantu yang efektif dan berbiaya rendah, yang dapat membantu menjembatani kesenjangan komunikasi antara penyandang disabilitas rungu dan orang dengan pendengaran normal, sekaligus mendorong komunikasi yang lebih inklusif.

INTRODUCTION

The condition of deaf and mute people in Indonesia is marked by significant communication barriers that hinder their social, educational, and employment opportunities. The lack of understanding of sign language among the general public creates a communication gap, making it difficult for deaf and mute individuals to interact effectively with others. This isolation can lead to feelings of loneliness, depression, and exclusion, as well as difficulties in accessing education and employment opportunities (Khotimah et al., 2018) (Khan et al., 2021). Furthermore, the lack of sign language interpreters and the limited availability of sign language training programs contribute to this issue, making it challenging for deaf and mute individuals to participate fully in society.

Technological advancements have been developed to address these communication barriers, such as translator gloves that use dielectric elastomer sensors and machine learning to recognize hand gestures and translate them into speech (Antillon et al., 2022). These gloves facilitate communication between deaf and mute individuals and the general public, providing a more accessible solution. However, these solutions are often expensive and complicated for society to develop, making them inaccessible to many deaf and mute individuals. Additionally, the high cost of these solutions can be a significant barrier for many deaf and mute individuals who may not have the financial resources to access them.

In response to these challenges, the Gladiator (Glove for Deaf Translator) project using flex sensors proposes a simpler and more accessible innovation. This project aims to provide an easier and more replicable solution for deaf and mute individuals to communicate with others, bridging the communication gap and enhancing their overall quality of life.

METHOD

System Design Analysis

In the making procedure of the tool, first, a system blueprint is made to be designed later, producing a desired tool design system. This design aims to assemble a tool in the shape of an automatic control system from the sign language translator gloves using Arduino Nano as a microcontroller board. The hardware used in the design of the control system of this tool, namely:

a. Arduino Nano

The Arduino Nano is one of the variants of the popular Arduino microcontroller development board. Designed as a small and compact version of the Arduino, the Arduino Nano is similar in shape to a USB flash drive, with a smaller size than standard Arduino boards such as the Arduino Uno. Despite its small size, the Arduino Nano has similar capabilities to other Arduino models, such as the ability to program and control many variations of electronicprojects (Nano, 2018).

The Arduino Nano is commonly used in electronic projects and applications that range from prototype IoT (Internet of Things) devices, automatic control systems, and interactive learning tools to medical devices and others. The Arduino Nano can be programmed using the Arduino programming language based on the C/C++ language and can be connected to various sensors, actuators, and other devices through the available input or output pins.

The advantages of the Arduino Nano include its small and compact size. It is easy to use, even for beginners and has extensive support from the developer. This reason makes the Arduino Nano a popular choice for anyone looking to start an exploration into the world of electronics and microcontroller development.

b. DF Mini Player

The DF Mini Player is an audio player module used in electronics projects to play audio files in MP3 and WAV formats from microSD cards. The module is equipped with control buttons, making it easy for users to select songs, adjust volume, and control audio playback. Users can control audio playback through microcontrollers such as Arduino with a serial interface. The module has audio outputs that can be directly connected to speakers or amplifiers. Due to its small size, it can be easily integrated into various devices (Malarvizhi et al., 2024).

The DF Mini Player is perfect for projects that require audio playback on a small to medium scale, with advantages in ease of use, convenient control, and support for a wide range of electronic applications.

c. Speaker

Speakers are devices that convert electrical signals into sound waves that can be heard by humans. Researchers use a mini speaker for applications with low to medium power requirements. With a membrane diameter of about 2 inches, an impedance of 8 ohms, and a nominal power of 3 watts, this speaker has compact physical dimensions, making it suitable for use in portable devices or confined spaces (Smolenski, 1701).

Despite its small size, this mini speaker can produce a clear sound. However, due to its small size, it may be limited in its ability to produce deep bass. The 8-ohm impedance makes it easy to drive by an amplifier and provides stable sound output. The nominal power of 3 watts indicates the speaker's ability to handle electrical power without excessive damage or distortion.

2-inch 8-ohms 3-watt mini speakers are used in many applications, including portable speakers, vehicle audio devices, communication devices, and other consumer electronic devices. They are suitable for announcements, notifications, or entertainment speakers in small to medium-sized environments. These speakers are popular for audio purposes in confined spaces with satisfactory sound quality and compact size.

d. Zero PCB

Zero PCB, or Zero Insertion Force PCB, is a printed circuit board (PCB) equipped with a particular connector system that allows users to install and remove electronic components without soldering. By using a Zero PCB, users can easily replace or customize electronic components without the need to perform the time-consuming soldering process that requires specialized skills. It is very convenient in the early stages of electronic prototype development, where quick changes in design are often needed. Zero PCB provides high flexibility and reusability and can be a more economical choice in the long run due to its reusability (Copani et al., 2019).

Circuit Diagram

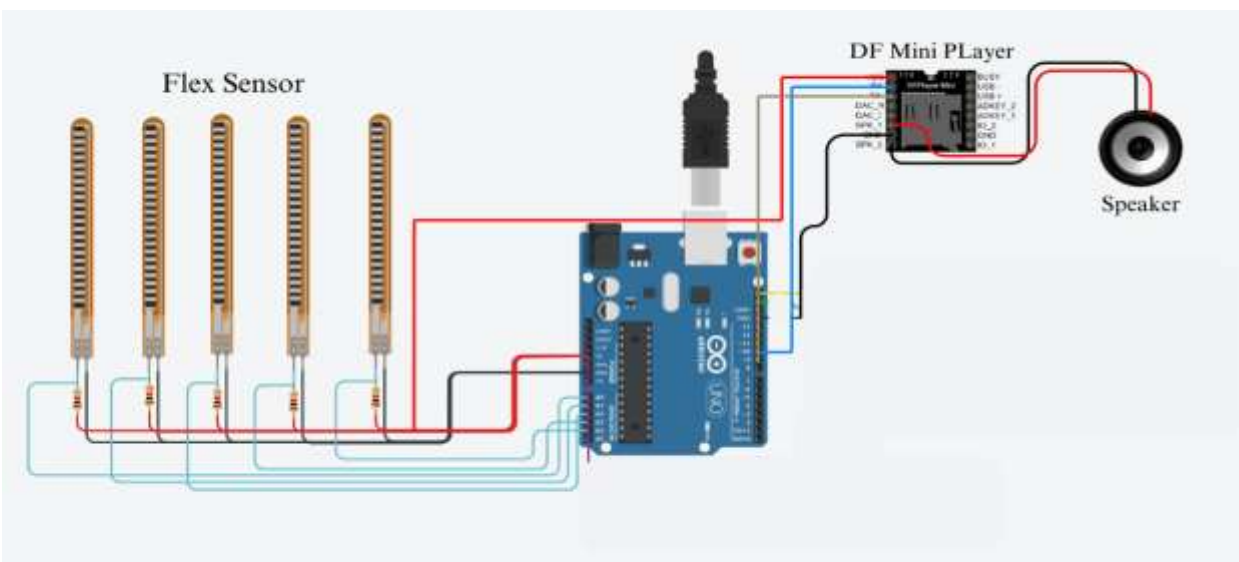

Figure 1 Circuit Diagram

The first step involves creating a working sensor system. As shown in Figure 1, the **sarung tangan** system consists Arduino Nano ATMEGA 328, flex sensors, 2500 Ω resistor, DF MiniPlayer, 2 Watt speaker, and zero PCB. Each flex sensor has 2 pins (P1 and P2). The P2 is connected to GND and the P1 is connected to the 2500 Ω resistor that has 2 terminal. The terminal 1 is connected to the 5V pin (Arduino Nano) and VCC (DF MiniPlayer). Next, the terminal 2 is connected to the analog pin (Arduino Nano). The DF MiniPlayer has a more complicated configuration compared to the flex sensors, it has 14 pins in total. The RX pin is connected to the digital 10 pin and the TX pin is connected to the digital 9 pin. The GND pin (DF MiniPlayer) is connected to GND pin (Arduino Nano). Additionally, the other two pins; SPK_1 pin and SPK_2 pin are connected to the speaker.
Experiment for Flex Sensor

Two experiments are done to calculate the readable binary for the flex sensor. The first test is done by using the voltage dividing schematic and the second test is done by using Arduino IDE application (serial monitor).

a. Readable Binary Calculation by Voltage Dividing Schematic

The maximum power of resistance (R) in the flex sensor is 0.5 watt. The maximum electricity current in the Arduino Nano is 3 mA based on the electric current using this formula:

$P = I^2 R$

P = Power (Watt)

I = Electricity Current (Ampere)

R = Electricity Resistance (Ω)

$I_{max} = \sqrt{\frac{P_{max}}{R_{min}}}$

$I_{max} = \sqrt{\frac{0.5\ Watt}{45\ k\Omega}}$

I_{max} = 0,003 A = 3 mA

To find the value of the resistance do not use the max value in real schematic, instead use 2 mA. The resistance in the flex sensor is 45 kΩ to 125 kΩ (Sanca et al., 2018). So, the minimum resistance of the flex sensor is 45 kΩ.

The formula shown below is used to find the value of the resistance:

$V = I \times R$

$V_{cc} = I \times (R + R_{flex\ min})$

$$R + R_{flex\,\mathrm{min}} = \frac{Vcc}{Is}$$

$$R = \frac{Vcc}{Is} - R_{flex\,\mathrm{min}}$$

$$R = \frac{5\ V}{2 \times 10^{-3}\ A} - 45 \times 10^{3}\Omega$$

$$R = 2499{,}955\ \Omega$$

Therefore, 2500 Ω resistor is used for the project.

Additionally, V_{out} and $\mathrm{V_{flex}}$ are needed to find the readable binary. The following formula is used to calculate V_{out} and $\mathrm{V_{flex}}$:

$$\mathrm{V_{out}} = \frac{\mathrm{R_{flex}}}{\mathrm{R1}} \times \mathrm{V_{R1}}$$

$$\mathrm{V_{flex}} = \frac{\mathrm{R_{flex}}}{\mathrm{R1} + \mathrm{R_{flex}}} \times \mathrm{V_{cc}}$$

Arduino Nano has a maximum ADC resolution value that is 1023 (10 byte) (Barrett, 2022):

$$\text{Readable Binary} = \frac{\mathrm{V_{flex}} \times 1023}{\mathrm{V_{cc}}}$$

After calculating the resistance and readable binary, the result is shown on table 1.

Table 1 Result of, R1, and readable binary.

R_{flex}	R1	V_{cc}	V out	RB	motion
25000	2000	5	4.63	947	Straight Thumb
45000	2000	5	4.79	979	Full Bent Thumb
32000	2000	5	4.71	963	Half-O Thumb
58170	2000	5	4.83	989	Half-E Thumb
26000	2000	5	4.64	950	Straight Index
55540	2000	5	4.83	987	Full Bent Index
54833	2000	5	4.82	987	Half-E Index
48000	2000	5	4.80	982	Half-C Index

49000	2000	5	4.80	983	Half-O Index
23200	2000	5	4.60	942	Straight Middle
60000	2000	5	4.84	990	Full Bent Middle
64000	2000	5	4.85	992	Half-E Middle
43000	2000	5	4.78	978	Half-C Middle
47000	2000	5	4.80	981	Half-O Middle
24200	2000	5	4.62	945	Straight Ring
62000	2000	5	4.84	991	Full Bent Ring
60000	2000	5	4.84	990	Half-E Ring
49000	2000	5	4.80	983	Half-C Ring
33890	2000	5	4.72	966	Half-O Ring
22900	2000	5	4.60	941	Straight Pinky
66000	2000	5	4.85	993	Full Bent Pinky
71000	2000	5	4.86	995	Half-E Pinky
41000	2000	5	4.77	975	Half-C Pinky
51000	2000	5	4.81	984	Half-O Pinky

The readable binary that is calculated from the formula is then compared the readable binary from the serial monitor in the Arduino program.

b. Readable Binary Calculation by Serial Monitor

In this method, the readable binary will be seen from the Arduino IDE programming software which will be displayed via the serial monitor and finger movements will be carried out straight, ¼ bent, ½, bent, and full bent. The results of the readable binary will be shown in the following table:

Table 2 Results from Serial Monitor

Straight Thumb	948-970
Full Bent Thumb	985-995
Half-O Thumb	975-988
Half-E Thumb	985-1000

Straight Index	935-970
Full Bent Index	988-995
Half-E Index	985-996
Half-C Index	954-973
Half-O Index	960-981
Straight Middle	935-958
Full Bent Middle	988-995
Half-E Middle	985-996
Half-C Middle	960-980
Half-O Middle	975-987
Straight Ring	953-950
Full Bent Ring	988-995
Half-E Ring	982-995
Half-C Ring	958-971
Half-O Ring	957-975
Straight Pinky	935-951
Full Bent Pinky	988-995
Half-E Pinky	985-1000
Half-C Pinky	957-965
Half-O Pinky	956-965

Dictionary of Program

The dictionary was created based on the results of measuring the voltage in each finger when moving sign language. then calculated according to the calculation in point to get a readable binary. The dictionary is formulated using equations that form a range of readable binary for each finger as table 2.

Table 3 Dictionary Table using Readable Binary

Input					**Output**
Thumb	**Index**	**Middle**	**Ring**	**Pinky**	
939<T<965	985<I<1001	985<M<1001	982<R<1001	985<P<1000	A
984<T<1001	934 < I <970	934<M<958	934<R<951	934<P<955	B
940<T<970	953 < I < 974	959 < M < 981	957<R<972	956 < P < 966	C
974<T<989	934<I<946	975 < M < 986	973<R<986	967 < P < 986	D
984<T < 1001	985<I<996	985<M<996	982<R<996	985<P<1000	E
984<T < 1001	985<I<1001	985<M<1001	982<R<996	934<P<955	I
939<T<960	934<I<970	985<M<1001	982<R<1001	985<P<1000	L

974 < T < 989	971 < I <986	974<I<988	970<R<986	968 < P < 985	O
984<T<1001	934<I<970	934<m<958	979<R<1001	979<P<1000	U
975<T<997	934<I<970	934<I<958	934<m<951	979<P<1000	W
974 < I < 1001	959 < I < 980	985<I<1001	985<R<1001	985<P<1000	X
939<T<965	980<I<1001	985<M<1001	975<R<1001	934<P<955	Y
974<T<989	973<I<986	934<M<958	934<R<951	934<P<955	OK
948<T<970	934<I<978	934<M<958	934<R<951	934<P<952	HIGH 5

RESULT AND DISCUSSION

Result of Accuracy Testing

In determining the number of samples used by Sugiyono, (2017:91) suggests that a reasonable sample size in research is between 30 to with 500. If the sample is divided into categories then the number of sample members in each minimum category 30.

Researchers evaluated the tool's accuracy by repeating input of each letter and word 30 times. They recorded the success of each output in Table 3.1 and calculate the percentage of accuracy. This meticulous testing provides quantitative insights into the tool's reliability and identifies areas for improvement.

Table 1 Result of Acuracy Testing

Output	Output													
	A	B	C	D	E	I	L	O	U	W	X	Y	OK	HIGH 5
1st	V	V	V	V	V	V	V	V	V	-	V	V	V	V
2nd	V	V	V	V	V	V	V	-	V	V	V	V	V	V
3rd	V	V	V	V	V	V	-	V	V	V	V	-	V	V
4th	V	V	V	V	-	V	V	V	V	V	-	V	V	V
5th	V	V	V	-	V	-	V	V	V	V	V	V	V	V
6th	V	V	V	V	-	V	V	-	V	V	V	V	V	V
7th	V	V	V	V	V	-	V	V	V	V	V	V	V	V
8th	V	V	-	V	V	V	V	V	V	-	-	V	V	V
9th	V	V	V	V	V	V	-	V	V	V	V	V	V	V
10th	V	V	V	V	V	V	V	-	V	V	V	V	V	V
11th	V	V	V	V	V	V	V	V	V	V	V	V	V	V
12th	V	V	V	V	-	V	V	-	V	V	V	V	-	V
13th	V	V	V	V	V	-	V	V	V	V	V	V	V	V
14th	V	-	V	V	V	V	V	V	-	V	V	V	V	V
15th	V	V	-	V	V	V	V	V	V	V	V	-	V	V
16th	V	V	V	V	V	V	V	-	V	V	V	V	V	V
17th	V	V	V	V	V	-	V	V	V	V	V	V	V	V

18th	V	V	V	V	V	V	V	V	V	V	V	V	V	V
19th	V	V	V	V	V	V	V	V	V	V	V	-	V	V
20th	V	V	V	V	V	V	V	-	V	V	V	V	V	V
21st	V	V	V	V	-	V	V	V	V	V	V	V	-	V
22nd	V	V	V	V	V	V	V	V	-	V	-	V	V	V
23rd	V	V	V	V	V	-	V	V	V	V	V	V	V	V
24th	V	V	V	V	V	V	V	V	V	V	-	V	V	V
25th	V	V	V	V	V	V	V	V	V	V	V	V	-	V
26th	V	V	V	V	V	V	V	V	V	V	V	V	V	V
27th	V	V	V	V	V	V	V	-	V	V	V	-	V	V
28th	V	V	V	V	-	V	V	V	-	V	V	V	V	V
29th	V	V	V	V	V	V	V	V	V	V	V	V	V	V
30th	v	v	V	V	V	V	V	V	V	V	V	V	V	V
Percentage (%)	100	97	93	97	83	83	93	77	90	93	87	87	90	100

Description: v (correct), - (incorrect)

After record and calculate the accuracy of the TOOL we can find the average of percentage by using the formula below:

$$\text{mean} = \frac{\text{Sum of accuracy percentage}}{\text{Number of data}}$$

$$\frac{100+97+93+97+83+83+93+77+90+93+87+87+90+100}{14} = 90.7$$

CONCLUSION

This study successfully developed GLADIATOR (Glove for Deaf Translator), a smart glove that utilizes an Arduino Nano and flexible sensors. The device is designed to translate sign language hand gestures into text or speech in real time. The system was developed as a simple, low-cost, and easily reproducible assistive device to improve communication accessibility for individuals with hearing or speech impairments.

Based on the experimental evaluation, which consisted of 30 trials for each predefined letter and word, the prototype demonstrated a high level of success in recognizing sign language gestures. The results indicate that the combination of flexible sensors and the Arduino Nano effectively detects finger movements consistently and accurately translates them into the corresponding outputs. Although slight variations in recognition accuracy were observed for certain hand gestures, the overall system performed reliably and achieved its intended functionality.

Therefore, GLADIATOR has the potential to serve as an assistive technology that helps reduce communication barriers between deaf individuals and the general public while promoting more inclusive communication. Future research may focus on expanding the vocabulary and sign language gestures that can be recognized, optimizing sensor calibration to accommodate variations among users, and integrating artificial intelligence or machine learning techniques to further improve the accuracy and robustness of sign language translation.

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