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Bridging the Communication Gap: A Flexible Sensor-Based Smart Glove for the Speech-Impaired with Custom Phrase Functionality

Fitra Nurakbar, Mia Galina*, Faisal Samsuri, Iksan Bukhori, and Kok Swee Sim

Abstract – In daily life, we frequently encounter individuals with restricted verbal communication abilities, commonly referred to as having a speech impairment. They utilize hand and finger gestures known as ASL (American Sign Language) to communicate with others, including those with speech difficulties and individuals without such challenges. Nevertheless, numerous ordinary individuals lack comprehension of this mode of communication. In this technological era, the author has developed a smart hand glove translator capable of converting speech-impaired hand motions into comprehensible sounds. The primary elements of this design are the Arduino Uno as the central data processing unit, complemented by a flex sensor and a gyroscope sensor to capture hand movements. Subsequently, employing an LCD and speaker as output devices, along with a micro-SD reader to access a pre-existing database, facilitates user interaction in daily activities. The ultimate outcome of this design is an intelligent glove equipped with 50 databases, accessible to users through the selection of required phrases.

Keywords—ASL (American Sign Language), Smart Handglove Translator, Arduino Uno, Sensor Flex, Gyroscope.

I. INTRODUCTION

Individuals with disabilities possess enduring intellectual, mental, physical, and sensory impairments that, when interacting with their environment and societal attitudes, may present barriers to their full and effective participation on an equal rights basis (Law Number 19 of 2011 concerning the Ratification of the Rights of Persons with Disabilities) [1]. According to 2021 data from the Bekasi Regency Central Statistics Agency, West Java has 28,207 individuals with disabilities, of whom 14.32% (4,040 individuals) experienced speech or communication problems [2]. Among this population, we occasionally meet individuals with speech impairments who face challenges in communication, as they utilize sign language, which depends on hand movements and finger positions that represent letters or words; however, this sign language is universally comprehensible.

The necessity for communication can be addressed through technical advancements, since numerous studies and system designs have previously demonstrated various advantages and downsides. Numerous prior studies have addressed this issue, including study in [3], which presented a system utilizing the Arduino Mega 2560 as a data processing unit and a Flex sensor as the input device. This technology is limited to four statements in its database: need water, need medicine, require food, and turn the TV on. Moreover, research [5] indicates

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that substituting the flex sensor with push buttons as input diminishes user flexibility in its application. These push buttons are positioned on each finger joint, serving several tasks.

Existing studies can be further improved by incorporating vocabulary or phrases and enabling users to generate their own sentences, so expanding the application's functionality

This study intends to present a smart glove design capable of converting finger movements into audible sentences, resulting in smart gloves with an extensive database from which users can select their own sentences using words from the database. This tool is designed with gloves that incorporate sensors to detect the position and movement of the hands and fingers. This data is processed by a microcontroller and converted into spoken Indonesian through a speaker. Additionally, users have the capability to formulate their own sentences and access an extensive word database.

II. LITERATURE STUDY

In 2017, students from the Moradabad Institute of Technology in India developed a system called Augmentative and Alternative Communication Using Smart Glove, utilizing Arduino Nano as the primary data processing component. The input components consist of an accelerometer and a flex sensor. The data output is transmitted to the Android mobile through a Bluetooth module. This design relies on other devices for functionality. In 2019, students from Sapthagiri College of Engineering in Bangalore, Karnataka, India. Developed a system named Smart Speaking Glove for those with speech impairments, utilizing the Arduino Mega 2560 as the primary data processing component. The input components consist of flex sensors and switch buttons, whereas the output components incorporate an LCD, speakers, and buzzers. This research aids individuals with speech difficulties in communication; nevertheless, the limited vocabulary in the tool's database restricts its utility, and users are unable to autonomously modify or add output phrases within this framework.

In 2018, students from Bapurao Deshmukh College of Engineering in Sevagram, Wardha, India. Developed a solution named Smart Hand Glove for individuals with disabilities [4]. This design use the Arduino Mega 2560 as the primary data processing component and a flex sensor as the input component. In 2019, students from the Bangalore Institute of Technology in Bengaluru, India. Developed a technology named Smart Glove: A Wearable Device for Individuals with Disabilities [5]. This design utilizes the Arduino Uno as the primary data processing component, incorporating a total of 16 push buttons positioned on the finger joints, with each button corresponding to a single command. This design incorporates two devices: a hand glove and a mobile phone as the secondary device. This design model has a drawback that it is not stand-alone or depends on a 2nd device or mobile phone as a translator or sound-emitting device.

Ultimately, in 2020, students from the Government College of Engineering, Nagpur, India. Developed a solution named Multipurpose Smart Glove for those with hearing and speech impairments [3]. This design employs a Microchip PIC18F45K20 microcontroller as the primary component of the data processor and utilizes a flex sensor as input for determining the position of the fingers. This design has a limitation due to the restricted number of sentences available, namely only three sentences. The author demonstrates that the five reviewed literatures share a common limitation: the lack of a database system encompassing a comprehensive collection of sentences applicable to ordinary use. The objective of developing this system design is also to achieve this aim.

A. American Sign Language

American Sign Language (ASL) is a fully developed natural language with grammatical characteristics akin to those of spoken languages. This technique is employed by those with speech problems and is also utilized by those with hearing impairments for communication purposes. American Sign Language comprises five primary components: hand form, palm orientation, location, hand movements, and facial expressions [8]. Variations in palm orientation can result in significant variances in interpretation. The position of the hand during a movement significantly influences the interpretation of this gestural language [9]. When doing ASL actions, ensure the hand is positioned correctly. Hand gestures can signify direction, position, or the interlocutor, but in ASL, they predominantly serve to depict an action. Moreover, facial emotions are crucial in American Sign Language (ASL) [10]. Since ASL users do not require auditory input, facial expressions are employed to convey and accentuate the spoken sentences.

B. Arduino Uno

Arduino is a software and hardware platform designed to facilitate the straightforward and concise creation of electronic designs for all users. The suitable software for programming this board is Arduino IDE (integrated development environment). The Arduino board encompasses several varieties and specifications tailored to specific applications [11], [12].

FIGURE 1. Arduino Uno.

C. Flex Sensor

Flex sensor is an input device made of resistive carbon components. Analogous to variable resistors,

the output value of this sensor will fluctuate in accordance with the bending that transpires. The increased bending results in heightened resistance of the flex sensor. This sensor operates on the idea of resistance variations due to mechanical deformation. The carbon layer is located on the substrate composed of polyester, fiberglass, or polyimide. Deformation leads to fluctuations in the density of carbon particles, therefore altering the total resistance. The identical fundamental principle is employed to quantify strain, which underpins the function of the flex sensor [13],[14].

This sensor produces an analog output, necessitating an extra resistor configured as a voltage divider, as illustrated in Figure 2.
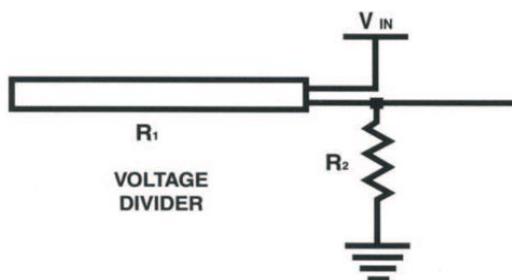
FIGURE 2. Schematic Flex Sensor [13].

D. Gyroscope

Gyroscope is a module that measures the angular velocity around a certain axis of rotation. Similar to other gyroscope variants, MEMS (Micromachined Electromechanical Systems) gyroscopes utilize the physical principle of Coriolis force for measurement purposes [15]. The fundamental operating principle of MEMS gyroscope sensors involves detecting movements induced by the Coriolis effect, resulting in output represented as angular variations across three axes: the x-axis corresponds to the roll angle, the y-axis to the pitch angle, and the z-axis to the yaw angle.

FIGURE 3. Gyroscope [15].

This sensor can measure angular variations across three axes, with a user-selectable measuring range. This module allows for the selection of bandwidth or data output speed, features a FIFO (first in first out) buffer, and includes a pin and interrupt system [16]. Positioned on the dorsal side of the hand to signify the angle and general orientation of the palm.

E. Battery Lithium Polymer

Battery is a device that directly transforms the chemical energy in its active material into electrical energy via an electrochemical oxidation-reduction (redox) cycle. Batteries are categorized into two sorts based on their usage: rechargeable and non-rechargeable batteries. Among the various varieties of rechargeable batteries, one is the Lithium Polymer battery. This battery type closely resembles the Lithium-Ion battery; however, the Lithium Polymer variant employs a dry polymer electrolyte, manifested as a thin plastic film, rather than a liquid electrolyte [17], as illustrated in Figure 4.
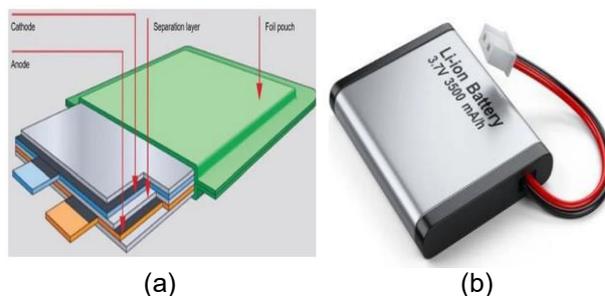
(a)   (b)

FIGURE 4. (a) Battery Lithium Polymer Construction, (b) Battery Lithium Polymer [18].

E. Speaker

Speakers or loudspeakers are apparatuses that transmute electrical information into sound frequencies by vibrating a thin membrane, which subsequently propagates through the air, allowing sound waves to be perceived. The components are illustrated in Figure 5.
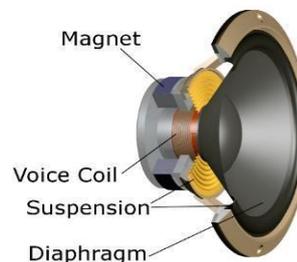
FIGURE 5. Speaker Construction [19].

F. LCD Screen

The Liquid Crystal Display (LCD) is a crucial part to improve readability by providing information visually [20]. This LCD in this study employs a single-chip low-power CMOS LCD driver controller module manufactured by Philips, designated as PCD8544. This LCD encompasses an area of approximately 4.2 cm², including 84x48 individual pixel. Figure 6 illustrates the LCD utilized in this design.

FIGURE 6. LCD used in the study.

G. Analog Digital Converter

Certain sensor components provide diverse output values that can be categorized into two types: analog and digital. The output of components having digital values can be directly interfaced with the I/O pin on the microcontroller without necessitating a specialized function on the microcontroller. In contrast to sensors or components with fluctuating or analog voltage values, the analog output sensor type requires connection to a specific ADC (Analog-to-Digital Converter) data processing pin. The ADC input of the Arduino Uno is situated on pins A0, A1, A2, A3, A4, and A5. The ADC on the Arduino Uno possesses a 10-bit resolution, whereby the analog voltage reading from a sampled input is transformed into a 10-bit binary number. When expressed in decimal, the maximum voltage value on the analog pin, corresponding to the reference voltage of 5 volts, yields a reading of 1023.

III. DESIGN AND IMPLEMENTATION

The Smart Hand Glove Translator system use the Arduino Uno as the control hub, utilizing a flex sensor in conjunction with a gyroscope sensor to ascertain the location and movement of the user's hand. The system's design is categorized into four primary components.
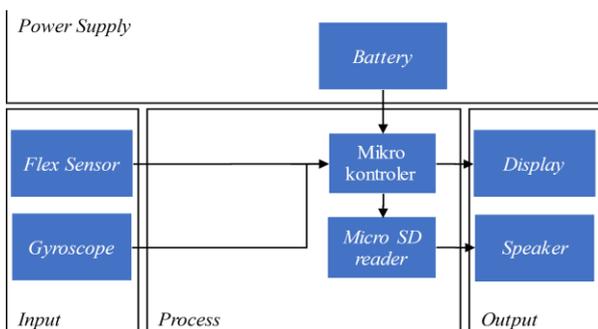

FIGURE 7. Smart Handglove Diagram Block.

A block diagram illustrates a power supply that utilizes a battery as the primary voltage source for the entire system. The input element comprises a flex sensor and a gyroscope, which will delineate the position of the fingers and the movement of the palm. In the process section, a microcontroller serves as a data processor for input from the flex sensor and gyroscope. The final segment of this block diagram is the output, comprising a display that presents words or sentences during operation, along with a speaker that emits sound processed by the microcontroller.

The operational framework in this design adheres to the flowchart depicted in Figure 8. Initially, the system will initialize the ADC (analog-to-digital converter) and I2C serial connection to identify devices utilizing the communication pathway. Subsequently, the LCD will present a menu featuring two options: start or custom. Upon selection of 'start', the system will commence reading sensor input, correlating it with the database, subsequently displaying the data and outputting it via the speaker. However, if the custom menu is chosen, the system will interpret the sensor

input, which will then be recorded in the database as an additional vocabulary entry.
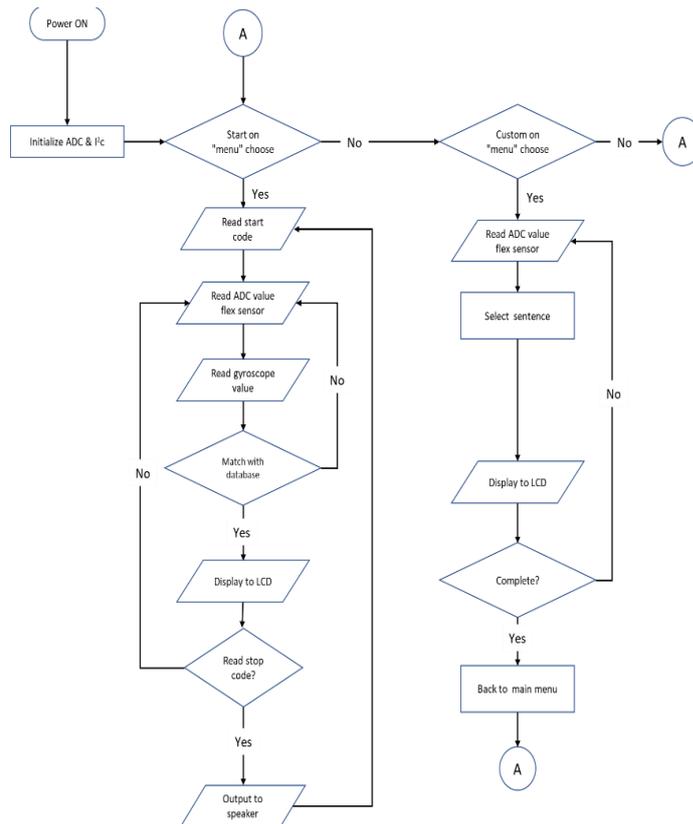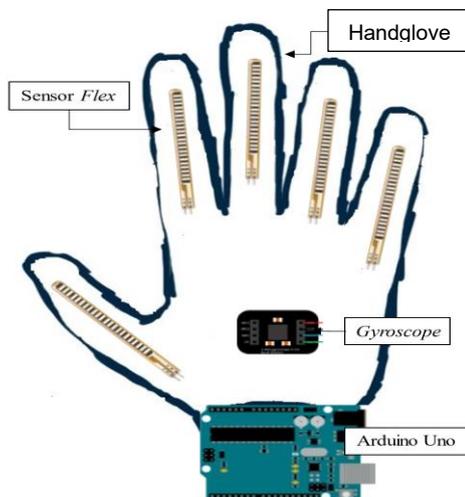

FIGURE 8. Smart Handglove Flowchart.

FIGURE 9. Hardware Illustration.

This concept employs one flex sensor on each finger joint to accurately map the finger's form in more detail. The sensor's output will be directly connected to the Arduino Uno. A gyroscope sensor is affixed to the glove to indicate the angle and general orientation of the palm. The sensor's output will be directly connected to the Arduino Uno. The primary control device, or Arduino Uno, will be situated on the wrist, an area that will undergo minimal movement during operation. The primary control unit of this system employs an Arduino Uno; hence, the electronic setup is illustrated in Figure 10.
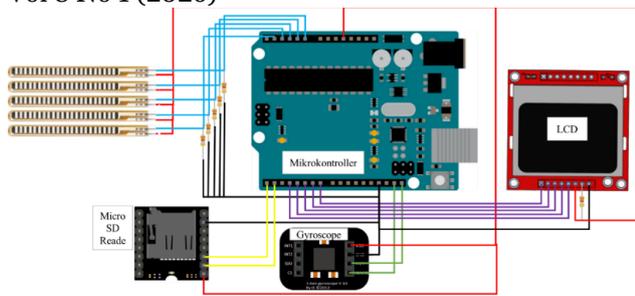
FIGURE 10. System Configuration.

The input part contains a gyroscope sensor module, which features two power supply channels (VCC and GND) and SDA and SCL channels that are directly interfaced with the Arduino Uno using the I2C/SPI communication line. The output part contains a microSD reader module connected through a serial channel (RX TX). The final component is the LCD module, which is linked to pins 3, 4, 5, 6, and 7.

IV. RESULTS AND ANALYSIS

Figure 11 illustrates the complete physical structure of the smart handglove. All components and modules are affixed to the glove.

FIGURE 11. Smart Handglove.

The image above depicts flex sensors on each finger joint, with one sensor per joint, a gyroscope sensor affixed to the back of the palm to indicate palm orientation, and an Arduino Uno, display, and micro-SD reader positioned on the wrist for user accessibility to the LCD.

A. Analog Digital Converter Flex Sensor Input Reading Testing and Analysis

This flex sensor input test aims to independently verify the sensor input value while the fingers are flexed. Data acquisition from this flex sensor is conducted by bending the finger at a 90-degree angle five times to capture and document the output data from the sensor. The outcomes of the flex sensor examination are displayed in Table 1.

TABLE 1. ADC Flex Sensor Value.

Flex sensor	Quantity of data extractions	Linear sensor condition value	Bent sensor condition value
Little Finger Sensor (SF1)	1	278	130
	2	263	119
	3	280	125
	4	261	117
	5	279	130
Ring Finger Sensor (SF2)	1	281	149
	2	285	131
	3	273	123
	4	269	141
	5	278	120
Middle Finger Sensor (SF3)	1	279	145
	2	289	139
	3	277	128
	4	275	131
	5	270	130
Index Finger Sensor (SF4)	1	261	150
	2	256	129
	3	270	140
	4	271	134
	5	263	129
Thumb Sensor (SF5)	1	283	134
	2	287	149
	3	269	142
	4	250	139
	5	289	150

The data indicates that the value of the sensor in a straight position runs from 250 to 289, with an average of 273.44, whereas the value when the sensor is bent ranges from 117 to 150, with an average of 134.16, signifying a drop in value when bent. The resistance of the flex sensor escalates in conjunction with the bending radius of the sensor. This sensor circuit has a fixed resistor functioning as a voltage divider, with a resistance of 10 kΩ. Both factors lead to a diminished voltage reading when the flex sensor is flexed. The ADC sensor value is depicted in Figure 12.

The illustration depicts SF1, SF2, SF3, SF4, and SF5, each corresponding to a sensor located on the little finger, ring finger, middle finger, index finger, and thumb, respectively.
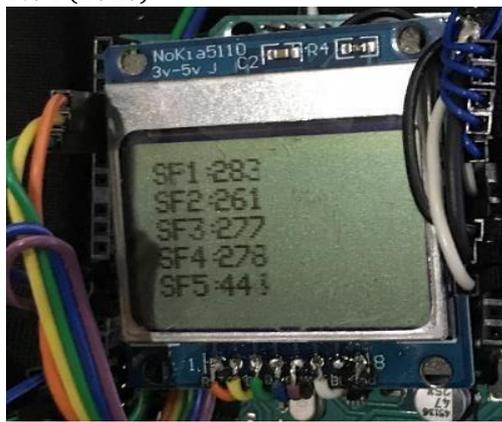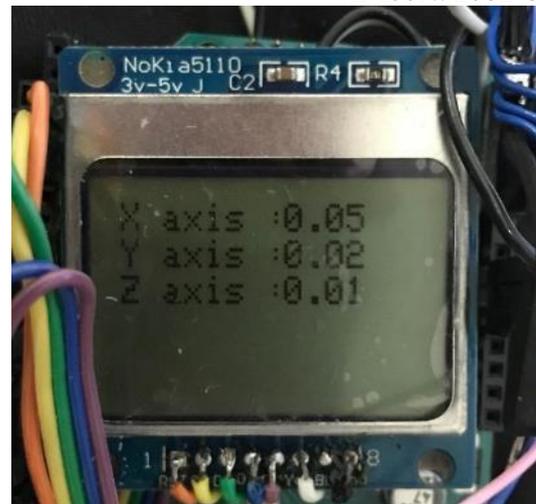
FIGURE 12. ADC sensor reading value display.

B. Gyroscope Input Reading Testing and Analysis

This gyroscope input test seeks to independently verify the sensor input value. The test is conducted by rotating the sensor along the y-axis while the palm is inclined on the x, y, and z axes. The outcomes of the gyroscope examination are displayed in Table 2.

TABLE 2. Gyroscope Value.

Gyroscope	Number of data collection	Initial value	Change in gyroscope output value 180º
X-Axis	1	0,05	5,79
	2	0,01	4,89
	3	0,03	5,32
	4	0,01	4,86
	5	0,01	4,62
Y-Axis	1	0,01	5,89
	2	0,02	4,98
	3	0,01	5,32
	4	0,01	6,01
	5	0,03	5,32
Z-Axis	1	0,02	5,89
	2	0,01	4,68
	3	0,01	5,79
	4	0,05	6,34
	5	0,01	6,01

The alteration in gyroscope output values is contingent upon the orientation of palm movement across the three axes: x, y, and z. When the sensor is repositioned from an angle of 180 degrees to -180 degrees, it will produce a result indicative of the palm's orientation. Figure 13 illustrates the output of the gyroscope.

FIGURE 13. Gyroscope value reading display.

C. Overall System Testing

Comprehensive System Evaluation The comprehensive system testing aims to ascertain whether the integration of all components, modules, and programs operates in accordance with the design objectives, wherein the smart handglove translates hand movements into sentences, and these handgloves possess a database of 50 selectable sentences for user utilization. The results of this design experiment are detailed in Table 3.

TABLE 3. Smart Handgloves testing result.

Index number	Gesture	Sentence display
1		
2		
3		
4		
5		

The test findings indicate that the entire system functions as intended. Sentences stored in the database can be emitted through the speaker in response to finger motions. Table 4 elucidates the sentences included in the database.

TABLE 4. Sentence Index in the database.

No. Database indeks	Sentence	No. Database indeks	Sentence
1	Good morning	26	What were you leaving by?
2	Good day	27	I was leaving by car
3	Good evening	28	I was leaving by bike
4	I need to hit the restroom	29	How old are you?
5	I'm hungry	30	Where are you working?
6	I want to eat	31	Okay
7	I don't feel well	32	What is this?
8	I want to sleep	33	Please come in
9	What is your name?	34	I don't understand
10	What time is it?	35	I know what you mean
11	I want to take a bath	36	Happy birthday
12	Nice to meet you	37	I want to pray
13	How are you doing?	38	No smoking
14	I'm good	39	Be careful on the way
15	I'm not feeling too well	40	I'm really tired
16	Where are you?	41	Where is AC's remote?
17	I want to take a holiday	42	Where is TV's remote?
18	I'm busy	43	I don't like this food
19	I can help	44	I don't like the taste of this food
20	How much does it cost?	45	What is your hobby?
21	Please help me	46	Thank you for your help
22	What day is it?	47	Sorry for bothering your
23	What month is it?	48	I love you
24	Can I have the menu?	49	I'm hot
25	What is the Wifi's password?	50	I'm cold

V. CONCLUSION

A smart handglove has been designed with an Arduino Uno microcontroller, incorporating a flex sensor and a gyroscope sensor. The device is capable of effectively translating finger movements and gestures into sound and displaying the results on an LCD screen. This design incorporates 4GB of storage, capable of accommodating over 50 sentences that can be chosen based on the user's preferences. The design of this smart handglove presents various deficiencies that could serve as valuable concepts for future enhancement, specifically:

1. Incorporating flex sensors at each finger joint and utilizing gloves with a snugger fit on the fingertips to enhance mapping accuracy.

2. Substituting the module with a custom-designed PCB to enhance compactness and usability.

3. Incorporating functionalities for the management of household devices

AUTHOR CONTRIBUTIONS

Fitra Nurakbar: Conceptualization, Design and Implementation, Methodology, Writing – Original Draft Preparation;

Mia Galina: Project Administration, Supervision;

Faisal Samsuri: Data Collection;

Iksan Bukhori: Review and Writing – Final Draft Preparation;

Kok Swee Sim: Review and Revision.

CONFLICT OF INTERESTS

No conflict of interests were disclosed.

ETHICS STATEMENTS

Ethical approval was not applicable to this research since it did not involve human participants, animals, or sensitive data.

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