Tongue Drive Wheelchair

Mohamad O.Diab , Nizar Awar , Abdul Aziz Al-Hojairi , Abdul Rahman Baalbaki , Ali Ghamloush and Nehmat El-Hariri

Abstract— **Tongue Drive Wheelchair is a non-invasive development that explores how technology can be assistive for individuals with severe disabilities to communicate with their environment. This tongue control system leads to a more self-supportive independent life.This paper discusses a project based on a contact sensor attached to a headset that is connected to a circuit. The circuit is triggered by the sensors to control the wheelchair's motors. Results occurring from the contact between the cheek and the sensor, due to the tongue movement, apply order to the motors to work allowing the person to move right, left, forward and even to stop according to his needs. This development was accomplished to make patients feel more satisfied because it is a safe and easy technology that doesn't need any complicated programs to realize and perform the movements.**

I. INTRODUCTION

BEGIN to see yourself as a soul with a body rather than a body with a soul."This small but meaningful quote said by Wayne Dyer highlights the point that although the body is the entire structure of a human organism, yet it is controlled and prohibited by a soul. When a person looses the ability to move this human formation, he is not loosing everything because our soul, which is still inside, is the main thing that makes us continue our lives.

A human body is a machine for living. It is the main structure that helps us move, play, work and does everything. If a person suffers the loss of the ability to move this body or becomes paralyzed, he thinks that life has stopped and lives in a very depressed and gloomy environment.

Paralysis is the loss of muscle function in a part of the body [1]. It happens when something goes wrong with the way messages pass between the brain and muscles. It can affect a small area (localized) or be widespread (generalized). It may affect one side of the body (unilateral) or both sides (bilateral). If the paralysis affects the lower half of the body and both legs, it is called (Paraplegia). Moreover, if it affects both arms and legs, it is called (Quadriplegia). Most paralysis is due to strokes or injuries such as spinal cord injury or a broken neck or back [1].

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Spinal cord injury, which leads to generalized paralysis, can be devastating but it doesn't mean an end to fun and being a part of the good things in life [2]. New technologies have found a very useful way to help individuals with serious disabilities to go over their sadness and allow them to lead to a more active and self-reliant life due to the movement of their tongues. Scientists chose the tongue to control the system because unlike the feet and the hands, which are connected by brain through spinal cord, the tongue and the brain have a direct connection through cranial nerve (Fig. 1) [3]. In case when a person has a severe spinal cord injury or other damages, the tongue will remain mobile to activate the system.

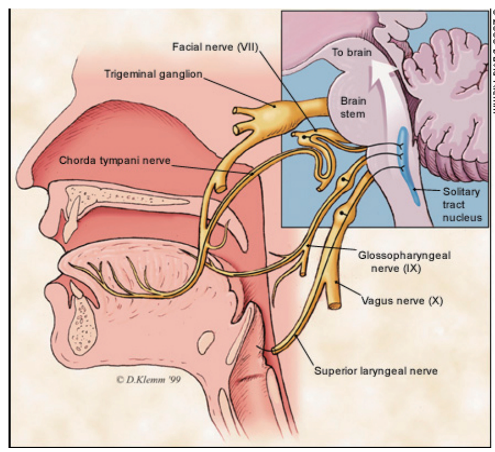

Fig. 1: Cranial nerve

A new assistive technology developed by engineers at the Georgia Institute of Technology could help individuals with severe disabilities achieve more independent lives. The novel system allows individuals with disabilities to operate a computer control powered wheelchair and interact with their environments simply by moving their tongues [3].

Engineers designed this system based on magnets that enables disabled persons to use the tongue to control the movement of a wheelchair. Movement of the magnetic tracer, which has to be glued onto the surface of the tongue or surgically implanted into the tip, is detected by an array of magnetic field sensors mounted on a headset outside the mouth as shown in "Fig. 2". The sensor output signals are wirelessly transmitted to a portable computer that can be carried on the user's wheelchair, which in turn translates them into commands for the device the user wishes to control. [4] A unique set of specific tongue movements can be tailored for each individual based on the user's abilities, oral anatomy, personal preferences and lifestyle.

Additionally, scientists designed another type of driven

Fig. 2: Tongue Drive System based on magnetic tracer.

wheelchair based on eye movement. In this case, to send different commands they have used electrooculography (EOG) techniques, so that, control is made by means of the ocular position (eye displacement into its orbit). A neural network is used to identify the inverse eye model, therefore the saccadic eye movements can be detected and know where user is looking (Fig. 3). This control technique can be useful in multiple applications, but in this work, it is used to guide an autonomous robot (wheelchair) as a system to help people with severe disabilities. The system consists of a standard electric wheelchair with an on-board computer, sensors and graphical user interface running on a computer [5].

Fig. 3: User-wheelchair interface based on EOG signal.

While using these systems, patients faced a lot of problems. They were unsatisfied in using the magnetic sensor due to the process of gluing or surgically attaching the magnet to the tongue. On the other hand, they were displeased in using the EOG system due to the systems sensitivity to the eye movement; any wrong eye movement might cause injury to the patient. As a result, the Tongue Drive Wheelchair, which is the tongue-operated assistive technology developed for paralyzed people, was achieved. It depends on sensors to detect the movement that the patients want to go through, a wheelchair that the patient sits on and motors that move the chair's wheels (Fig.4).

II. METHODS

Helping a person with such severe disability to live almost normally was the key to start and succeed in this development. First of all, we began by choosing the best sensor, which gives successive results, and designing a model where the sensor will be mounted on.

In this paper, we proposed several prototype designs; one based on a headset (Fig. 5) and the other on eyeglasses (Fig. 6). Both prototypes used three contact sensors, two placed near the cheeks of the patient's face and the third near his/her lower lips. Without the need of extracting the tongue from the mouth, the patient applies a force on one of the cheeks by the tongue such that the skin becomes in direct contact with the

Fig. 4: Tongue Drive Wheelchair

sensor. In this situation, when one of the sensors is triggered, a signal will be sent directly to the controlling circuit giving an order to the motors to rotate the chair according to the patient's purpose.

Fig. 5: Control headset using contact sensor.

Fig. 6: Control eyeglasses using contact sensor.

A wheelchair is a wheeled mobility device in which the user sits on. The device is propelled either manually (by turning the wheels by the hand) or via various automated systems (such as the tongue drive system). Wheelchairs are used by people for whom walking is difficult or impossible due to illness (physiological or physical), injury, or disability.

Patients with generalized paralysis case can not use any type of wheelchairs. Such people need specific kinds of wheelchairs that will support their situation and will offer a more easy and comfortable life. As a result, the chassis of the chair must have small wheels attached to motors that will be triggered according to the patient's need.

Tongue Drive Wheelchair's chassis was very important. This development consisted of a base which was made out of 4 small wheels with motors attached to, a box that has several uses and a chair that the patient sits on.

The box of the wheelchair was located above the base of the chassis. It was attached to it tightly to maintain support. It was designed with a W= 40 cm, L= 60 cm and H= 34 cm. The sides of the box were made up of aluminum, while the bases were made up of wood to maintain isolation of any leakage current that might happen. The main purpose for building this box design was to avoid any contact that might happen accidentally between the patient and the motors linked to the base. In this case, due to the height of the box, the patient will be far enough from the base. Moreover, it was used as a cabinet. Inside it, all the components needed to take the order from the patient and translate it to the motors were positioned (Fig. 7).

Fig. 7: The box and chair of the wheelchair

A. Sensors

Moreover, three several types of sensors were tested which are humidity, piezoelectric and contact sensors. Humidity sensor is used in environments where fluctuation in temperature and humidity occurs. The most common type of humidity sensor uses ”capacitive measurement”. This system relies on electrical capacitance,or the ability of two nearby electrical conductors to create an electrical field between them. The sensor itself is composed of two metal plates with a non-conductive polymer film between them. As the patient’s tongue touches the sensor mounted on the headset, the film collects moisture which causes minute changes in the voltage between the two plates. In this case, the amount of humidity at the sensor will be very high. The main disadvantage that faced us while using this type of sensor is that, due to the saliva from the tongue, a delay of time occurs while the sensor wants to go back to its steady state. This inconvenient situation might lead to a patient’s injury because the sensor will not be able to detect the patient’s need to orient the chair, until it goes back to its stable state.

A piezoelectric film has been used in thousands of sensing applications. It is a device that uses the piezoelectric effect to measure pressure, acceleration, strain or force by converting them into electrical signals. In this advancement, we tested a piezoelectric film which is based on the principal of detecting the deformation of the patient’s cheek after the tongue’s movement. Due to the high sensitivity this sensor has, a major problem had arisen. The sensor’s high detection of noise caused the chair to take wrong orders which might affect the patient’s safety.

After testing the advantages and disadvantages of the sensors, we concluded that the best choice was dealing with the contact sensor. This sensor is a type of an On/Off switch that only has to be touched by an object to function. When the paralyzed person pushes his tongue, a contact between the cheek and the sensor occurs.

B. Control Circuit

After choosing the appropriate sensor to be mounted on the headset, it was time to start thinking how the order given by the sensors will be translated to make the wheelchair move.

The establishment of the control part began by designing a circuit using computer software that includes all components and gates needed to be able to take the signal and transport it to the triggered motors (Fig. 8). It was then simulated to guarantee the wanted outcomes.

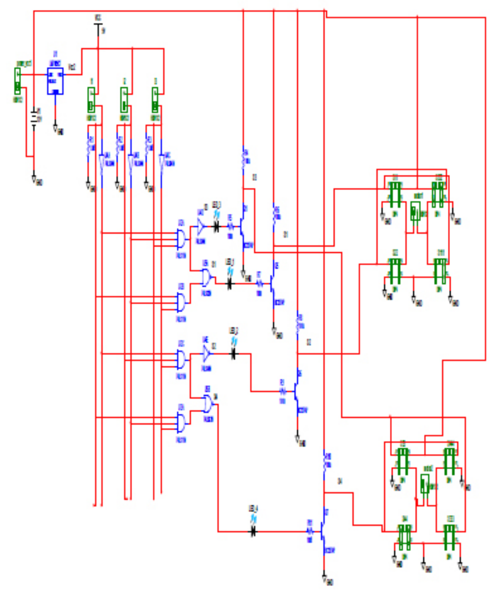

Fig. 8: Control Circuit block diagram

First of all, a power supply, 12 volt battery, is connected to a voltage regulator in order to feed up the circuit with appropriate voltage to run the components. The voltage regulator is then linked to switches which are the contact sensors mounted on the headset that the patient triggers according to his desires as shown in (Fig. 5).

Moreover, the order coming from the switches goes to different logic gates that translate the patient’s need to commands that trigger the transistor to pass the voltage at its emitter to the H-bridge. In the control circuit, there are two H-bridges, each one controls the movement of a single motor, backward or forward motion. The combination of both bridges will translate this motion into to a rotational movement for the wheelchair. Each H-bridge consists of four relays that manipulate the signal to control the motor.

If the current passes from R1 to R4 and R5 to R8 the motor will rotate to move the wheelchair forward. Moreover, if the current passes from R2 to R3 and R5 to R8 the chair will move to the left. Furthermore, if the current passes from R1 to R4 and R6 to R7 the chair will move right.

Obtained results, from the simulation of the circuit, were printed on a double layer circuit board to save space. This double layer circuit board gets the patient's order and translates it into the movements needed.

Moreover, another system was made to trigger the motors to move. This system was based on powered relays (Fig. 9).

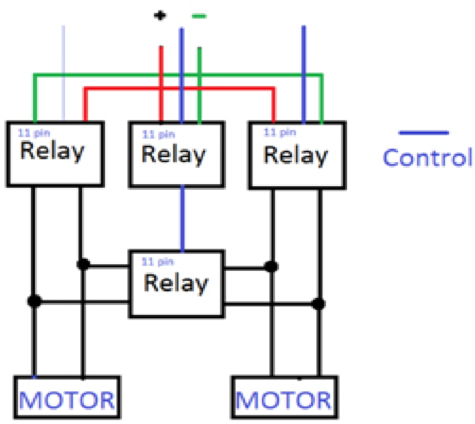

Fig. 9: Powered Relay Bridge

Without the use of the circuit, a bridge was made by using four powered relays. The need for the control circuit in the first system was based on our need to convert a 3 input orders to 4 outputs in which we can control the 2 H-bridges. On the other hand, in the new system, we replaced the 2 H-bridges by one Power Bridge that can control the movement of the 2 motors. Its principle is based on 3 relays placed on the top, which are the power supply relays, and one in the center, which is the polarity relay that is activated only when the relay in the middle is activated. The center relay takes its power from one of the 2 motor's supply to reverse and supply it to the other motor. Furthermore, when it is activated, it will supply it without reverse. As a result, the power supplied polarity will be controlled and the motors rotate.

Working on a hardware project results in many consequences. On the other hand, to reach the goal, several trials must be done.

The housing of the circuit is placed in the aluminum-wood box that contains openings for ventilation to cool down the high power resistors, transistors and voltage regulator (Fig. 10).

C. Mechanical Part

Working on the mechanical part was very important because an optimum design had to be made concerning speed, weight and robustness to come up with a movable tong-driven

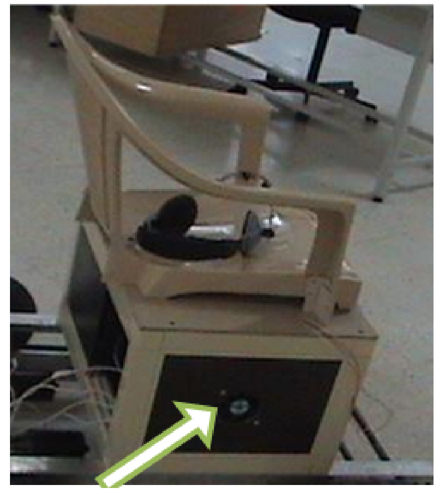

Fig. 10: Ventilation System

wheelchair. It had to be simple and effective to handle the patient's weights, powerful motors with high torque, four-pin screw wheels and efficient transition system. As a conclusion, we decided that this model should have a rectangular base with Length: L=90 cm, Width: W= 60 cm, Height: H= 17 cm, four wheels with Diameter: D= 28 cm. and two motors connected to it (Fig. 11).

Fig. 11: Ventilation System

After testing several materials to start building up the chassis of the wheelchair, aluminum with Thickness: Th=5 mm was that most appropriate (Fig. 12). Aluminum is a component that is rigid, light, and endures corrosion.

Based on the chair's principle of motion, which is placing a motor at each side of the chassis, two Direct Current (DC) motors (Fig. 13), driven by a 12 Volt (V) GEL Battery, were used. These motors take the order from the patient's tongue to rotate in same direction, moving forward, or in opposite directions, moving left or right.

Unfortunately, the motors' shaft was very small and couldn't handle heavy weight. A boite system with bigger shaft of D=2.5 cm and L=15 cm was used (Fig. 14). The new shaft was engaged with the old one to perform superlative results (Fig. 15). Further more, an aluminum motor box, to handle this shaft and to let it rotate easily without any resonance or vibration, was made. Moreover, two new squared aluminum

Fig. 12: The wheelchair aluminum sides

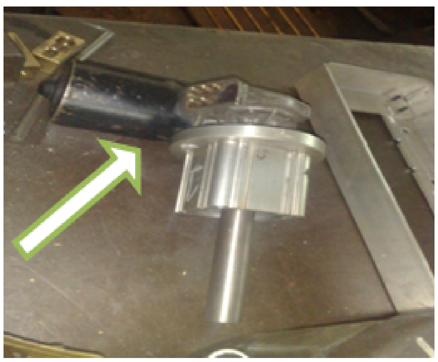

Fig. 13: The wheelchair chassis design

flanges were made to latch the motor box to the wheelchair's chassis and at the same time to handle the motors in place. In addition, four steel cylinders of D=16 mm were done to join the two sides of the chassis together forming the rectangular base.

Fig. 14: The boite system

In addition, four steel cylinders of D=16 mm were manufactured to join the two sides of the chassis together forming the rectangular base as shown in Fig. 16.

A Chain-Sprocket System (Fig. 17) was built up from four 20-toothed gear of Pitch= 0.5 in. and a compatible chain of L=3.75 m to obtain the goal of making a mechanism that will drive each front shaft independently from the other, with the help of its neighborhood motor.

Following the transition system, a wheel's assembly similar to that in cars was created. Wheels should not be directly

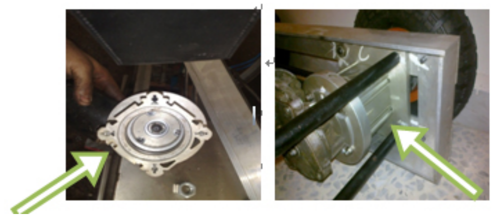

Fig. 15: The assembly of the motor engaged by the boite and the wheelchair

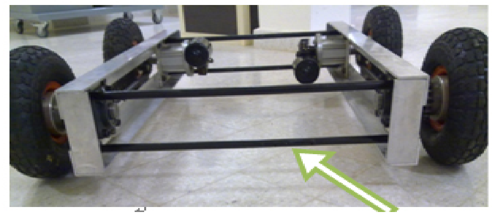

Fig. 16: Four steel cylinders

attached to the shaft because this will result in high forces upon rotation and may consequently damage the shaft over time. Usually, a cylindrical flange is attached to the shaft and the wheel is assembled to the flange through screws (Fig. 18). In this case, forces are distributed all aver the flange, and wheels can easily be removed and exchanged.

The flages were made from pure aluminum. Each cylindrical flange had L=6 cm and D=10 cm. at the end, the flanges were drilled and the wheels were screwed into place.

After checking that all parts and mechanisms were functioning normally, a Black Teflon plastic tube (isolation stiff plastic material) with a D=18 mm and L=15 cm had to be used (Fig. 19). The motors worked on were designed such that there body is the ground (negative terminal). Moreover, the chassis of the chair was made up of conducting material (Aluminum and Steel). As a result, the body becomes electrically charged. In this case, the motors can never rotate in opposite direction since one of the terminals is fixed.

Fig. 17: Chain-Sprocket System

Fig. 18: Wheels assembly

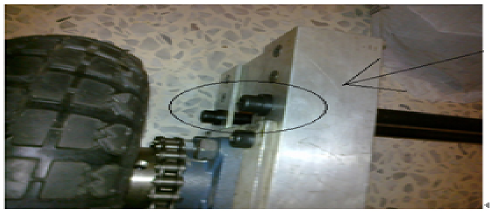

Fig. 19: Black Teflon plastic

III. RECOMMENDATION FOR FUTURE IMPROVEMENT

In order to reach our goal in this BS project, which is making the wheelchair move according to the tongue order, a lot of time and effort was needed. Successful results were obtained based on the plans and schedule followed but to make it much more professional, here are some recommendations for future enhancements:

Another type of sensor might be used. This sensor might be more sensitive and don't need any headset to be placed on.

Larger motors might be used to maintain easier and faster movement.

A medical chair can be placed on the wheelchair's chassis to give more comfortable sitting situation for the generalized paralysis patient.

An easier circuit might be used based on wireless connections.

A more generalized program that would make the wheelchair move in more different directions.

An advanced way for steering the chair instead of the method used in a tank like steering system.

The control switches might be placed in a way the patient carries them permanently, where he can control the chair wirelessly to bring it closer to him.

A system that might make this paralyzed patient gives an order from his tongue to trigger the chair to move upward. These recommendations might give the patient more self-confidence.

A set of sensors that prevents the patient to hit a wall in front also might be used.

IV. CONCLUSION

The result from using a contact sensor, attached to a headset, is to help people with general paralysis to live more independently. This acknowledgement reaches a lot of advantages and disadvantages. In contrast with the researches and wheelchairs done before, which were based on eye or magnetic movement, this project offered the patient a simple technology to use and benefit from.

While using a magnetic sensor to obtain the patient movement, a magnet should be glued on the tongue or a surgical procedure should be made. This complex idea might avoid the patient from using this sensor even though; it might be very beneficial for his whole life. Moreover, using an eye sensor can also be avoided by patients because any wrong eye movement might cause the chair to take a wrong order leading to the person's injury. In addition, both projects needed high sophisticated microcontrollers in order to analyze the patient's need to convert orders to movements.

The Tongue Drive Wheelchair, this paper is talking about, avoided any problems that might make the patient unsatisfied. Furthermore, this project dealt with a contact sensor that is attached to the headset. Without the need of extracting the tongue out of the mouth and by just letting the tongue touch the inner part of the cheek, the switch will close giving an order for the movement specified by using simple circuit. In addition, this development will not work except when a force is done on the contact sensor which makes the patient talk freely without being afraid of wrong orders.

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