Tongue Operated Wheelchair for Physically Disabled People

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Abstract- The "Tongue Dive System" is a tongue operated Assistive Technology (AT) developed for people with severe disability to control their environment. Tongue Drive consists of an array of Hall Effect magnetic sensors mounted on a mouthpiece to measure the magnetic field generated by a small permanent magnet secured on the tongue. The sensor signals are transmitted across a wireless link and processed to control the powered wheelchair. In past a lot of Assistive Technologies have been designed but each one of them had certain demerits. The tongue is considered an excellent appendage in severely disabled people for operating an Assistive device. This paper presents an efficient, low cost solution to all the issues encountered in previous AT's. Detailed analysis of various design processes has also been discussed. Complete system proposed in this paper has been designed around PIC microcontroller and a RF module. The design has been tested and result achieved confirms the design approach illustrated.

Keywords— Assistive Technologies (AT), Tongue Drive System (TDS), magnetic field sensors, RF module.

I. INTRODUCTION

Assistive Technology (AT) refers to any item, piece of equipment, or system, whether acquired commercially, modified, or customized, that is commonly used to increase, maintain, or improve functional capabilities of individuals with disabilities [1]. The spectrum of disabilities varies widely in type and severity. AT encompasses an enormous range of devices, including mobility aids, augmentative communication devices (voice synthesizers and communication boards), prosthetic and orthotic devices, and a myriad of adaptive computer equipment. AT can be "low- tech" (a cup-holder for a wheelchair tray) or "high-tech" (brain-computer interfaces for communication and environmental control). AT can help people with disabilities improve their quality of life, contribute economically and socially, and increase their independence [2]. In spite of potential usefulness, the availability of appropriate AT for people with disabilities may be problematic. Most notably, due to the specialized needs of each person with a disability, the market for one particular assistive device may be exceedingly small, driving up the cost of specialized assistive devices. The high cost of AT compounds the problem of finding an appropriate AT device: people may not be able to afford to try different devices and loan programs can be cost-prohibitive [3]. Second, due to small markets, and the limited capacities of the AT commercial sector, appropriate assistive devices may simply not exist for many specialized needs, or potential users may not be aware of them.

A large group of AT devices are available, that are controlled by switches [4]. The switch integrated hand splint, blow-n-suck (sip-n-puff) device, chin control system, and Electromyography (EMG) switch are all switch based systems and provide the user with limited degrees of freedom. A group of head-mounted assistive devices [5-7] has been developed that emulate a computer mouse with head movements. Cursor movements in these devices are controlled by tracking an infrared beam emitted or reflected from a transmitter or reflector attached to the user's glasses, cap, or headband. Tilt sensors and video-based computer interfaces that [8], [9] can track facial features have also been implemented by many researchers. One limitation of these devices is that only those people whose head movement is not inhibited may avail this technology. Another limitation is that the user's head should always be in positions within the range of the device sensors. For example the controller may not be accessible when the user is lying in bed or not sitting in front of a computer.

Another category of computer access systems operate by tracking eye movements from corneal reflections [10] and pupil position. Electro-oculographic (EOG) potential measurements [11], [12] have also been used for detecting the eye movements. A major limitation of these devices is that they affect the users' eyesight by requiring extra eye movements that can interfere with users' normal visual activities such as reading, writing, and watching.

Till date, very few assistive technologies have made a successful transition outside research laboratories and widely utilized by severely disabled in their routine life. Many technical and psychophysical factors affect the acceptance rate of a particular Assistive Technology. The most important factors are the ease of usage and convenience in control. Operating the assistive device must be easy to learn and require minimum effort on the user’s part. The device should be small, unobtrusive, low cost, and non- or minimally invasive. Finally, a factor that is often neglected is that the device should be cosmetically acceptable. Moreover, a disabled person would never want to look different from an intact person.

II. USE OF TONGUE FOR MANIPULATION

Since the tongue and mouth occupy an amount of sensory and motor cortex in the human brain which rivals that of the fingers and the hand. Hence, they are inherently capable of sophisticated motor control and manipulation tasks with many degrees of freedom [13]. The tongue muscle is similar to the heart muscle in that it does not fatigue easily [14]. Further, the tongue is non-invasively accessible and not influenced by the position of the rest of the body, which can be adjusted for maximum comfort. This is evident in their usefulness in vocalization and ingestion. The tongue is connected to the brain by the cranial nerve, which generally escapes severe damage in spinal cord injuries. It is also the last to be affected in most neuromuscular degenerative disorders. The tongue can move very fast and accurately within the mouth cavity. It is thus a suitable organ for manipulating assistive devices. Therefore, a tongue operated device has a very low rate of perceived exertion [15].

An oral device involving the tongue is mostly hidden from sight, thus it is cosmetically inconspicuous and offers a degree of privacy for the user. The tongue muscle is not afflicted by repetitive motion disorders that can arise, when a few exoskeleton muscles and tendons are regularly used. The tongue is not influenced by the position of the rest of the body, which may be adjusted for maximum user comfort. The tongue can function during random or involuntary neurological activities such as muscular spasms. Also non-invasive access to the tongue movements is possible. The above reasons have resulted in development of tongue operated assistive devices such as the Tongue Touch Keypad (TTK) [16], which is switch based device. Tongue mouse [17] is another device that has an array of piezoelectric ceramic sensors. The sensor module is fitted within the oral cavity as a dental plate.

III. PROPOSED DESIGN

A tongue operated magnetic sensor based wireless AT has been developed for people with severe disabilities to lead a self-supportive independent life by enabling them to control their environment using their tongue. In TDS, a small permanent magnet, the size of a grain of rice is secured to the tongue as a magnetic tracer by using tissue adhesives, tongue piercing, or simple implantation under the tongue mucosa through injection. The magnetic field generated by the tracer inside and around the mouth varies as a result of the tongue movements. These variations are detected by an array of sensitive magnetic sensors mounted on the mouthpiece, as shown in Figure1. The analog outputs are then digitized, modulated and wirelessly communicated to the targeted devices in the user’s environment [18]. This technology works by tracking the movements of a permanent magnet, secured on the tongue, utilizing an array of linear Hall-effect sensors. This allows a small array of sensors to capture a large number of tongue movements [19].Further in the process; the signals received by the external controller unit are demodulated and de-multiplexed to extract the individual sensor outputs. By processing these outputs, the motion of the permanent magnet and consequently the tongue within the oral cavity is determined. Assigning a certain control function to each particular tongue movement is done in software. These control functions may then be used to operate a powered wheelchair.

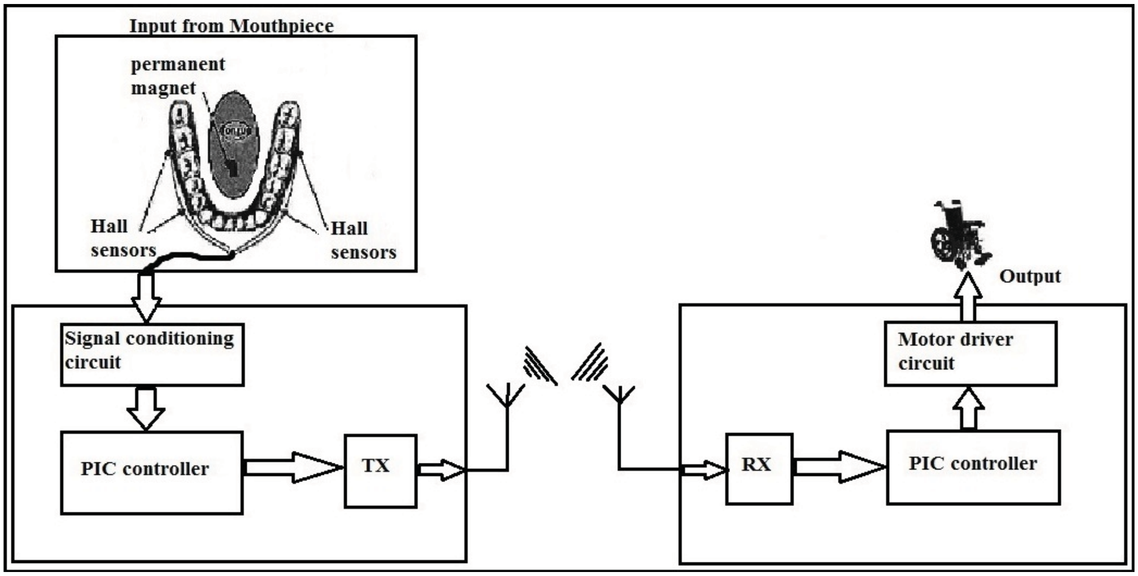

Figure 1. Simplified block diagram of proposed design

The raw signals are picked by the sensors connected to the mouthpiece which are then amplified using Amplifier circuit [20]. The signals are then sent to the ADC channels of PIC where they get converted to digital form. The signals are then transmitted wirelessly. These wirelessly transmitted signals are received and receiving circuit responds accordingly. The control algorithms are burnt into PIC, with the efficient use of microC [21].

3.1 Mouthpiece-

We devised a prototype Mouthpiece system shown in Figure 2 using off-the-shelf commercially available components to evaluate the feasibility and performance of this approach in developing assistive device.

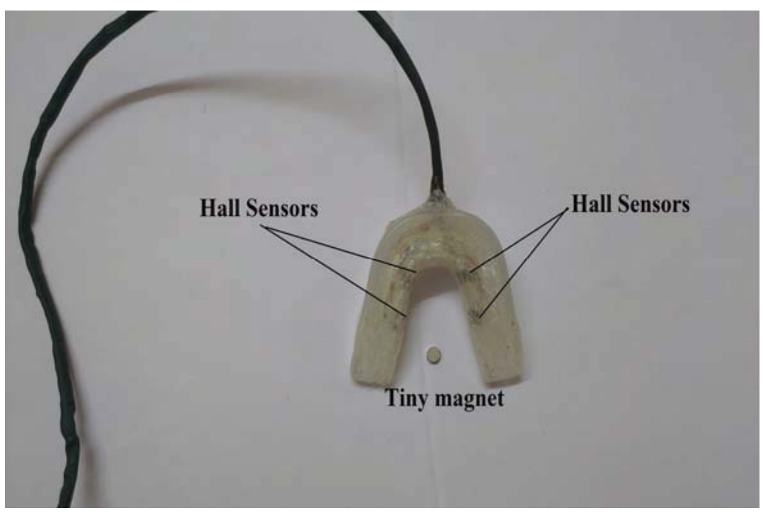

Figure 2. Mouthpiece designed from off-the-shelf components

The main purpose of this prototype device was to move a Powered Wheelchair based on location of permanent magnet relative to four Hall- Effect sensors [22]. Four Ratiometric linear Hall- Effect sensors with 5 mV/G sensitivity were installed in a Shock Doctor Max mouth guard [23]. The sensors readily provide temperature compensated linear voltage output proportional to the magnetic field. The arrangement of sensors was at the comers of a parallelogram, as would be in a real setting. A set of six wires was required for supply and sensor output connections.

3.2 Signal Conditioning Circuit-

The sensors sense the magnetic field and output an analog voltage. The output is then fed to the amplifier circuit, to convert a 2.5volts signal to around 5 volts signal as shown in Figure 3.

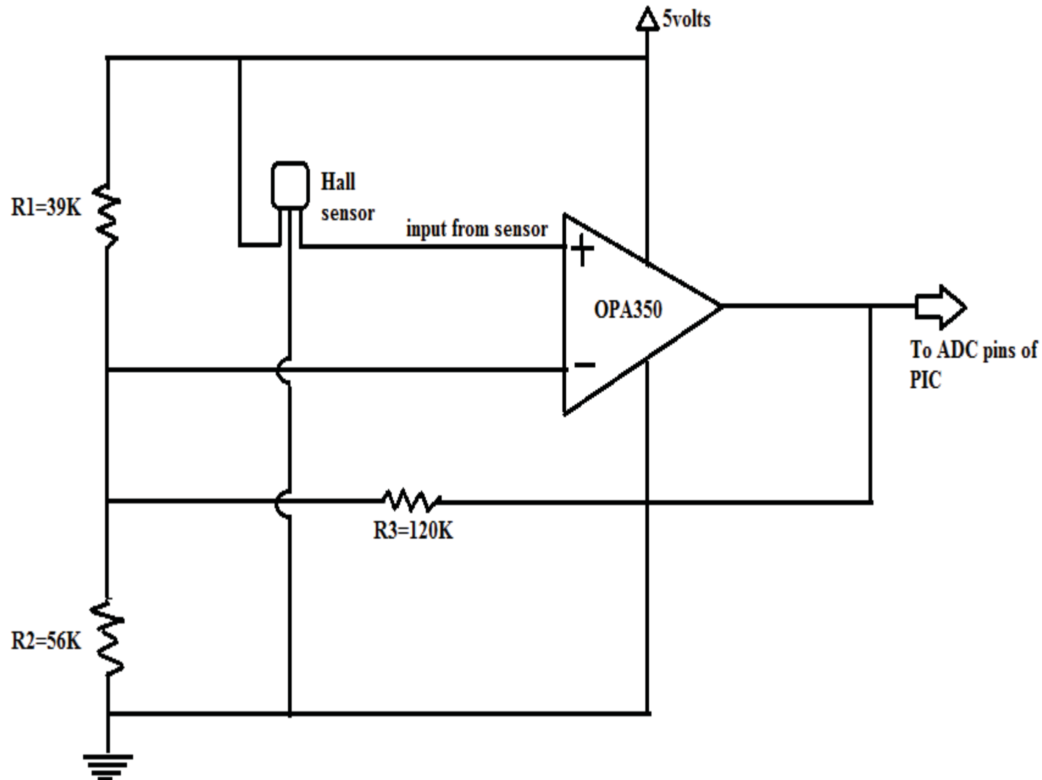

Figure 3. Amplifier Circuit

This signal is then sent to the ADC pins of PIC.

3.3 PIC Microcontroller-

PIC16F876A has built in 10-bit Analog-to- Digital Converter module (A/D) with fast sampling rate approximately 0.632 MHz and good linearity (≤1 LSb). It has high current sink/ source (25mA) for digital input/output. It has 3 external interrupt pins and four timer modules. The PIC16F876A features 256 bytes of EEPROM data memory, self programming, an ICD, 2 Comparators, 2 PWM functions, and a Universal Asynchronous Receiver Transmitter (USART). All of these features make it ideal for more advanced level A/D applications.

3.4 RF Module-

The RF module, as the name suggests, operates at Radio Frequency. The corresponding frequency range varies between 30 kHz & 300 GHz. In this RF system, the digital data is represented as variations in the amplitude of carrier wave. This kind of modulation is known as Amplitude Shift Keying (ASK). Transmission through RF is better than IR (infrared) because of many reasons. Firstly, signals through RF can travel through larger distances making it suitable for long range applications. Also, while IR mostly operates in line-of-sight mode, RF signals can travel even when there is an obstruction between transmitter & receiver. Next, RF transmission is more strong and reliable than IR transmission. It uses a specific frequency unlike IR signals which are affected by other IR emitting sources. Above listed qualities makes RF, a better substitute for wireless communication.

IV. CONTROL SCHEME

The flow chart of our Control scheme is shown in Figure 4 and Figure 5.

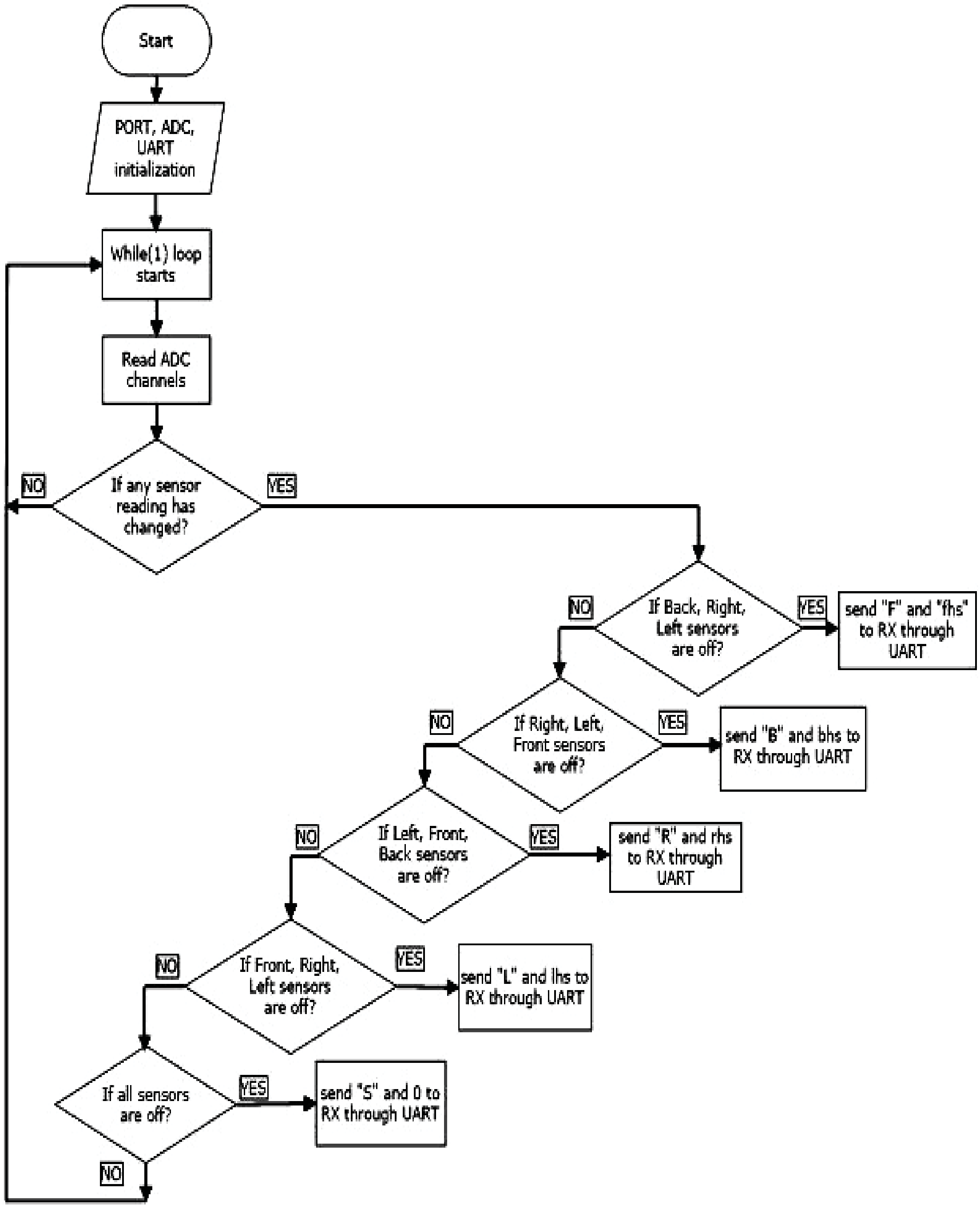

Figure 4. Flowchart depicting transmission process

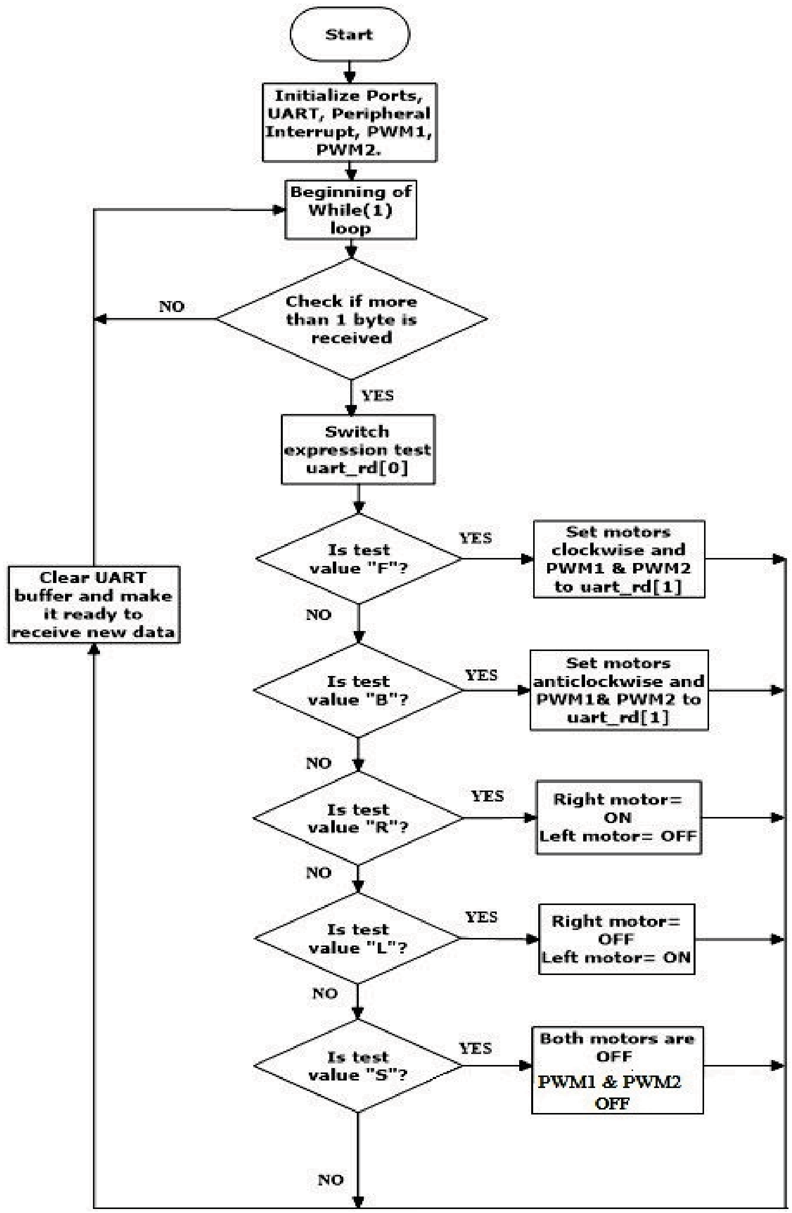

Figure 5. Flowchart depicting receiving process

V. SIMULATION AND TESTING

The control algorithms for the system were designed using microC. MicroC offers a full-featured ANSI C compiler for 5 different microcontroller architectures and is the best solution for developing code for microcontroller. It features intuitive IDE, powerful compiler with advanced SSA optimizations, lots of hardware and software libraries, and additional tools.

Codes written were tested using circuit designing and simulation software, Proteus Professional [24]. Proteus is software for microprocessor simulation, schematic capture, and printed circuit board (PCB) design. System components

- ISIS Schematic Capture - a tool for entering designs.
- PROSPICE Mixed mode SPICE simulation - industry standard SPICE3F5 simulator combined with a digital simulator.

- ARES PCB Layout - PCB design system with automatic component placer, rip-up and retry auto-router and interactive design rule checking.

- VSM - Virtual System Modelling lets co simulate embedded software for popular micro-controllers alongside hardware design.

The variation in ADC values were monitored using Termite Terminal software [25]. If the user quickly flicks the magnet towards one of the four sensors starting from the dead zone, the sensor outputs an analog signal. This results in variation in ADC values for the particular sensor.

VI. RESULT

PIC16F876A was used to design the TDS system. The sensor outputs were amplified and the variations in ADC values, due to the presence of magnetic field were observed through Termite terminal software. The signals transmitted by transmitter were received by receiver circuit, which resulted in movement of powered wheelchair. The control algorithms and circuits were tested using Proteus Professional software.

The prototype is complete and successfully tested.

VII. CONCLUSION

A tongue operated magnetic sensor based wireless assistive technology has been developed for people with severe disabilities to lead a self-supportive independent life by enabling them to control their environment using their tongue. This technology works by tracking the movements of a permanent magnet, secured on the tongue, utilizing an array of linear Hall-effect sensors. The sensor outputs are a function of the position-dependent magnetic field generated by the permanent magnet. This allows a small array of sensors to capture a large number of tongue movements. Thus, providing quicker, smoother, and more convenient proportional control compared to many existing assistive technologies. Other advantages of the Tongue Drive system are being unobtrusive, low cost, minimally invasive, flexible, and easy to operate.

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