A Novel Galvanic Vestibular Stimulation Based Navigator For The Blind

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Abstract

Sight; or visual sensory is undoubtedly the most important source of information that a human requires for mobility and navigation. Without this, humans become passive and dependant on others. The major problems faced by the visually impaired while walking are tackling short distant obstacles, and planning long distance trajectory. Technology today has devised a plethora of short distant obstacles detection systems like the Electronic Travel Aids, but the problem of planning long distances, i.e. keeping up with the intended bath to travel and not deviating from it, still remains unsolved. This project aims to solve this problem using the phenomenon of Galvanic Vestibular Stimulation as a means to subconsciously guide the visually impaired.

Introduction

According to a report released by the World Health Organization, 285 million people are estimated to be visually impaired worldwide: 39 million are blind and 246 thousand have low vision. About 90% of the world's visually impaired live in low-income settings. The major causes are uncorrected refractive errors , un operated cataracts and glaucoma. [1]

Technology has helped the blind to get a sense of the environment around him and also to walk past obstacles without facing much difficulties. At present the most commonly used aid for a blind is the white cane, as it is inexpensive, lightweight and small. However, the cane is only capable of short range probing of the environment and is also unable to detect overhanging obstacles. It also requires over 100 hours of training. The second most successful blind aid is the Guide Dog. They are an effective form of blind aid, but can be very expensive - Approximately $35,000 to train one and also guide dogs are very limited in number(especially in a country like India), so is not easily accessible by everyone and some places are restricted to dogs, where the blind may face problems.

Electronic Travel Aids

Development of Electronic Travel Aids (ETAs) began about 45 years ago motivated by the lack of information feedback from the existing visual prosthesis such as the cane. These devices usually rely on ultrasonic or laser or camera input, usually displaying the interpreted information through auditory display or through tactile devices or in some extreme cases through cortical implants of electrodes.

The key attributes of the ETA's at present are:

- The ease of display interpretation
- Portability of the device
- The performance of the device
- Cost

On the other hand, the limitations of the existing ETA's are,

- Lack of usability evaluations to validate the design of the interfaces for blind people. For example, devices that use an auditory display require users to use headphones, affecting the hearing perception of blind individuals, upon which they base most of their navigation on.
- So far, ETA research has been aimed mainly at obstacle detection and avoidance, not being able to contribute to the overall improvement of navigation for the blind.
- Another limitation ,which is also a motivation for this project, is that ETA's DO NOT plan long distance trajectories.

AIM

Discussing the struggle of adapting in a world full of intricacies ,there are numerous problems that a visually impaired faces, while on the road or at home. They have to prevent themselves from hitting into obstacles as well as keep up with their intended path to travel and not deviate from their path. This problems is so big that that sometimes it happens that when blind people try to cross a wide street or multiple lane street, they end up at the same side of the street where they started from. So they actually walk half a circle while trying to cross the street. And this problem is not solved by the white cane or other electronic travel aids.

The project aims to help blind to stay on the track he wants to travel and not walk into the path of vehicles on a road. Using the phenomenon on Galvanic Vestibular Stimulation, this device acts as a secondary device(primary being the ETA's) which can enable a person, along with dodging obstacles , to easily stay on the track on which he wants to travel without deviating from his intended course.

Another highlight of this device is that it acts at a subconscious level of brain activity, hence the subject need not voluntarily adjust the direction of his gait. The functioning of this device is discussed in the following pages.

BACKGROUND

THE VESTIBULAR SYSTEM

The human vestibular system is made up of organs that have the ability to sense both angular and linear accelerations. On each side of the head there are a set of three angular sensors individually called the superior, posterior and horizontal semicircular canals. These are configured orthogonally to one another, allowing for sensing of angular acceleration in all axes (Fig. 1.1). To sense linear accelerations, including the effect of the gravity vector, the vestibular system also contains (on each side of the head) a pair of otolith organs, namely the saccule and the utricle. As a result of their orientation in the vestibular system, the utricle is sensitive to horizontal accelerations whilst the saccule measures vertical acceleration. [3]

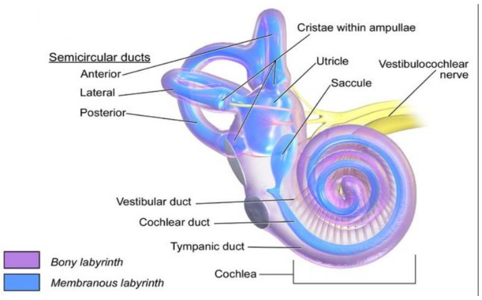

Fig. 1.1

Canal and Otolith Configuration. Both the semicircular canals and the otolith organs combine to provide sensory information pertaining to balance and head motion. It should then be noted that the vestibular system is not only important for maintaining upright stance but also for the functioning of eye and head motion, particularly the Vestibulo-Ocular Reflex (VOR). In the VOR, the reflex is primarily driven by the sensory organs of the vestibular system.[4] Providing a constant and silent stream of information from these sensors to the brain, the vestibular system has been observed as fairly unique in the human body.

GALVSNIC VESTIBULAR STIMULATION

The principles of galvanic stimulation and its wider effects on the human body have been known and experimented with for hundreds of years. Indeed one of the earliest investigations into the conductivity of nerves and muscles was carried out by Luigi Galvani who spent 20 years exploring the associated phenomena before publishing his major work. Since then, methods of GVS have become more refined in order to lead to safer clinical testing apparatuses, and it is now possible to produce vestibular responses without approaching pain thresholds in patients. Despite this long history, however, debate continues amongst modern medicine and scientific communities with regards to the exact outcome of galvanic stimulation on the nervous system.[5]

Galvanic vestibular stimulation, in its current form, involves placing electrodes on the mastoid process of the temporal bone (behind the ear) and at a common reference point, often the back of the neck at the C7 vertebra, and applying a small electrical current. Along with a feeling of vertigo and dizzying effects, when applied during regular stance, the response to the current input is a body sway in the direction of the anodal (positive) ear.[6] This has also been verified as independent and irrespective of which direction the head faces and culminates in a constant posture that is tilted away from the vertical axis. [7]

The magnitude of this sway response is proportional to the magnitude of the galvanic stimulation. Indeed, clinical tests performed involve applied currents ranging in magnitude from as low as 0.05mA to 5mA .

ELECTRODE CONFIGURATION

There are two methods to arrange the electrodes to get the desired results.

- Monaural: In this, one electrode is placed on the mastoid process and the other on the central neck. Relatively lesser swaying response is observed but it can asses each vestibular organ individually. (Fig. 1.2)

Fig. 1.2

- Bilateral-Bipolar: Both the electrodes are put on each mastoid process. Significant swaying response is observed, but, it cannot asses either of the vestibular organs individually. (Fig. 1.3)

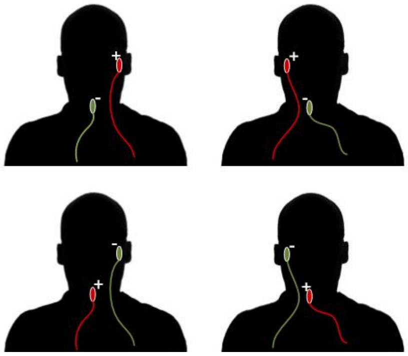

Fig. 1.3

Results of different methods to apply current stimuli: There are three ways to provide current to the electrodes.

- Square wave method: It is a consistent method and found to be the most effective of the three. The responses are directly proportional to the current provided. Its effectiveness depends upon the duration of current supplied.
- Sinusoidal stimulus: Uses varying amplitude and frequencies. The most effective frequency range is found to be 0.5-0.25hz. This method is not much preferred over the square wave method and the stochastic method as patients sometimes get habituated to this method which makes the response less effective.
- Stochastic random stimulus: This is a modification of Sinusoidal stimulus as it reduces the habituation characteristic created by the Sinusoidal method by applying random Gaussian noise (what we hear when a TV channel doesn't work). Latency of input and output is 60-120 milliseconds.
- Skin resistance: The skin resistance can vary from person to person depending on the thickness ,nature ,cleanliness and moistness of the skin. Also it depends upon the type of electrolytic gel that is used. So either the user has to be precautioned not to put on the device while sweating as it can act as an hazard or the device should be collaborated according to each individual.

RESPONSE

Whenever current is passed through the electrodes, the subject suffers from mild dizziness and vertigo. Also various experiments were carried out in two different scenarios, first -when the man is stationary, second- while walking. Both the cases are discussed distinctly below.

- Stationary tests: Head sway, anterior-posterior sway and lateral sway were observed.
- Walking tests: Limited papers are available in this field but when experiments were conducted, very exciting results were seen. The results of experiments prove that if a man is blind folded and asked to walk, by passing current through the electrodes attached to his mastoid process the person will start deviating towards the direction of the anode and change its path of trajectory.

Further some important points were noted

- This deviation is highest when the GVS is applied during the heel contact stage of the gait cycle.
- It was also observed that the deviation is caused due to the modification in ankle movements, at medium latency.
- The GVS, gait tracking and communication components of the system must be of small enough form to be wearable and portable.
- All wearable components of the system must not restrict walking motion and must therefore use only wireless communication methods.
- The stimulator device must be capable of delivering up to 5mA square or stochastic pulses in any of the four monaural configurations.
- Measurement of balance response will be in the form of walking trajectory in the horizontal (with respect to gravity) plane.
- Time synchronization must exist between the applied stimulus signal and the measurement data.

IMPLEMENTATION

This device would be based on the working of a PID controller.[8]

Integrating a PID controller to the GVS system attached to the body will help a person to stay on the intended path to travel. That is, when the person is moving on a certain track which is either curved or non-uniform, the PID controller can detect the error measured about the upcoming curve and send this information to the GVS system to minimize the error and try to come back on the original path. We have an anode on each ear and in response to the PID detection the GVS device would allow current to pass through the circuit which has its anode (+ve) electrode in the direction as that of the intended path. The stimulation caused by the current would make the person turn towards his intended path.

Using this device, a Blind person walking on the street will not have to bother about getting away from the footpath and walking into vehicles. This potential device can, by itself, make the person stay on his intended path, that too, without seeking the person's labor.

LIMITATIONS

- The person might sense a feeling of dizziness and vertigo as a result of interfering with the vestibular system.
- It is difficult to test the device as we cannot do live testing on humans with current.

CONCLUSION

This device can serve as a secondary device to plan long distance trajectories, without letting the person know about the change in his gait. The major advantage being its working on the subconscious level of brain activity.

With the pace of advancement of technology, we can confidently overcome the limitations. Also, in the upcoming years, the GPS may become more accurate by minimizing its error ratio and hence enable us to incorporate in our device to make it better[9].

There is also a huge possibility that the GVS may adapt to the human body perfectly and the problem of dizziness is not faced at all, with the upcoming technology revolution.

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