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Continuous Intraocular Pressure Monitoring by Non-Invasive Wireless Pressure Sensor

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Abstract
This project presents that the glaucoma is the second leading cause of blindness and is most accurately defined as a collection of diseases that have in common, damage to the optic nerve and loss of visual field with increased intraocular pressure (IOP) being the primary risk factor. Though there are treatments available, there is a requirement to develop improved diagnostic and therapeutic techniques to overcome this disease. A continuous intraocular pressure measurement during the patients' routine daily activity can provide a valuable insight. Here microcontroller is used to convert the analog signal to digital and which the sensor output through which the pressure of the eye is measured continuously and the monitored data can be send via wireless technology through ZigBee. The transmitted data can be viewed by the doctors through PC were it is received by the ZigBee transceiver.

1. Introduction

Glaucoma is a condition that causes damage to the eye's optic nerve and gets worse over time. Statistics show that glaucoma is the second leading cause of blindness in the world according to World Health Organization. It's often associated with a build-up of pressure inside the eye. Glaucoma tends to be inherited and may not show up until later in life. The increased pressure, called intraocular pressure, can damage the optic nerve, which transmits images to the brain. If damage to the optic nerve from high eye pressure continues, glaucoma will cause permanent loss of vision. Without treatment, glaucoma can cause total permanent blindness within a few years. Because most people with glaucoma have no early symptoms or pain from this increased pressure, it is important to get diagnosed regularly and treated before long-term visual loss occurs. Glaucoma usually occurs when pressure in your eye increases. This can happen when eye fluid isn't circulating normally in the front part of the eye. Normally, this fluid, called aqueous humor, flows out of the eye through a mesh-like channel. If this channel becomes blocked, fluid builds up, causing glaucoma. Methods like Tonometry, Ophthalmoscopy, and pachymetry are available for continuous monitoring. Variations of IOP in humans have been known for at least a century, with fluctuations occurring in a regular pattern as a circadian rhythm, or randomly over short and long periods. Statistics show that glaucoma is the second leading cause of blindness in the world according to World Health Organization [4]. Devices capable of monitoring IOP around the clock would improve our ability to understand the dynamic processes at work in glaucoma.

2. Structure of Eye

The eye is a slightly asymmetrical globe, about an inch in diameter. The front part of the eye (the part you see in the mirror) includes: The iris (the pigmented part), the cornea (a clear dome over the iris), the pupil (the black circular opening in the iris that lets light in), the sclera (the white part), the conjunctiva (a thin layer of tissue covering the front of the eye, except the cornea).Just behind the iris and pupil lies the lens, which helps to focus light on the back of the eye. Most of the eye is filled with a clear gel called the vitreous. Light projects through the pupil and the lens to the back of the eye. The inside lining of the eye is covered by special light-sensing cells that are collectively called the retina. The retina converts light into electrical impulses. Behind the eye, the optic nerve carries these impulses to the brain. The macula is a small extra-sensitive area within the retina that gives central vision. It is located in the centre of the retina and contains the fovea, a small depression or pit at the centre of the macula that gives the clearest vision.

Vitreous humour is a transparent jelly-like mass located behind the lens. It acts as a 'suspension' for the lens so that the delicate lens is not damaged. It helps to maintain the shape of the posterior chamber of the eyeball. Likewise aqueous humour helps to maintain the anterior chamber of the eyeball.

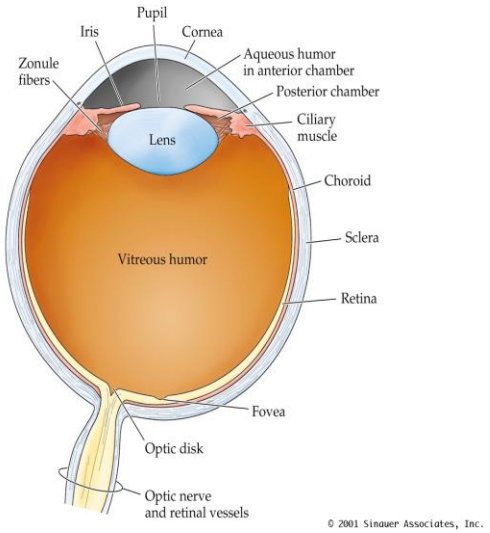

Fig: 1. Structure of Eye

2.1 GLAUCOMA

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Glaucoma is an ocular disorder with increased intraocular pressure-associated optic neuropathy. The increased intraocular pressure can permanently damage vision in the affected eye(s) and lead to blindness if left untreated. It is normally associated with increased fluid pressure in the eye (aqueous humour). The term "ocular hypertension" is used for people with raised intraocular pressure (IOP) without any associated optic nerve damage.

The nerve damage involves loss of retinal ganglion cells in a characteristic pattern. The many different subtypes of glaucoma can all be considered to be a type of optic neuropathy. Raised intraocular pressure (above 21 mmHg or 2.8 kPa) is the most important and only modifiable risk factor for glaucoma. However, some may have high eye pressure for years and never develop damage, while others can develop nerve damage at a relatively low pressure. Untreated glaucoma can lead to permanent damage of the optic nerve and resultant visual field loss, which over time can progress to blindness.

In glaucoma, the neuroretinal rim of the optic nerve becomes progressively thinner, thereby enlarging the optic-nerve cup. This phenomenon is referred to as optic-nerve cupping. Its cause is the loss of retinal ganglion cell axons, along with supporting glia and vasculature. Without proper treatment, the elevated IOP would damage patients' optic nerves in the backside of the eye, and causes the blindness in the end.

In this project, propose a non-invasive device that monitors daily and nocturnal IOP changes could assist in establishing the effect of IOP fluctuation in glaucoma, which is important to determine when considering implantable devices.

2.2 Existing Technique

2.2.1 Goldmann Applanation Tonometers

Introduced in 1955, the Goldmann tonometer was the first example of a variable force applanation tonometer, Goldmann (1955). Nowadays Goldmann-type applanation tonometry is the most common way to measure IOP in Europe and USA. It is believed to be the most reliable and accurate tonometer; thus, it is used as the standard against which other tonometers are evaluated. This type of tonometry is often utilized to measure IOP after a simple screening test (such as non-contact tonometry) has indicated increased IOP.

2.2.2 Non-Contact Tonometers (NCT)

The noncontact tonometer (NCT) is an applanation tonometer, which works on the principle of a time interval, Grolman (1972); Forbes et al. (1974). It has an advantage of eliminating mechanical contact with the eye, other than by jet of air and is also called "air-pu_" tonometer or noncontact pneumatonometer. Noncontact tonometry does not use eye-drops to numb the eye, and, hence could be used as a simple way to screen for high IOP and to test children. The instrument estimates the IOP from the change in the light reflected o_ the cornea as it is indented by the air puff, Moseley (1995). The maximum of light reflected to a sensor occurs at the point of applanation. The time taken is recorded and computed by the instrument to produce a reading of ocular tension in mmHg. Because the air-puff tonometer relies on corneal applanation, it is subjected to the same potential measurement errors as the GAT, Zadok et al. (1999). An additional source of error in NCT measurements is that IOP is determined at a single very brief instant in time (1□3 ms), while IOP can pulsate considerably over time as the choroid fills with blood and then empties in concert with the cardiac cycle. Instantaneous fluctuations may occur and it is recommended to do at least three readings for each eye, calculating the average. It is suggested that NCT is reliable for measuring IOP within the normal range, but this instrument is limited by abnormal cornea and decreasing reliability in higher pressure range, Shields (1980); Menage et al. (1994). It is also less portable and more expensive than many other tonometers

2.2.3 Electronic Tonometers

The MacKay Marg tonometer is a recording electronic applanation instrument that may be called a Tonometer with "composite" applanated areas. This type of tonometric measurements may be performed in any position (lying or sitting) and is particularly useful for patients with corneal disease and irregular corneal surfaces due to edema or scarring. In these patients, the optical applanation tonometry cannot be accurately used, producing grossly misleading results, Kau_man (1972). MacKay Marg tonometer o_ers another alternative, correlating exceedingly well with the true measurements of IOP, Kau_man et al.(1970); McMillan & Forster (1975).

3. System Architecture Design

In this project, the Transmitter section, a microcontroller is used to convert the analogue sensor output to digital, through which the pressure in the eye is measured continuously. The monitored data can be send via wireless technology through ZigBee. In the Receiver Section, the transmitted data can be viewed by the doctors through PC were it is received by the ZigBee transceiver.

In glaucoma diagnosing process, after the input signal is received, the signals are amplified and then send to the microcontroller. Microcontroller converts the analogue signal to digital signal and also helps in serial communication. MP lab is used to compile the acquired signal from one language to the other to obtain the required output.

Here, ZigBee network is used to transfer data from the system to the doctor's laptop. Since there is no data loss and no interruption occurs in ZigBee, here this network is been used. The required IOP values are displayed in the PC through MATLAB.

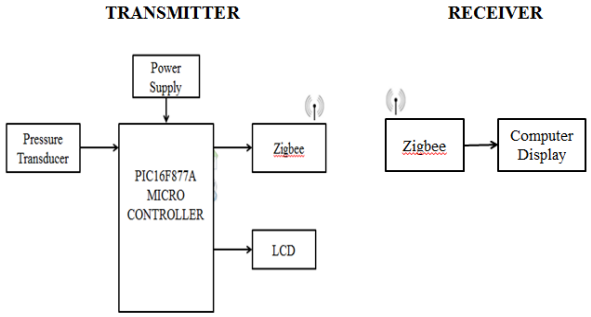

Fig: 2. Block Diagram

3.1 System Requirements

3.1.1 Software Requirements

Compiler - MP lab
Language - MATLAB 10
Simulation - Proteus

3.1.2 Hardware Requirements

Transducer - Pressure Transducer
Microcontroller- PIC16F877A
Network - ZigBee
Oscillator - 12 MHz Piezo Electric Crystal Oscillator

4. Conclusion

This project is simple and is highly efficient for continuous monitoring of IOP with less cost. The work described in this project is concerned the better and accurate output of intraocular pressure. An interesting development has been the shift in emphasis towards high level vision tasks that aim to understand the interpret of the signal and the pressure signal. The project helps to identify the pressure fluctuations with respect to the time. Nocturnal and diurnal pressure varies from one individual to the other. In order to maintain a positive criterion, it is important to measure the IntraOcular output. The simulation output is successfully executed using Proteus software and the system is ready to be implemented for hardware phase. The use of microcontroller converts the signal from analogue to digital that can be displayed as a pressure output.

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