2010

P. N. Goswami

Thesis title

Prediction and Measurement of Human Body Composition using non-invasive Techniques

Abstract

This thesis deals with studying the internal biomechanical characteristics of the human upper extremity. This issue long ago proved to be very complex by numerous researchers. The problem of determining biomechanical properties in the upper extremity was dealt with in a laboratory environment using industrial robots which are normally used for other tasks in different environments. In the presented experiments we took advantage of the fact that robot movements can be accurately repeated as many times as desired and that several other sensory devices can also be incorporated into the experimental setup enabling us a very wide range of experimental possibilities. It needs to be emphasized that most upper extremity studies come from a more medically-oriented environment resulting in a fairly different approach researchers have towards the subject. On the other hand however, there are also many engineering oriented works which usually utilize special purpose robots developed especially for a certain experimental task.

In our experiments we used two different types of industrial robots (Yaskawa c _ Motoman sk6 and Motomation c _ St¨aubli - RX90) to impose accurately controlled robot motions into the upper extremity. The upper extremity was modeled as a simple 3 degree of freedom (3DOF) planar manipulator while all the experiments were performed in the sagittal plane of the studied subject. The subject's hand was always lightly strapped to the robot attached handle while not exerting any voluntary muscle activity. The upper extremity was then lead through a specified trajectory in space. During this process angle measurements were taken by means of an optical 3D positioning system and end-point forces were measured with a force sensor attached to the robot end-effector.

Firstly we tried to determine the nature of upper extremity joint passive moments while assuming other biomechanical parameters such as masses and centers of gravity (COG) from the literature. The parameters were determined when the shoulder and elbow flexion-extension angles were fixed at ten different angles while the unfixed joint was allowed to slowly move through a wide portion of its range, along a programmed robot trajectory. The method for determining passive moments was derived from the inverse dynamic equation of a planar 3DOF arm. Comparing the obtained passive moments of six young male subjects unequivocally showed that there was a large non-linear adjacent angle dependency. On the other hand this non-linear nature could also be observed in relation to muscle activation and different joint velocities. The results came as a further confirmation to those obtained by other authors and showed a severe complexity with which the modelling of upper extremity biomechanical behaviour can be performed.

The second experimental phase of this thesis focused on identifying all biomechanical parameters which determine upper extremity motion at low speed. Again the upper extremity was guided through a specified trajectory while measuring angle data and contact forces. A suitable low velocity trajectory was imposed into all joints, with very small angular deviations. The arm was assumed to be linear within a small angular region, since passive properties from the first experiment showed no significant nonlinearities for such small angular ranges. The outcome of the identification was an estimate of masses and COG coordinates for the lower arm and palm segments, their products for the upper arm and the passive moments around the measured angle of all joints in the sagittal plane. These results were then compared to the literature estimates which are based on average population. An optimization based identification procedure was developed, which assumes the upper extremity model of a 3DOF rigid body planar structure in a closed kinematic chain configuration with the robot. The solution is based on fitting the joint torques calculated from contact forces to those predicted by the inverse dynamic model of the linkage. In order to verify the proposed identification procedure the experiment was first performed on a 2DOF mechanical arm with dimensions similar to those of the actual human arm. This mechanical model was designed using CAD software that provided an accurate assessment of all necessary dynamic parameters. The results showed good correlation between our identification outcome and reference values.

Thirdly a simulation of the whole experimental setup made with Matlab c _ - Simulink is presented. This gave a better insight into the experimental quantities and allowed us to gain much more control over performing the experiment. The simulation environment allowed us to observe all kinematic data such as joint angles, angular velocities and angular accelerations on one side and dynamic quantities such as joint torques and contact forces on the other. This also allowed us to hypothetically perform experiments which were not performed in reality. The results of the simulation gave comparable results to those obtained from measurement.

In the following chapters, the data from all performed experiments are shown, analyzed and put into context with current biomechanical research. It is also discussed whether the study could have useful implications to developing future application and research methods.

The purpose of body composition assessment is to partition the body into quantifiable components, representing the primary tissue or chemical components of the human body. The body composition assessment is mostly linked to the determination of the relative amount of fat in the body or percent body fat. Interest in body fat content has grown over last 50 years spurred by research which links body composition and health, with measurement of body fat content having applications in several fields of study such as medicine, public health, nutrition, health and fitness, and exercise science. The average body fat content for boys is 15% (10-25%; Normal Range) and for girls is 25% (18-32%). Several key relationships between health and obesity have been identified; obese individuals have a higher risk of impaired cardiac function, hypertension and stroke, diabetes, renal disease, gall-bladder disease, pulmonary disease and/or impaired pulmonary functioning, degenerative joint disease, abnormal plasma lipid and lipoprotein concentrations. However, while these relationships exist, recent research indicates that it is the patterning of adipose tissue distribution which determines the health risk of obesity, independent of total body fat. Visceral adipose tissue poses a greater health risk than subcutaneous adipose tissue.

2011

Dipali Bansal

Thesis title

Design and development of portable wireless system for assessment of human physiological parameters.

Abstract

Cost, quality and access are the three major parameters on which the health care systems can be gauged objectively. In view of this, various systems used presently to detect, transmit and analyze human physiological parameters have addressed a wide variety of clinical and technical issues. This includes enhanced power competence, reduced development cost, compact physical structure, convenient sensor arrangement and signal processing, wireless networks etc. which provide adept and simple ways to continuously monitor human physiology. Although enormous research efforts have been made in the fields of human physiological signal monitoring, wireless transmission and signal feature extraction, most of them are truly not affordable and reachable to the masses. There is a further scope for improvement, especially in terms of noise sensitivity, universal connectivity, response time and on-line processing. Advancement in computer based portable data acquisition (DAQ) hardware and software could facilitate development of monitoring instruments which are not only simple but also provide compatibility at a much lesser cost. This thesis focuses on design and development of computer based enhanced system to detect, digitally process and remotely transfer human ECG, EMG and Carotid pulse waveform in real time.

The computer based simple system developed using Piezo-electric transducer allows detection of Carotid Pulse Wave and manifests changes in it under different body postures. The acquired signal is viewed on a freely downloadable virtual oscilloscope, stored and loaded into MATLAB® for digital filtration. The system developed is tested on human subjects. It is then transmitted from one PC to another using Windows Hyper-terminal utility and ZigBee wireless network modules. In parallel a Simulink model is created to analyze the effect of digital filtering techniques on real time acquired Carotid pulsation.

Further, an amplifier arrangement is developed using TL084C instrumentation amplifier (IA) and Ag-AgCl sensor to acquire single channel EMG signal under different levels of bicep muscle contractions. Front end of the cascaded amplifier developed include DC restoration circuit, active analog filter and right leg drive. Virtual oscilloscope and digital filter algorithm are developed in MATLAB to view real time filtered EMG signal. A commercially available wireless FM microphone system is used for real time transmission of EMG signal. A dual channel acquisition hardware and algorithm in MATLAB is further developed to simultaneously acquire time coherent EMG and Carotid pulsation so as to analyze the effect of rectus abdominal pressure change in Carotid wave.

Six different 50 Hz notch filter designs are verified in P-Spice to evaluate their performance and the developed hardware of the optimized circuit is used along with the tested amplifier system to obtain improved ECG signal. The acquired ECG is transmitted in real time wireless mode using FM transmission module. Further a starter kit from Microchip, dsPIC 33F Digital Signal Controller (DSC), which has a wide application in audio processing, is explored for automated analysis and re-acquisition of ECG signal. Algorithm is additionally developed in MATLAB for automated analysis of real time acquired, filtered ECG signal. The dual channel arrangement is also utilized to acquire time coherent ECG signal and Carotid pulse wave to calculate time domain Heart Rate Variability (HRV) parameters.

The computer based system developed is capable of direct interface through the sound port of the PC and does not require proprietary DAQ units and ADC units. The system tested for Carotid pulse wave acquisition requires only a Piezo-electric sensor and no additional electronic arrangement. ZigBee wireless module successfully transfers digitally filtered Carotid data from one PC to another. Simulink model also allows real time acquisition and digital filtering of Carotid pulse. The amplifier system developed is successful in acquiring real time EMG and ECG signal on a MATLAB based oscilloscope using versatile Ag-AgCl sensor. Cost effective Wireless FM Microphone used, is compatible to the sensor and the computer arrangement and transmits EMG and ECG signal in real time. Hardware 50 Hz notch filter and DSC based enhanced system gave improved ECG signal.

Algorithm developed in MATLAB for on-line feature extraction enables QRS peak detection, RR interval, Heart rate and power spectral density (PSD) calculation in ECG. The statistical time domain HRV parameters successfully evaluated using this arrangement are the mean

Heart rate (bpm), Mean RR interval, RMSSD, SDNN and SDindex. The algorithm is finally converted into an independent executable stand alone application program. The dual channel arrangement developed depicts raised amplitude in Carotid pulse wave with increased rectus abdominis pressure and also correlates time domain HRV parameters derived from ECG and Carotid data. Negligible difference was found in the HRV values derived from both the signals and hence use of Carotid pulse wave for HRV analysis can be explored in critical situations. This thesis thus marks an attempt to provide a relevantly cost effective solution to human physiology real time monitoring and transmission that is more realizable and would directly benefit larger population.

Shabana Urooj

Thesis title (2011)

Design and development of a computer based biophysical model for diagnosing Pulmonary Edema

Abstract

In the area of clinical diagnosis a physician always depends on the technology, instrumentation and engineering principles to be surer about their opinion. In present scenario diagnostics, health treatments and critical care is solely depending upon advance technology based systems and equipments. It is also necessary to point out that clinical diagnostics prefers to rely on non-invasive methods. Some disease requires diagnosis in early stages, rapid and continuous monitoring, and one such disease i.e. Pulmonary Edema is considered in this work. The objective of this research is to save and help mankind by collaborating the two essentials, medicine and technology to develop new tools for the development of healthcare and monitoring systems. This work is focused to design a computer based, fast and reliable system which should be able to diagnose Pulmonary Edema quickly and quantitatively.

The need of clinical measurements incorporating diagnosis to prognosis is emphasized and the importance of non-invasive measurements in clinical applications is discussed. Brief descriptions on the survey of literature for the diagnosis of pulmonary edema with and without involving computer based systems are highlighted in the introductory chapter. A little light is also thrown on the software LabVIEW. In second chapter two important aspects of the disease 'Pulmonary Edema' are unfolded. The first is physiological aspect in which the physiology of the involved organ especially lungs in terms of the focused disease is discussed. Definition causes and symptoms of Pulmonary Edema are explained. Various types of Pulmonary Edema are also described briefly. In the second aspect the electrical impedance analysis of Pulmonary Edema is described. Secondly principle of electrical impedance technique and measurement of impedance of thorax are taken up. In preceding section the transthoracic electrical impedance is predicted by using empirical relations based on anthropometric dimensions of thoracic area. The predicted values of transthoracic electrical impedances are compared with the previously reported data to validate the current technique and software approach using LabVIEW. The reported approach is more accurate than the existing methods hence can be used as a routine clinical tool furthermore the amount of fluid accumulation i. e fluid volume can also be closely approximated. The developed LabVIEW software based program is able to detect and diagnose pulmonary edema by quantifying the thoracic fluid volume accurately. The amount of edema is difficult to estimate. Clinical examination, chest radiography, and blood gases have proven to be of limited

significance in quantifying pulmonary edema. Previous attempt lacked an absolute quantification of the disease and looked only at the presence of the disease. A simple expression is being extracted from a pre defined curve and the obtained relation is able to predict the quantity of fluid present inside the lungs for diagnosis of Pulmonary Edema and monitoring. Moreover the utilized technique is purely non-invasive and able to predict the severity of the disease.

A Microprocessor Based System (MBS) for non-invasive measurement of Pulmonary Edema is also analyzed and tested to diagnose High Altitude Pulmonary Edema. Twenty subject's data collected at All India Institute of Medical Sciences (AIIMS), New Delhi is used for the system validation. The MBS is able to detect Pulmonary Edema quantitatively in the patients and normal subjects. At the same time it also provides the value of measure and predicted transthoracic electrical impedance. It is observed that the difference in measured and predicted impedance is more for patients. The difference is leading to higher amount of fluid quantities in patients and hence validates the presence of HAPE.

Model based approach is also incorporated in this thesis. A simple cylindrical model is drawn and the main aim of the reported simplified modeling for volumetric estimation of Pulmonary Edema is to educate and prove that the volumes are greatly responsive to the act of breathes i.e. the inspiration and expiration states and hence can be adopted for diagnosis of several diseases. This model based approach shows the extent of its sensitivity in terms of volumetric variations even in the state of inspiration and expiration itself. An observable difference is found in the values of thoracic impedances and thoracic volumes at the state of full inspiration and at resting or expiration state. Remarkable differences in thoracic volumes are computed with the act of breathe just by using anthropometry. The variations in thoracic volumes are quite obvious even for the normal subjects.

Finally intelligent, fast and non invasive systems for diagnosis of Pulmonary Edema and other thoracic impedance investigations for various related diseases are proposed. The proposed systems facilitates the development of a system or device which could be extremely portable and clinically adoptable for smart and expert diagnosis, if practices. It is essential to highlight that this technique is non-invasive or non-destructive. Any invasive method can only be performed in

a clinical environment. That's why the development of the designed model may lead to a device which may become conventional and can be commercialized. The proposed online model is based on LabVIEW environment. In addition it may also employ a data acquisition card. With the aid of suitable signal processing and hardware optimizations the instrument might become a truly portable and non-invasive pulmonary monitoring system. The research work is further extended for two more systems that has been studied, analyzed and proposed in the thesis. The first is; DAQ based online computer based model for diagnosis of Pulmonary Edema and the other is a DAQ-Based volt-amperometric transthoracic impedance measurement system.

The proposed model may lead to a hardware which would be adequate for clinical diagnosis and monitoring patients. Several results obtained for a number of volunteers further evidence the feasibility of the proposed system in monitoring the breath activity of a patient or normal subject and also in extrapolating the relevant diagnostic parameters. With the aid of suitable signal processing and hardware optimizations the software model may be converted to a hardware system and in future work it might become a portable, non-invasive and computerized diagnostic instrument.

2015

Ghazala Perveen Khan

Thesis Title: Prediction of body composition for Indian population using bioelectrical impedance

Abstract

Body composition analysis (BCA) is necessary to yield data about normal growth, maturity, and longer life. By measuring body composition, a person's health status can be more accurately assessed. Bioelectrical impedance analysis (BIA) is a commonly used method for estimating body composition which actually determines the electrical impedance, or opposition to the flow of an electric current through body tissues which can then be used to calculate an estimate of body composition. The method is popular owing to its ease of use, portability of the equipment and it's relatively low cost compared to some other methods of body composition analysis. To the best of our knowledge there were no prediction equations that were validated on Indian subjects. The objective of the study was to develop prediction equations for Fat free mass (FFM) and Total body water (TBW) for Indian subjects based on Bio electrical measurement of weight, age, sex, height and Impedance Index. To predict the same; a form of statistics known as multiple regression Analysis have been used which allows an immeasurable component such as Total Body Water, Fat Free Mass etc. to be predicted from one or more measured variables. The multiple regression analysis of the data is carried out with the help of statistical software R version (2.9.2) which is useful for multiple regression analysis and easy handling of the data. In the current paper; based on the correlation between Total Body water, Fat free Mass, Impedance Index at different frequencies and weight, age, sex and height;8 sets of prediction equations were developed.

Keywords: Bio Electrical Impedance Analysis, Prediction Equation, Multiple Regression Analysis, Total Body Water, FAT Free Mass.

Introduction: The present thesis embodies the researches carried out by testing hypothesis of prediction equation obtained from Matron-II Bio Electrical Impedance Analyzer on Indian subjects who participated or volunteered in the study. Their clinical data were included to carry out various studies based on the work plan that is discussed below. It must be mentioned that as early as 1940 researches on Human Body Composition has been area of interest for scientists. Based on studying this parameter of Human Body Composition, Population specific Prediction Equation of subjects have been studied from time to time using different research tools and body compartmental models. The first type of method is called as reference method where some component of the body are measured directly and from these measured component calculate the body fat percentages are calculated. Examples of reference method include Hydro densitometry (Under Water Weighing), Dual Energy X-Ray absorptiometry (DEXA), Hydrometery, and Air Displacement Plethysmography. The second types of methods are called as field methods such as Skin fold method (SKF), Body Mass Index (BMI), Bio Electrical Impedance method (BIA), and Near-Infrared Interactance. These are indirect methods of measuring something with the hope of getting the same value of the body component as obtained through reference methods.

Maintaining a healthy body weight and level of fatness is the key to healthier and longer life. Scientists have been trying to develop the prediction equation for human body based on the basis of age, sex, level of fatness and ethnicity. The purpose of the study was to develop prediction equations of Indian subject. Bioelectrical Impedance Analysis started as research tool but then it greatly advanced providing clinicians with data that they have no other rapid, reliable or non-invasive method. In the present study, Bio Electrical Impedance Analyzer Matron-II has been used as an instrument to obtain individual data of the subject giving following information: age, sex, weight, Total Body Water (TBW), Fat, Fat Free Mass (FFM), Muscular weight, Total Body Potassium (TBK), Body Density, Body Volume and various other such parameters of human body composition such as Intra cellular water, Extra cellular water, Resting Energy Expenditure, Body Cellular Mass, Lean Body Mass, Dry weight, Mineral , Protein and Body density.

Obesity is the cause of major heart problem in the world. Due to excessive fat in body, there is blockage in artery and due to this fact people suffer from heart diseases. In every region of the world, obesity has doubled since 1980 present in either of the sex male or female. But with the Indian living style and eating habits, and obesity is most prominently seen in the women because of most of the women in India are housewife. They are living at home and consume eatables at regular interval of time. They also gain obesity immediately after pregnancy. At later stage of life obesity is the cause of diabetes, cardiovascular disease and some type of cancer. Besides this, stress and anxiety are the effects of extra fat in the body. Thus, maintaining the proper health and having proper level of fat in the body is the need of the hour. Therefore the present study deals with the general trend in health status of the Indian people. For this, prediction equations have been developed to check the trend.

One of the major causes for obesity is overeating. If a person consumes certain amount of calories daily and saves certain amount of calorie daily. Then if the person consume certain extra amount of calorie on a particular day, this will add up as Fat in the Body, and the extra Fat will then accumulate every day when he consume extra calorie. So, this habit of overeating is also the major cause of obesity. Therefore, a prediction equation for Indian subjects is developed using Fat, Fat Free Mass Component, Total Body Water, Height and Sex. From these parameters, predictions of Indian subjects have been made. To carry this study the experimental data of Indian subjects who volunteered to participate in the study have been used. To predict the same; a form of statistics known as multiple regression Analysis have been used which allows an immeasurable component such as Total Body Water, Fat Free Mass etc. to be predicted from one or more measured variables. The multiple regression analysis of the data is carried out with the help of statistical software R (2.9.2) which is useful for multiple regression analysis and easy handling of the data. The purpose of the study was to investigate the utility of multi frequency BIA for the estimation of human body composition parameters and validate the results with measured BIA value. College students provide excellent groups to study the body composition of cohorts of individual, due to variance in living style and eating habits. Thesis is based on the following work plan:

- To study the various multi-compartment models from the parameters of body obtained through Matron-II BIA Analyser.
- Test the validity of results obtained through these multi-compartment models with that obtained through BIA analyzer.
- To obtain prediction equation of these subjects using linear multiple regression analysis using (R 2.9.2) software and test the validity of results obtained through BIA analyzer.
- To test and develop the Resting Energy Expenditure equation for Indian subjects.

- Test the validity of results through Bio Electrical Impedance Analyser.

In the current thesis based on the correlation among Total Body Water, Fat Free Mass, Impedance index, weight, age, sex and height at different frequencies different sets of prediction equations are obtained. Besides this, comparative compartmental model of subject is also studied.

The work plan discussed above is carried out by developing linear prediction equation. As discussed above, R version (2.9.2) have been utilized for the study. Basically this is nothing but statistical software carried out for various statistical work. R is basically a statistical language tool with the help of which various statistical information have been achieved about the data such as; t-ratio, multiple R^2, adjusted R^2, correlation, mean, and ANOVA (Analysis of Variance) and Scatter Matrix Plot. Basically it is very much similar to S- Plus language which has been used for statistical analysis purpose. It is also used for graphical analysis, calculation of arrays, in particular matrices.

2015

Sharda Vashisth

Thesis title: Design and development of a biophysical embedded system for G-stress management of an aircraft pilot.

Abstract

Aircraft technology has advanced to give us the modern high performance aircraft, which not only pulls high G but also are highly maneuverable. Acceleration and its effects on the body have concerned the flying community since World War I. A variety of physiological effects are experienced by the aircraft pilot due to combination of acceleration and gravity encountered during flight in the atmosphere. G-stress can debilitate pilots of modern fighter aircraft and consequence accidents due to G-induced loss of consciousness (GLOC). The physiological effects of high G-stress include reduction in head level blood pressure and cardiac output that subsequently results loss of vision and GLOC. Many methods have been used to study and analyze G-stress effect. Furthermore, orthostatic intolerance (gravitational stress) is an operational trouble for the crew members of space shuttle flights who experience pre-syncopal episodes through post-flight stand tests.

Researchers have paid attention to measurements of physiological parameters of human subjects in an attempt to recognize potential means that explains the problem. The cardiovascular system is the most vital organ system for finding out the overall tolerance and response to +Gz stress. The ability to bear gravitational stress is dependent on adequate blood flow to the brain. Carotid artery is responsible for the blood flow between heart and brain. Previous studies of physiological parameters of gravitational stress affected persons conclude that heart rate variability (HRV) is the most vital parameter which can be effectively acquired, stored and analyzed. Carotid pulse waveform gives useful information that helps in assessing HRV.

A computer model is developed for carotid artery using finite element software (ANSYS FLUENT) to analyze effect of PPM. This work shows that the velocity profile at each part of bifurcating carotid artery is decreased during -1G exposure and is increased when exposed to

1G in comparison to 0 G. Wall shear stress shows that the reversed flow region along the sinus of the internal carotid artery (lCA) becomes narrower as the diameter increases. In comparison with 0 G gravity result, 1G case shows a maximal contraction of the vessel diameter due to the decreased blood pressure in the brain and -1G case shows maximal expansion of the vessel diameter due to the increased blood pressure in the brain.

A simple, noninvasive, cost effective, portable and reliable system is developed in which a piezoelectric sensor is placed on the carotid artery of the human subject and the analog output of the sensor is acquired, filtered and analyzed using application software. The developed piezoelectric sensor based system is used to conduct the experiment on the tilt table made by Dr KK Deepak at All India Institute of Medical Sciences (AIIMS). The table could be tilted from head down tilt (-70º) to head up tilt (+70º). It was not possible for that tilt table to move between -90º and +90º and the speed of rotation was also very slow. Then a tilt table was designed and developed in the lab to provide a tilt possibility from -90º to +90º. Tilt Table has been developed for replicating push pull maneuver (PPM) in the lab. It is inexpensive to construct, maintain and run as compared to in-flight or gimbaled centrifuge research. Human Subjects are exposed to -90° as head-down and leg up (HDT) from 0° (supine) and from HDT to +90° as head up and leg down (HUT) position. The tilt table is rotated at a speed of 45°/sec during HDT and HUT. Carotid pulse of all the subjects has been acquired by placing the sensor on the Carotid artery and subsequently processed using MATLAB. Increase in RR interval is observed in case of HDT position which indicates slower heart rate. Increase in pulse amplitude is also noticed in case of HDT position. In contrast to HDT position, RR interval in HUT position is reduced which indicates higher heart rate. Decrease in pulse amplitude is observed in case of HUT position. The algorithm is finally converted into an independent executable standalone application program.

Further, the piezoelectric sensor based system is modified to make wireless real time acquisition of carotid pulse possible. Carotid signals of healthy human subjects in sitting and active standing position are acquired. RR interval, pulse amplitude and heart rate are quantified. RR interval in active standing position is reduced which indicates higher heart rate. Increase in pulse amplitude is also observed in case of active standing position. The developed system shows percentage change in RR interval and pulse amplitude of all the subjects almost same which validates the system. Cost effective Wireless FM Microphone used is compatible to the sensor and the computer arrangement and acquires Carotid signal in

real time. The present work relates the effect of change in heart rate in different body postures to the change in heart rate due to G-stress which further can be used for measurement and management of G-stress of aircraft pilots.

The computer based system developed is capable of direct interface through the sound port of the PC and does not require proprietary DAQ units and ADC units. The system developed for Carotid pulse wave acquisition does not involve any intricate electronic circuitry but requires only a piezoelectric sensor which makes it quite effective for investigating Carotid pulse signal. This thesis thus marks an attempt to provide a relevantly cost effective solution to assess G-stress effect and would directly benefit aircraft pilots.

2016

Thesis title: Simulation of Biophysical Model of Cardiac Biosensors.

Abstract

Modern lifestyle has led to increase in various cardiovascular diseases causing around 40% of all human deaths all over the world. Cardiac biosensors are the important devices to control the rhythmic action of the heart for patients suffering from cardiac diseases. Cardiac biosensors can be implanted inside the human body or can be fitted externally to maintain the heart rhythm. These portable devices are powered by rechargeable batteries which discharge over a period of time and hence suitable charging circuitry and alternative power sources are required to maintain continuous power for these devices. Low power consumption and small size power supply is crucial for medical implant devices. For external cardiac biosensors such as defibrillators, charging techniques need to be devised in areas where charging facilities are not available.

This thesis work describes the design and implementation of power supplies for sustainable operation of implantable cardiac biosensors (pacemakers and defibrillators) and external defibrillators. The work carried out in the thesis has been organized in three sections.

The first section of the thesis deals with the SIMULINK model of solar cell based energy harvesting for powering implantable cardiac pacemakers. Operation of implantable medical devices depends on the manner to supply them power for their continuous operation. Replacement of batteries produces discomfort for the patient and high economic costs. The voltage corresponding to maximum power point has been measured graphically at various irradiance levels and fed to the DDBC. The power and voltage output provided by the boost converter show the capability of the setup to maintain the level of the battery of the implantable cardiac pacemaker thus leading to its sustainable operation.

The second section of the thesis presents the implementation of a solar cell based implantable power supply for cardiac biosensors which involves maximum power point tracking to improve the efficiency of power conversion keeping minimal complexity of components. The entire circuitry of implantable power supply has been simulated using SPICE. The proposed schematic contains a PV Array, a boost converter, MPPT controller all implanted beneath the skin and coupled with the implanted cardiac biosensor.The novel fractional open circuit voltage methodology extracts maximum power from the implanted solar cell receiving infrared radiation through the skin from the external world and the working of the circuitry does not rely on any other power source for its operation other than the solar cell itself. In measurement of open circuit voltage Voc, neither we disconnect the used solar array from the load nor do we use any dummy solar cell to determine the V_{oc} periodically,

but rather, we use a virtual V_{oc} with the help of a peak detector, that captures the maximum input voltage value of the used solar array and continuously keeps it held as it sees a very high input impedance of an op-amp based buffer. The results obtained show that the implanted solar cell power supply produces sufficient power and voltage to charge the battery of implantable low power cardiac biosensors like pacemaker and defibrillators. Thus the proposed scheme can supply uninterrupted power to the biosensors without compromising with the area and other biological constraints within the human body.

The third section of the thesis is a computer simulation of Perturb and Observe (P&O) and Incremental Conductance (INC) maximum power point tracking (MPPT) algorithms to extract maximum power of solar cell suitable for powering automated external defibrillators (AEDs) using MATLAB. Design and development of solar cell based AEDs require primary focus to optimize efficiency of solar power conversion in order to maintain requisite power. Peak power points indicated on the power-voltage plots proved that the INC technique yielded more maximum power as compared to the P&O technique at various irradiance levels. The practical implementation of solar cell powered AEDs could increase overall lifespan and may reduce the cost of maintenance.

2016

Savita Sondhi

Thesis title: Study of Voice Stress Analysis Based Interrogation Tool.

Abstract

Human voice is a social communication tool which can also convey information about the psycho-physiological state of an individual under stress. Stress is a significant threat characterized by anxiety and dysfunctional physiological response. Past studies have indicated that stress in an individual can be accurately estimated by measuring the physiological parameters, such as electroencephalogram, heart rate or few biochemical markers in blood, but some of these measurements are invasive, require additional electrodes and are time consuming. Therefore the present research work proposes a non-invasive and non-contact method to detect stress in an individual by simply analysing his/her voice. A person may experiences stress due to psychological reasons or physical conditions.

Psychological stress stems from internal perceptions wherein an individual experiences anxiety, guilt, embarrassment or finds himself in fight or flight situation due to the fear of getting caught and the dire consequences. Such stressor affects physical and mental health and degrades performance both at work and personal life. On the other hand, physical stress is caused due to environmental changes, fatigue, sleep loss or exertion. Physical stress due to fatigue deteriorates voice quality and efficiency to convey the message. Additionally, changes in atmospheric pressure on reaching high altitude, leads to reduced

concentration of oxygen molecules per unit volume of air thereby reducing its availability to the body. This insufficient supply of oxygen in the blood and tissues of the human body causes hypoxia. Hypoxic stress has been held responsible for several documented accidents and incidents at high altitude and aviation resulting in injuries and fatalities. Whatever be the cause, stress affects the natural phenomenon of phonation and articulation. No matter how efficiently a person tries to hide his emotions or physical state, voice reveals everything. The possible relationship between stress and the measurable changes in the basic voice parameters is the subject of this research work.

A glance into the literature indicates that researchers have independently examined the influence of psychological stress, hypoxic stress or physical stress on human voice. Past studies on psychological stress, lack the elements of deception as much of the research draws from laboratory induced stress. To analyse real life natural stress, there are very few studies which have examined police interviews with criminal suspects. However, majority of these studies have analysed behavioural cues of deception. Similarly, studies on hypoxia examines human voice either in natural field conditions of high altitude or inside chambers simulated to a particular altitude. So far no study has investigated the combined effect of stimulated altitude followed by real field conditions of high altitude on the voice of same subjects. Additionally, majority of past studies have examined the effect of physical stress on physiological parameters. However, there are very few studies which have investigated the effect of physical stress on voice as well as physiological parameters. But most of these studies have analysed voice samples of only male subjects. Therefore, research in this thesis presents an exhaustive study of the influence of all these three stressors (psychological stress, physical stress and hypoxic stress) under real life natural conditions on human voice. The main aim is to assess whether a consistent and reliable relationship exists between each of these stresses and the basic voice parameters like fundamental frequency, formant characteristics and voice perturbations (Jitter and Shimmer).

This thesis presents a series of experiments beginning with accusatory interviews and investigative interviews to analyse psychological stress in voice. Accusatory interviews were based on aggressive and coercive interrogation style to elicit criminal's confession. Real life natural data was obtained by recording the ongoing interrogation conducted on real criminals in the police station. Investigative interview was intended to gather information rather than confession. Therefore, episodes of popular FM broadcasts were obtained and analysed. Additionally, an attempt was also made to analyse real time voicing. For this a MATLAB

based algorithm was developed to acquire voice of University students in real time. Structured analysis of interrogation data, FM broadcast data and real time voicing indicated a significant increase in the mean fundamental frequency (F_0) under stress. Pitch contours of interrogation data indicated significant increase in the pitch of crime suspects while answering to specific direct question. Results also indicated marginal decrease in formant frequencies F1, F2 and jitter values under stress.

Subsequent to this, influence of hypoxic stress on voice was also explored. For this, research was conducted in two phases. In study-1, subjects were exposed to normobaric hypoxia (NH) inside a normobaric chamber simulated to an altitude of 12000ft. For hypobaric hypoxia, same subjects were airlifted to 11500ft above sea level. In study-2, combined effect of hypoxic and physical stress was evaluated. For physical stress, subjects were asked to perform step exercise after NH exposure inside the chamber itself. Results indicated that mean F_0 and intensity of formants were reliable indicators of hypoxic stress. It was observed that formant frequency was not affected by hypoxia. Benefits of NH exposure on humans before going to high altitude, has also been noted. Results confirm that fundamental frequency of voice can be used as non-invasive indicator of stress.

In the last part of this thesis, effect of fatigue on voice was explored. Treadmill running was used as a mode of exercise. Voice and physiological variables of both male and female subjects were collected before exercise on a treadmill, immediately after exercise and at recovery condition. Significant increase in mean F_0, jitter, PPQ5 and shimmer was observed under fatigue for both genders. Acoustic analysis was performed using PRAAT software.

Effect of all these three stressors on human voice were considered because while performing an interrogation, it is important to understand whether the suspect is under psychological stress alone or a combination of psychological and physical stress. Exposure to high altitude environment is a special form of physical stress. Especially in context of India where deployment of hundreds of thousands of military personnel in High and extreme areas is a strategic necessity, simple stress indicators need to be evaluated and developed.

Thus, this thesis is an attempt to identify which voice parameter carry reliable information about the psychological and physical state of the speaker and also the degree to which such vocal indicators are reliable across different subjects.

2018

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Thesis title: Robust Control of Dynamic Systems via T-S Fuzzy Technique.

Abstract

The main objective of the control theory is to design a controller to robustly stabilize the real dynamic systems which are nonlinear. This research focuses on the designing of robust control for dynamic systems. It presents the TS fuzzy model of complex nonlinear systems and then design controller scheme called Parallel Distributed compensator (PDC) to synthesize a state feedback controller for the system. The designed controller scheme is a straightforward controller and not a complicated technique to robustly stabilize nonlinear systems and attenuate the external disturbances that influence the behaviour of a system. The algorithm is used to improve the performance and to guarantee the steady state condition of the nonlinear system and ensures the robustness of the fuzzy model system. Then, PDC technique is applied to the Maglev system to stabilize the position of the ball in the Maglev system in the existence of disturbances. So this technique will guarantee the stability and performance of the closed loop nonlinear system and ensure robustness to external disturbances. Then, simulation results are given to prove that the proposed technique guarantees the stability condition of the closed loop nonlinear system.

Later, sufficient conditions have been developed to control and guarantee the robust stabilization of a complex nonlinear system. The design conditions and criteria for quadratic

stability of the TSF system are formulated in terms of linear matrix inequality (LMI), which can be solved efficiently by using the existing LMI optimization techniques. The LMI-based stability conditions are devoted to the TS fuzzy control system, which makes the approach to be more suitable for dealing with practical control problems. Hence, a proposed PDC controller is applied to stabilize a Maglev system, which are highly nonlinear and unstable open loop systems. Therefore the proposed PDC robustly controls the position of the iron ball in Maglev in the presence of disturbances for current-controlled and voltage-controlled scheme. The convex optimization algorithms are solved using a MATLAB toolbox YALMIP with the solver SeDuMi. Next, the designing technique is introduced to other nonlinear systems examples such as steering a model car, DC motor controlling an inverted pendulum via a gear train and 2-DOF helicopter in the existence of disturbances. Hence, the proposed technique will guarantee the stability and performance of the closed loop nonlinear system and attenuates the effect of external disturbances. Thereafter, the simulations verify that the designed technique assures robust H_∞ performance of the nonlinear system and guarantee robustness to external disturbance as compared to nominal response.

Finally, a modified algorithm has been proposed to enhance the performance of the controller. The relaxed algorithm is used to attenuate the exogenous disturbance and generates less conservative conditions robustness criteria, as the result, produces better results. Then the designing examples will be introduced to prove the efficiency of the controller technique under different conditions. Subsequently, the comparison results are given to prove that the proposed technique ensures the stability condition of the nonlinear closed loop system. It emphasizes a superior performance of the nonlinear system with the synthesize of designed controller and proves the efficiency of the proposed algorithm as compared to the other PDC.

Mosarrat Jahan

Thesis title: Analysis of Electromyography Signals for Sub-vocal Speech Recognition.

Abstract

Sub-vocalization is the little voice in the brain that says the words. The goal of this thesis is to propose a system that recognizes sub-vocal speech using sensor on the throat that may monitor neural messages from the brain. Even if this is not making any sound (reading in our head or speaking to our self), it seems that the brain is still sending signals to the tongue and vocal chords.

The research work deals with Electromyography (EMG) based on sub-vocal speech signals in order to incorporate the technique used in speech recognition. The systems are usually based on information related to the muscles of sublingual area below the jaw. Therefore, sub-vocal analysis requires recording of EMG of specific area of muscles, which provide useful information. Hence what we are saying to our self can be recorded. EMG sensors (Ag-AgCl electrode) attached to the surface of the skin in order to measure the electrochemical signals present in the human body due to the flow of ions along nerve fibres. Sensors detect the presence of certain signals and measure their changes.

Sub-vocal speech (SVS) recognition is highly desirable for silent communications among defence personals, civilians with incurable diseases and in underwater operations. The SVS of Hindi phoneme, vowels, and some selected words have a great role to transform the sub-auditory signals into textual information for verbally impaired Indians. Electromyography has been applied to record speech signals of Hindi phonemes क (Ka), ख (Kha), ग (Ga), घ

(Gha)…, vowels (अ आ इ ई उ ऊ ए ऐ ओ औ) and words (चलो, रुको, दायें, बाये, पीछे, Start, Fire, Forward, Backward, Stop, Go, Hide, Left, Right). EMG signals are picked up by placing two pair of electrodes over the neck areas below the chin of the subject. Theses electrodes are connected to the BIOPAC system with MP 30 acquisition unit (Instrument details). Twenty (10 male+10 female) Indian subjects participated in this study during data acquisition. In addition, EMG is also recorded wirelessly with…. (BioTrace+ is the software platform that powers every NeXus. It provides a user-friendly interface to manage clients and sessions, start training or physiological monitoring and analyze data). Wavelet based features and Auto Regressive (AR) coefficients features were extracted from acquired EMG. Analysis has been made using three classifiers; Linear classifier, Quadratic classifier, and Support Vector Machine (SVM).

Performances of all three classifiers are also evaluated in terms of accuracies. The classification accuracies of घ and ग are 87.90 % and 75.27% respectively. Accuracy of क and accuracy of ख is 77.148% and 88.20% respectively. Results also indicated that average classification accuracy of ten subjects is in between75% and 88%.The wavelet based features with SVM classifier is best suited among three classifiers for accuracy of SVS Hindi phonemes and word pattern recognition. Myoelectric signals proved to have an important role for classification of sub-vocal Hindi phonemes and words in speech pattern recognition.

The relevance of sub-vocal recognition can be seen in the areas that involve thought-controlled electro-mechanical platforms. These platforms may include bio-electronic prosthetics (BEPs) and thought controlled device. One of the examples of this type of device is motorized wheelchair whose movements are controlled by the user's thoughts implemented through sub-vocal speech. SVS recognition first detect neurological signals, decode them

into the resulting digital signals, recognize and interpret the words that the signals represent, and instruct the wheelchair to respond accordingly. For example, a user could subvocalize ‘left’ and the wheelchair will turn left.

Further investigation is carried out to address the challenges associated with EMG based sub-vocal speech recognition.

Sub-vocal speech recognition deals with electromyograms that are different for each speaker. Therefore, consistency can be thrown off just by the positioning of an electrode. To improve accuracy, researchers in this field are relying on statistical models that get better at pattern-matching the more times a subject speaks through the electrodes, but even then there are lapses.

2018

Bharat Sharma

Thesis title: Design and Development of a System to Modulate Perceptive Acoustic Effects.

Abstract

Acoustic is the key facet in sound related experiments on human subject. Acoustic Source Perception is capability of human to classify incoming sensory information from the surroundings. Perception of acoustic source accurately has advantages for performance of work by human. Perception plays an important role in performance of human under various environmental conditions. Introduction of noise affects the Acoustic Source Perception (ASP) and also decrease the concentration of human subject for a particular task. The acoustic perception differs with low and high frequencies. In low frequencies, the localization of the source is made through perception of phase difference of acoustic sounds and in high frequencies; the localization of the source is made through perception of amplitude difference on the ear level.

In the thesis a graphical user based application of MATLAB is designed to generate the acoustic effect in order to perform experiments related to acoustics. With accessibility of sound cards, advanced processor in this era gives compactness to the user for generating acoustic effects which can be listened through speakers and headset. The main purpose is to create acoustic environment for various experiment related to perception. Further, design of sound generator using MULTISIM with its hardware implementation is done with electronic components. Acoustic Source perception experiments are also performed using this hardware setup. Furthermore, listening tests are performed on simulation based test setup to analyse the

sound perception by various subjects. A suitable interface of electronic circuit has been developed for a prototype sound generator. This device consists of an input sound source, amplifier unit, high frequency speaker module and protection circuit. The output sound level is in the range of 96-103 dB at various frequencies. This prototype worked accurately till 12.1 kHz but with increase in frequency increases the noise components. This prototype is additionally modified with two channel sound generator and it gives output of 107dB at 14.7 kHz. The device is extremely useful in the range of 98-107 dB SPL. Finally, the compact acoustic source generator is developed which can generate sound in the range of 2-25 kHz. The acoustic source consists of integrated circuitry and speaker module to generate the variable frequency sound. The integrated circuit and speaker module is enclosed in wooden cabinet. The developed acoustic source can be utilized for performing various acoustic experiments. The significant part of this thesis is assessment of acoustic source perception in horizontal plane. The experiment on sound perception was performed on human subjects. For experiments to be performed in horizontal plane eleven Bluetooth enabled speaker (BES) tagged 1 to 11 numbers were placed evenly at 30 degree in a circular outline and input to BES was controlled with the help of computer. Two set of acoustic source perception experiments were designed for this study. In first experiment, buzz sound was used as acoustic source with low fixed frequency (LFF) and High fixed frequency (HFF). The experiments were performed for both LFF and HFF. Initially, set of LFF experiment was performed. The data recorded from the two set of experiments was compared and analyzed. The results show the perception of acoustic source in horizontal plane is affected by the addition of white noise to the LFF and HFF. Furthermore, assessment of acoustic source perception under noise and its comparative analysis is done. Various set of experiments are designed where exposure of acoustic source with fixed frequency on a number of subjects is done. A noise signal is added to the acoustic source to create a noisy condition. Response of

the subjects is taken in a tabulated form for the score of the quality of acoustic source. This experiment is designed to analyze the score of sound perception by various subjects. Experimental analysis is shown for the response provided by the subject for sound perception at various frequencies. In one of the research work, effect of aircraft acoustics on human perception is analyzed by using population based questionnaire survey methodology which is conducted at nearby residents of aviation acoustic prone areas. The comparative analysis of acoustic noise during plane takeoff and landing is accomplished for cargo and fighter aircraft. The analysis shows that fighter aircraft produce more noise as compared to cargo aircrafts and may lead to several problems related to hearing and sound perception.