Ife Journal of Technology, Vol. 18 (2), 63-71, 2009

Full Paper

A PLATFORM FOR INERTIAL MOTION CAPTURE AND MODELING OF HUMAN MOVEMENT

O.A. Moninuola
Department of Electronic and Electrical Engineering
Obafemi Awolowo University, Ile-Ife, Nigeria

K.P. Ayodele
Department of Electronic and Electrical Engineering
Obafemi Awolowo University, Ile-Ife, Nigeria
kayodele@oauife.edu.ng

L.O. Kehinde
Department of Electronic and Electrical Engineering
Obafemi Awolowo University, Ile-Ife, Nigeria

T.K. Yesufu
Department of Electronic and Electrical Engineering
Obafemi Awolowo University, Ile-Ife, Nigeria

ABSTRACT

In many aspects of medicine, there is a need for methods to convert human locomotion to data in a form that is amenable to mathematical processing and analysis. Most schemes involve the use of motion capture sensors. This paper presents the development of a platform for inertial motion capture and modeling of human movement. The hardware consists of micro sensor nodes and a base station. A sensor network was implemented to make the motion data from all the sensor nodes available at the base station from where it is wirelessly transmitted to a personal computer (PC) for processing. Each sensor has a sampling rate of 625 kHz. Wireless communication between the base station and the PC is achieved using the IEEE 802.15.4 protocol. Data acquired by the platform is processed using time series analysis with an autoregression moving-average model. Analysis of numerical data obtained from the prototype suggests that with calibration step implemented in software, the process of transforming human body motion into data can be done to a high degree of accuracy.

1. INTRODUCTION

Studies of human limb movement are emerging as a very important component in the study, diagnosis and treatment process in many aspects of medicine. The core premise behind these studies is that certain diseases influence the motion of subjects (for example, Fox et al. 2009;, Griffin et al, 1995 and Petrofsky et al , 2005). Certain medications have also been identified as causing movement disorders (Riker et al, 1997). These have led to more acute interest in observing and measuring movements of various parts of the body and linking them to illnesses or drug side effects. For this reason, motion capture has become an increasingly important tool in medicine.

Motion capture comprises of the several techniques which enable the gathering of motion data from human subjects. It is the recording of human body movement for immediate or delayed analysis and playback. Typically, complexity is reduced by tracking only key points like joints. The information captured can be as general as the simple position of the body in space or as complex as the deformations of the face and muscle masses. Motion capture devices are needed to present human body motion in a form much more suitable for mathematical modeling. Mathematical methods can then be employed to establish statistical patterns from which conclusions can be drawn

Early motion capture platforms employed optical sensors in which light reflected from optical markers worn by the human subject is used for digital reconstruction of body motion. In recent years however, there has been a sharp increase in the development and deployment of another class of motion capture systems: inertial motion capture systems. This increased focus has coincided with the maturity of micro-electromechanical (MEMs) techniques for fabricating cheap and highly accurate inertial sensors. Although optical motion capture systems have traditionally had higher precision, MEMs sensors are so cheap and are benefiting from research by having better performance values. The result of this is that inertial sensors are fast replacing other types of motion sensors in all areas of application.

Much of the initial research, development and marketing in this area were for military applications. Presently however, motion capture is used in many application areas such as biomechanics, sport performance analysis, tele-robotics, ergonomics, entertainment and general medicine.

When used in medicine, the purpose of motion capture is often to try to identify digital markers or signatures of various illnesses from body motion data. The possibility of obtaining such digital markers brings the exactness of mathematics into medical diagnosis and augments such traditional techniques as detection and measurement of vital signs.

This paper presents ongoing work on the development of the EEE-OAU09 motion capture platform targeted directly at medical research. This platform has a sensor network of ten tri-axial accelerometers placed at different parts of the human subject. The I2C protocol was used in implementing the sensor network. I2C was chosen because only two wires are needed to run through the different parts of the human subject which ensures that motion is not impeded.

The paper also reports initial attempts to analyze sample acquired data as a precursor to detecting digital markers. There are various statistical methods that can be employed for the data interpretation. These methods seek to establish if there are any statistical patterns that are characteristic of certain diseases. The search for patterns was based on the development of time series analysis and modeling of captured data. Although multivariate analysis was considered - because some interdependence is expected to exist between collected data streams - this paper argues that the data is better modeled with an autoregression moving-average model.

2. Motion Capture In Medicine

Much of the early use of motion capture in medicine was in the area of medical rehabilitation and was usually limited to the lower limbs in what is called gait analysis. Gait analysis data acquisition is a subset of motion capture. Long-term monitoring of gait in Parkinson's disease is usually used in the long term assessment of patients' response to medications (Moore et al , 2007). However, tremors associated with advanced stages of this disease can only be captured on a full motion capture platform. Recovery of normal gait function after Total Hip Arthroplasty (THA) is usually assessed using gait analysis (Akker-Scheek et al, 2007). The effect of type 1 and type 2 diabetes on movement have also been widely studies with, for example, a study on the effect of the disease sans sensory impairments [3] establishing that the it led to subjects taking more steps both on a linear path and during turns. In addition, a correlation was seen between suffering from diabetes and both the length of time required to walk a given distance, extension and lateral movement at major body joints. Also, gait analysis is usually used extensively in the rehabilitation of patients with chronically arthritic knee, stroke and hallux valgus Zhang et al (2006), Liberson et al (1961), Menz and Lord (2005).

Despite their potential importance however, gait analysis has not enjoyed wide adoption largely because the required instrumentation systems tend to be expensive and as such are not widely available. In addition to this, most gait analysis platforms require teams of trained personnel to operate. They often cannot be used effectively in free-living conditions, and impose constraints that make subjects exhibit slight departures from their normal ambulatory patterns. In recognition of these limitations, Churchill et al. (2002) used a simple inexpensive video-based kinematic analysis for clinical disorders of gait and Hansen et al. (2002) developed a simple method, using the relative positioning of the overall center of pressure and an ankle marker in the direction of forward progression for the determination of "heel-contact" and "toe-off" events. In one of the very few research efforts related to motion capture in Nigeria, (Buriamoh-Igbo et al, 1997), pressure sensors placed in the soles of shoes were used to determine certain aspects of gait asymmetry. While these methods diminished the overall expense of a formal gait lab, they still could not function in a free-living setting (Zhang et al, 2006).

According to (Zhang et al, 2006), the ideal platform in the free-living condition would be small, noninvasive, reliable, sensitive, low cost, and easy to operate and interpret. This has led to the development of a number of low cost alternative systems, with the emphasis in developing low cost systems is shifting to MEMs accelerometers.

Probably at the front line of active research in the field of accelerometer–based motion capture systems is the Sensor Networks and Applications Research Center. Current research efforts include solving the bias and drift problems associated with modern accelerometers, reducing noise level in motion data captured with accelerometers, resolving complications associated with the non-linear nature of human motion and the development of a complete mathematical framework for human body motion capture and analysis.

3. Instrumentation

3.1. System Requirements

The motion capture system was conceptualized as a number of sensor nodes sensing movement data and sending such to a computer for recording and analysis. A simplified version of the system is shown in fig 1.

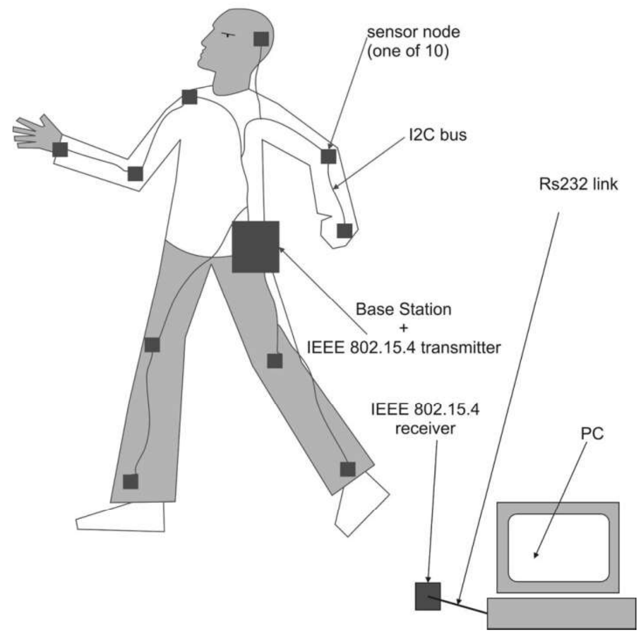

Figure 1: overview of motion capture system

The front ends of the motion capture system consist of MMA7260QT transducers to convert the motion of various body parts to electrical signals. The MMA7260QT micro machined accelerometer features embedded signal conditioning, a 1-pole low pass filter, temperature compensation and g-Select which allows for the selection among 4 sensitivities. Zero-g offset full scale span and filter cut-off are factory set and require no external devices. Sleep Mode feature also makes it ideal for handheld battery powered applications. The fixed offset voltage of around 2V also enables the connection of the accelerometers directly to a microcontroller directly for analog to digital conversion.

The design calls for microcontrollers capable of implementing hardware analog to digital conversion (ADC) and which must in addition, support at least a communication protocol capable of being used for a sensor network. The PIC18F2221 SOIC was chosen as it combines affordability and small size with the meeting of the above requirements. The analog to digital conversion process was achieved using PIC18F2221 capable of 10bit flash ADC, a sampling frequency of 2.4MHz, acquisition time of 0.4us and a voltage reference of 5V.

A sensor network is required to make the motion data from ten sensors available at a base station, which serves as a point at which data from all sensors are combined into a single stream. A wireless network would be ideal for this purpose to minimize obstructions but implementing such is prohibitively expensive for projects like this. I2C (a serial communication type with bus topology) was therefore chosen as only two wires are required for the implementation. This is seen as a good compromise between cost and unobtrusive operation. The bus configuration type was master/slave with a bandwidth of 1.6Kbps.

Communication between the base station and the computer is often achieved using wires. However, the belief in designing this platform was that such tethered systems would affect subjects and cause slight departures from normal movement patterns. Hence, in this design, communication between the base station and the computer is achieved wirelessly using the IEEE 802.15.4 based Zigbee protocol. The Zigbee protocol features simplicity, low latency, very low power requirement and the module are relatively cheap. The Zigbee implementation used has an operating frequency of 2.4GHz, using the Direct Sequence Spread Spectrum (DSSS) and a bandwidth of 250Kbps. The Zigbee transceiver used was the MAXSTREAM Xbee pro Zigbee transceiver ("Xbee").

3.2. Design Considerations

The I2C protocol limits the allowable bus capacitance to 400pf. To ensure that the bus implemented lies within this limit, the two-wire pair that forms the bus was modeled as a parallel plate capacitor. The equation that relates the capacitance to the geometrical characteristics of the bus is thus

$$C = \frac{k\mathcal{E}oA}{D} \quad (1)$$

Where
C = bus capacitance
k = dielectric constant
$\mathcal{E}o$ = permittivity of free space
D = distance between the two wires.

It can then be deduced that to minimize the bus capacitance, k and A must be minimized while D must be maximized. The dielectric constant was minimized in the design by ensuring that the space between the two I2C wires was air-filled. D was maximized by keeping the wires apart from each other as much as possible.

A trade-off must be made in minimizing A. The resistance of the wires increases as the A is reduced with implies greater signal attenuation. The exact relationship between resistance and the geometrical characteristics of the wire is

$$R = \frac{pL}{A} \quad (2)$$

Where
R = resistance of the wire
p = resistivity of the wire
L = Length of the wire
A = Cross sectional area of the wire.

Using these two equations as constraints, the Lagrange multiplier method was used to arrive at the optimum surface area.

Another design consideration was the need for offset nulling. Offset-nulling is the process of trimming down to zero the finite output signal that might exist in any system when the input signal is zero (often called zero error correction). At Zero-g, temperature of 25°C and supply voltage, V_{DD} of 3.3 V, the average output voltage of the accelerometers were measured to be as follows:

X- Axis offset voltage: 0.70V
Y-Axis offset voltage: 1.25V
Z-Axis offset voltage: 1.70V

The elimination of these offset voltages was carried out in software. Since the output of the analog-to-digital conversion are discrete numbers, the numeric values corresponding to these offset voltages were measured by simply observing the numeric output when the accelerometers were kept stationary. With the digital values corresponding to these offset voltages recorded, these offsets were subtracted from the readings for each axis in the code written for each sensor to assure accuracy.

4. Hardware Description

4.1. The Sustained Counter Torque Soldering Technique

Living in a developing country, one of the problems that often plague Nigerian professionals is the absence of equipment that are considered rudimentary in many developed countries. One such limitation was encountered in this work. Since the design requirements for the project called for small-sized components, surface mount integrated circuit (IC) packages were used where possible. This led to the problem faced by many Nigerian students and professionals: standard pick and place process equipment appropriate for the IC packages was not available. To solve this problem once and for all, a simple soldering technique was developed. This technique is the Sustained Counter-torque Soldering technique (also called the "Spider" soldering method because of the shape that results when it is used.

The spider soldering method was designed specifically for Quad Flat No-Lead (QFN) chips although it can be adapted to other chip designs. The primary motivation for the development of the spider method was the fact that the datasheet for MMA7260QT micro machined accelerometer specifically cautioned against hand soldering. In tests, the spider method achieved hundred percent successes.

The procedure for the spider method is as follows (see figure 2):

1. Permanently position the chip with the pads facing upwards (great care should be taken here as to the numbering of the pads. Conventional numbering assumes that the pad will be soldered down. Thus, the numbering to use in this case should be the lateral inversion of the conventional one).

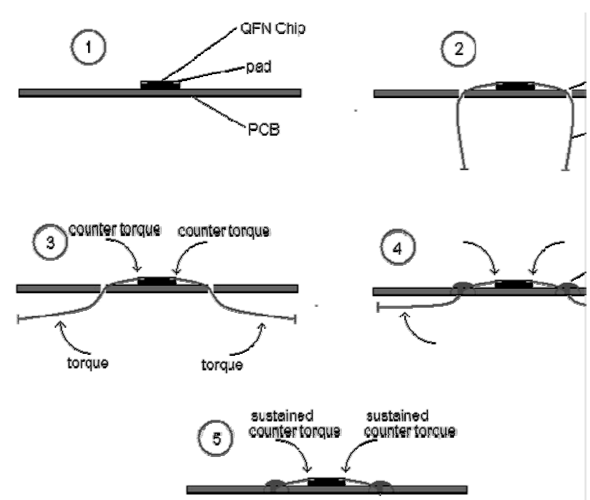

Figure 2: The Sustained Counter Torque soldering technique

1. Low malleability pins of about 2cm should be positioned such that their tips just make contact with the necessary pads on the chip.
2. To ensure that the pins make permanent contact with the pads, a first-class lever should be implemented as follows:
   i. Via holes should be made on the board to which the chip is attached at approximately half length the pins.
   ii. The pins should be bent through via holes such that the tips just touched the pads while the other half length of the pin was on the other side of the board.
   iii. Torque applied to the half-length of the pin beneath the board results in a **counter torque** that presses the pin tips to the pads. The greater the torque applied, the better the pad- pin tip contact.
   iv. To **sustain** this counter torque (which is the force that keeps the pad and pin tips in firm contact), the vias are heavily soldered.
   v. The half-length of pin beneath the pin can now be trimmed off.

An added advantage of using this method (apart from flexibility) is that the nodes the vias that are eventually soldered are typically about 1cm from the chip itself meaning that the heat transferred to the chip itself is minimal. It is also noteworthy that the chip is physically unaltered after the process (the chip can be recovered physically unaltered in any form). This means that the process in non-intrusive. The Spider technique has been described as the socket (non-invasive) form of the popular "dead-bug" soldering technique often used for prototyping.

The advantages of the Spider soldering technique can thus be enumerated as

- Simple equipment requirements
- Flexibility
- Minimal heat transfer (to chip)
- Non-intrusiveness

4.2. Circuit Design and Operation

The block diagram of the system is as shown in figure 3. Each of the accelerometers labeled 1 to 10 is interfaced with a slave microcontroller (the PIC18F2221 or "'2221"). These accelerometers sense the accelerations in three dimensional axis of each location they are attached. Three channels of the analogue to digital converter (ADC) module of the '2221s are used to digitize the accelerometer analogue outputs. Each slave '2221 stores the values of digitized accelerometer output value in its memory awaiting request from master '2221.

The master '2221 controls the operation of all the slaves and coordinates the data transfer of the system. The master places a request and destination address on I2C for data and the corresponding slave responds by placing its current reading on the network. The master '2221 receives and sends the readings of each accelerometer via serial communication using the RS232 protocol to the Xbee (transmitter, Tx) for wireless transfer. Xbee sends the data out and it is received by the second Xbee (receiver, Rx) interfaced to the computer through MAX 232 level translator. The output of the Xbee (Rx) is TTL and is converted to RS 232 using a MAX232 chip. RS232 communication settings were 9600 baud, 8 data bits, with no parity check or flow control.

This data is interpreted by the software on the computer for human motion modeling. Figure 4 shows the terminal circuitry of an MMA7260QT micro machined accelerometer while Figure 5 shows the sensor network with one master, a slave and the ADC inputs.

5. SOFTWARE AND DATA COLLECTION

CCS C was used for the program development. This is the de facto standard high level programming language for PIC microcontrollers as Microchip optimized most PIC's for CCS C programming. The base station (corresponding to the master in the network) requests for data from each of the sensors in turn. This is achieved by a program which instructs it to transmit the address of each slave (sensor) in turn to the I2C bus and to store in memory whatever the replying slave transmits. This is the data that the base station transmits to the PC wirelessly. The program written for the ten sensors (which correspond to slaves in network) are similar except for the address of each. The main program in each slave instructs it to carry out analog to digital conversion continuously in an indefinite while loop. An interrupt is triggered whenever an address match is received by any slave. The program branches out of the while loop into an interrupt service routine where the results of the most recent conversion are transmitted to the base station.

The algorithm is as follows:

Master code

```
Define the address of each slave
While (true)
{
        Transmit the address of slave1 to the I2C bus
    Read and store the reply from slave1
        Transmit the address of slave2 to the I2C bus
    Read and store the reply from slave2
    ...
        Transmit the address of slave10 to the I2C bus
    Read and store the reply from slave10
    Transmit whole data to Zigbee module
```

Slave Code

```
Assign slave address
Enable I2C activity interrupt
If address match is received
{
  Transmit latest ADC results to the master
}
Else
{
Continue ADC
}
```

The transmitted data can be viewed using any universal synchronous-asynchronous receiver-transmitter (USART) terminal software or read straight into MATLAB.

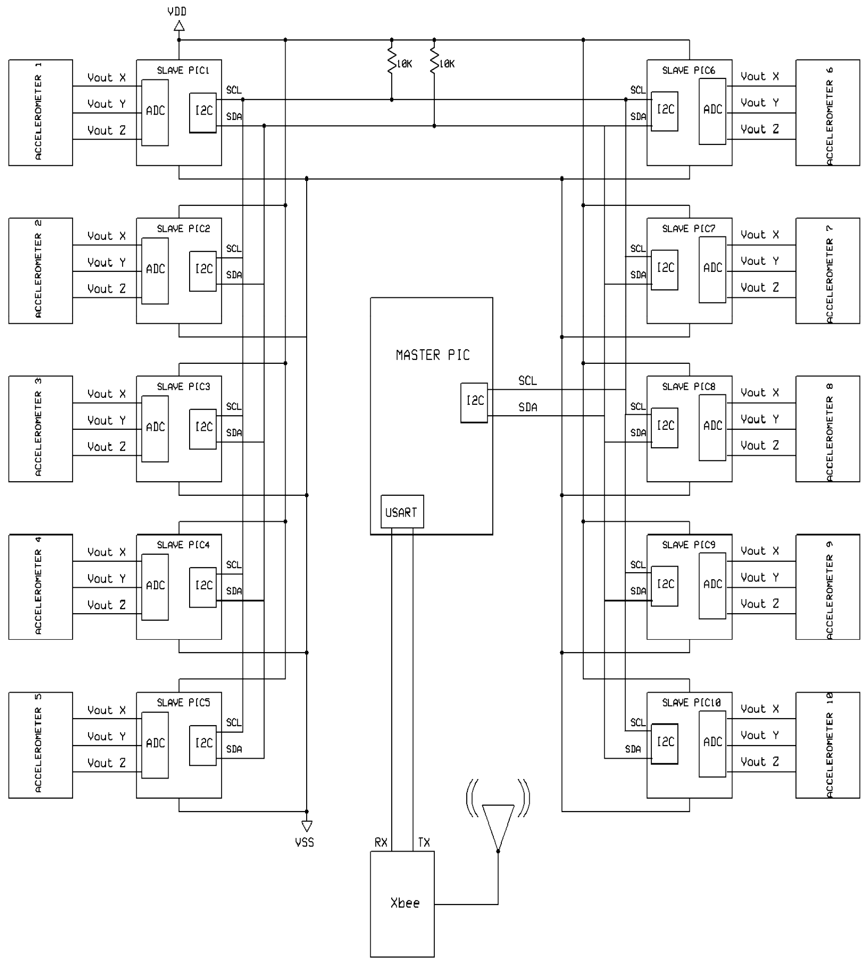

Figure 3: Block diagram of the EEE-OAU09 motion capture system

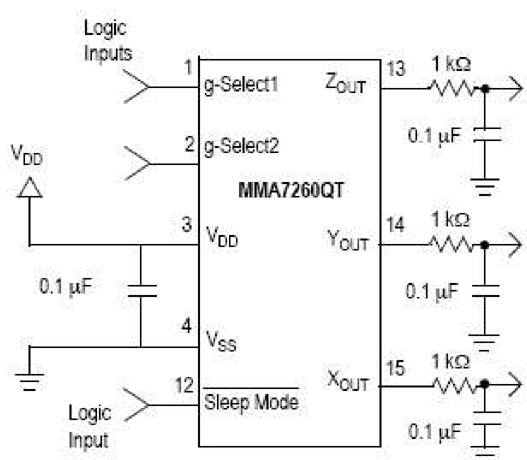

Figure 4: MMA7260QT micro machined accelerometer Terminal Circuitry

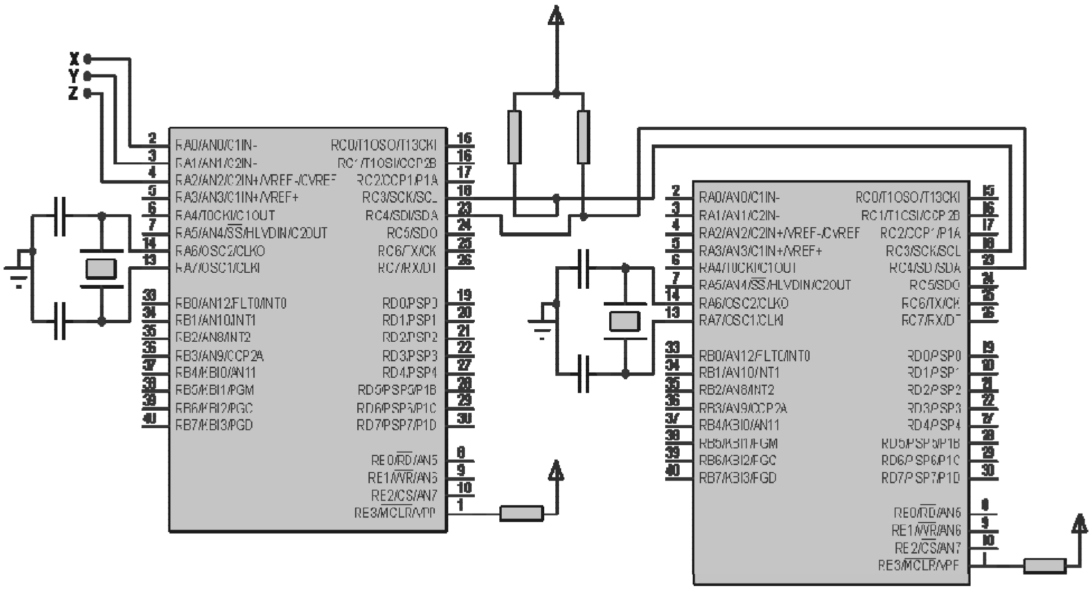

Figure 5 Sensor network with one master, a slave and the ADC inputs.

6. Model Development based on Time-Series Analysis

Motion is easier to observe than measure. Converting accelerometer readings to motion data with minimal errors was a big challenge. Accelerometer offset voltage, noise in the analog signal from the accelerometer to the '2221 were major sources of error. These were dealt with using software offset-nulling by minimizing the distance between the accelerometer and the microcontroller respectively.

With motion data converted to acceleration, it becomes feasible to carry out analysis on them by assuming that the data represent time series. Time series are data values sampled over time, in order and usually at equal intervals (Palit and Popovich, 2005). Time series analysis is concerned with identifying patterns, modeling patterns and forecasting values. Dedicated MATLAB functions and interactive tools perform time series analysis. Standalone MATLAB packages (executable) can be created so that users do not need to have the whole MATLAB software installed.

The steps involved in the analysis are given in figure 6:

6.1. Collecting and Formatting Time Series Data

For now, time series analysis cannot be performed in real time using any of the dedicated MATLAB functions and interactive tools. The motion data has to be stored for post-processing. Delayed processing of the motion data offers some flexibility; it can be stored in any format and the data can be arranged such that member time series in the motion data are evident. A screen capture of the PC data acquisition utility, displaying some data from the motion capture platform is shown in figure 7, while table 1 shows part of the same data, with each column of data forming a member time series.

Storing the motion data in a format in which the member series are distinct is crucial. The base station (master '2221) sends motion data to the PC using the format above and most USART terminals preserve this format.

6.2. Development of Time Series Models

The determination of the best time series representation for the motion data collected is an ongoing effort. The analysis of time series consists of a mathematical description of component variations present in the data.

There are a number of classes of time series models. These include regression models, time domain models and frequency domain models. The regression models adopted in engineering include autoregression model (AR), moving-average model (MA), autoregression moving-average model (ARMA), autoregression integrated moving-average model (ARIMA), and control autoregression integrated moving-average model (CARIMA). In addition, for systems which also have inputs from outside the system itself, there are model classes usually distinguished by the addition of an "X" to their names, with the said X representing "exogenous inputs" (or sometimes "auxiliary input"). Therefore, ARX models are autoregression models with exogenous inputs and so on.

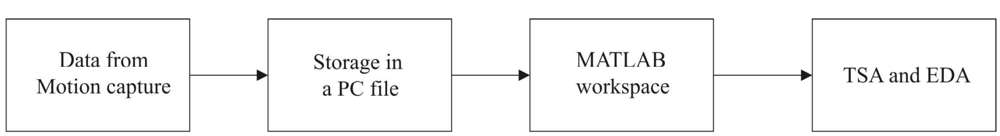

Figure 6: Steps involved in the data analysis

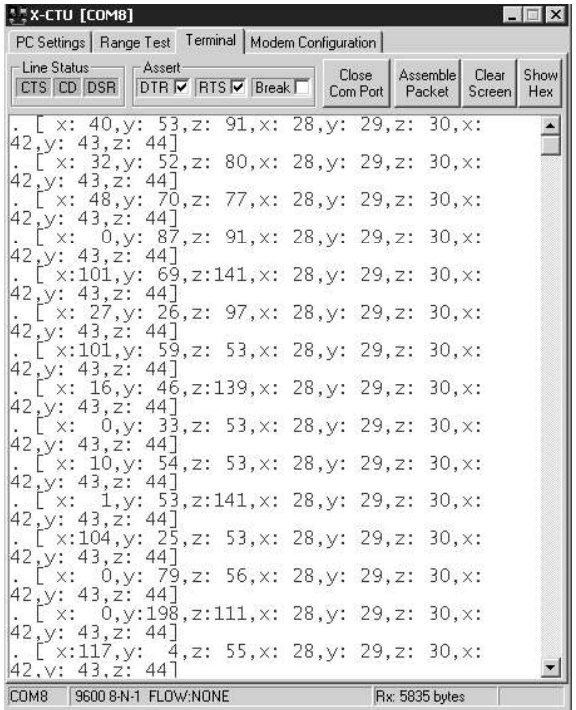

Figure 7: Screen shot of utility for receiving data from motion capture platform

Table 1: Motion data as a collection of time series

Time	Axis (node)					
	X (1)	Y (1)	Z (1)	X (2)	Y (2)	Z (2)
1	40	53	91	28	29	30
2	32	52	80	28	29	30
3	48	70	77	28	29	30
4	0	87	91	28	29	30
.	.	.	.	.	.	.
.	.	.	.	.	.	.
.	.	.	.	.	.	.
15	117	4	55	28	29	30

Since the underlying system could be modeled as linear or non-linear, there are also non-linear versions for all the models mentioned above (hence, NARX, NARIMA and so on).

Time domain models of time series include transfer function models and state space models. Transfer function models are very similar to regression models, with the distinction that the system transfer function, which is the relationship between the input and the output, is integrated into the model. State space models also factor in the inputs into the model, but differ from transfer function models by having two sets of equations representing each series. While the first set of equations represents the state of the system, the other set models the system output based on a number of factors.

Frequency domain models use various frequency domain techniques to model time series as series of sinusoids with noise superimposed. Although interest in frequency domain models has surged again in recent decades, time domain and autoregression models are still more popular.

Another large set of models are grouped under multivariate time series model. These are required when there are multiple time series which may have some relationship with one another. According to Palit and Popovich (2005) "*model building of multivariate time series is required when the values of one variable of an individual time series are dependent on the values of variables in other related time series*".

Since the movement data of the elbows for example would also influence that of the wrist (just like some other body coordinates would influence various other parts), it stands to reason that multivariate analysis may be the most appropriate tool to use, at least in some measure. The downside however is that multivariate series models are usually harder to develop. For this reason, other models will be tested first and multivariate analysis would be avoided unless the developed models fail to deliver satisfactory performance.

For this work, regression models have been identified as the best fit. Since the motion capture system is most easily modeled as having no exogenous inputs, X-class models, transfer function and state space models are disregarded. In addition, the system is assumed to be linear, as is the usual trend in model development. Only after linear models fail are systems modeled as non-linear. Finally, univariate analysis is adopted (assuming that there are different independent streams of data because the possible gains in accuracy would probably not be worth the added complexity of multivariate analysis.

The specific model class being adopted and tested is the ARMA model. The ARMA model is a combination of the AR and MA models.

For the AR model (mathematical development motivated by Palit and Popovich , 2005),

$$\phi(B)\widetilde{Z}_t = a_r \qquad (3)$$

Where $\widetilde{Z}_t$represents deviations from the mean, a_r is a white noise component, and the autoregression operator, $\phi(B)$ is defined as

$$\phi(B) = 1 - \phi_1 B - \phi_2 B^2 - \phi_3 B^3 - \cdots - \phi_p B^p \qquad (4)$$

$\mu, \phi_1, \phi_2, \phi_3, \ldots, \phi_a, \sigma_a^2$ are unknown parameters to be identified from collected data.

In moving average models,

$$\tilde{Z}_t = \Theta(B) a_t \qquad (5)$$

where the moving average operator, $\Theta(B)$, is defined as $\Theta(B) = 1 - \Theta_1 B - \Theta_2 B^2 - \Theta_3 B^3 - \cdots - \Theta_q B^q$ (6)

and again, the parameters $\mu, \Theta_1, \Theta_2, \Theta_3, \ldots, \Theta_a, \sigma_a^2$ are to be estimated from collected data.

Combining eq [3] and [5] to form an ARMA model yields

$$\tilde{Z}_t = \phi_1 \tilde{Z}_{t-1} + \phi_2 \tilde{Z}_{t-2} + \ldots + \phi_p \tilde{Z}_{t-p} + a_t - \theta_1 a_{t-1} - \theta_2 a_{t-2} - \ldots - \theta_q a_{t-q}.$$

Which can be rearranged as

$$\tilde{Z}_t - \phi_1 \tilde{Z}_{t-1} - \phi_2 \tilde{Z}_{t-2} - \ldots - \phi_p \tilde{Z}_{t-p} = a_t - \theta_1 a_{t-1} - \theta_2 a_{t-2} - \ldots - \theta_q a_{t-q}$$

Subsequently,

$$(1 - \phi_1 B - \phi_2 B^2 - \ldots - \phi_p B^p)\tilde{Z}_t = (1 - \theta_1 B - \theta\ B^2 - \ldots - \theta_q B^q) a_t$$

To arrive at the standard form:

$$\phi(B)\tilde{Z}_t = \theta(B) a_t \qquad (7)$$

where B is the delay operator. This model contains (p+Q+2) unknown parameters and the process of developing time series models from motion capture data would simply consist of determining these parameters for each subject.

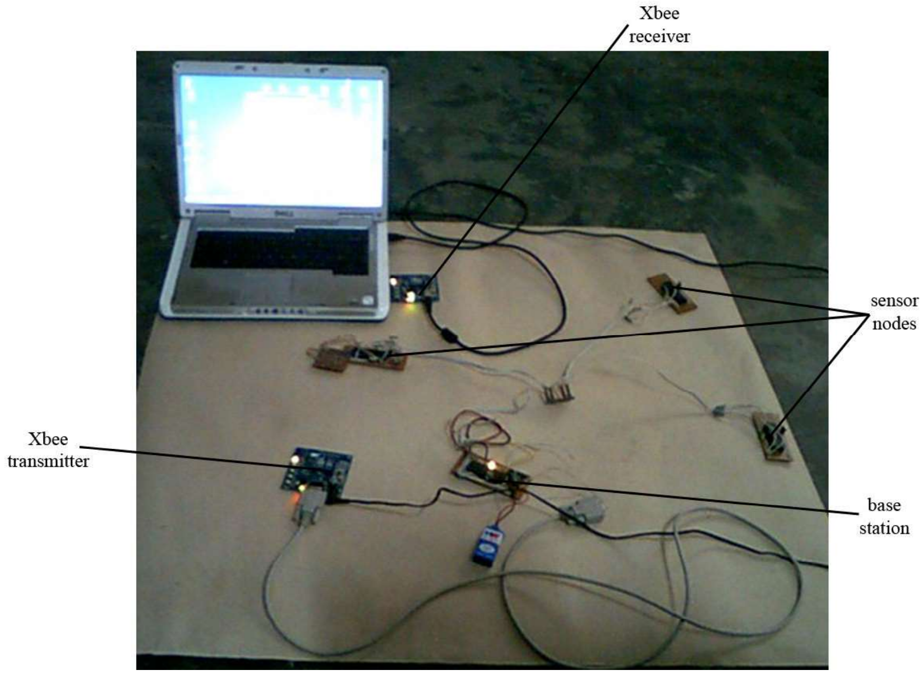

Figure 8: Prototype implementation of the EEE-OAU09 motion capture system featuring three sensor nodes

7. Testing and Results

The prototype consisting of three slaves and the master was tested. Figure 8 shows the prototype setup. It was tested by powering up the sensor network using a 9V battery, the Xbee transmitter was powered using the adapter provided while the Xbee receiver is powered through the USB connection it has with the PC.

The sensors were tested by observing the numerical readings on the PC screen when the sensors are moved in various directions and with varying speeds. It was observed offset nulling was not able to completely remove accelerometer offset. Finite (although small) readings were obtained when the sensors were stationary. The effect of noise was also observed, as reading changed often rapidly when the sensors were kept stationary.

The Xbee module worked as expected with good reception at the receiving end as distances in excess of 10m.

One important consideration in developing instrumentation devices for human subjects is the health implications of the system. The EEE-OAU09 platform is completely non-invasive and the radiation generated by the IEEE 802.15.4 transceivers is very much within standards.

Observation of numerical data obtained from the prototype has suggested that with a calibration step implemented in software (say a lookup table), the process of transforming human body motion into statistical data can be done to a high degree of accuracy

The need for a better implementation of software offset-nulling and further noise reduction measures are the most important points being looked at. Although the general class of models has been picked, detailed model generation and data analysis proper was not carried out on this prototype. That will be done when the final version is ready

8. Conclusion

A platform for motion capture using MEMs accelerometers has been described. The platform has ten MMA7260QT whose analog outputs are converted to digital form and transmitted to a central base station using I2C. The base station then transfers the data to a computer using IEEE 802.15.4. Data on the computer can then be analyzed using any suitable technique. For this work, motion capture data are modeled such that human movement is seen as an ARMA system. The platform has been tested and the results so far have been positive.

During course of work, a new soldering technique was developed. The new technique can be used in places where sophisticated soldering stations are not available.

References

Akker-Scheek I.,Stevens M., Bulstra S.K., Groothoff J.W., Horn J.R., and Zijlstra W. (2007): "Recovery of gait after short-stay total hip Arthroplasty". Arch Phys Medical Rehabilitation. No 88:pp 361–367.

Buriamoh-Igbo, L.A., Olaogun, M.O.B., Jubril, A.M. (1997): "Measurement of ground-foot reaction force to determine gait asymmetry using a computer-based telemetry system", *Journal of Rehabilitation Research and Development*, vol. 34, no. 2, pp 53-55.

Churchill A.J., Halligan P.W., and Wade D.T. (2002): "A Simple Video-based Kinematic Analysis for Clinical Disorders of Gait". *Computer Methods Programs Biomed*. 69:197–209.

Fox S.H., Chuang R., and Brotchie J.M. (2009): "Serotonin and Parkinson's disease: on movement, mood, and madness. *Movement Disorders*, Vol. 24, No. 9, 2009, pp. 1255–1266

Griffin, M., Olney, S., and McBride, I. (1995)" "Role of asymmetry in gait performance of stroke subjects with hemiplegia". *Gait Posture* 1995(3): 132–142.

Hansen A.H., Childress D.S. and Meier M.R. (2002): "A Simple Method for Determination of Gait Events". *Jour. Biomech*.35: 135–138.

Liberson W.T., Holmquest H.J., Scott D., Dow A., (1961): "Functional Electrotherapy: stimulation of the peroneal nerve synchronized with the swing phase of the gait of hemiplegic patients", *Arch. Phys. Med. Rehab*. 42, 101-105.

Menz H.B., and Lord S.R. (2005): "Gait Instability in older people with Hallux Valgus". *Foot & Ankle International*, Vol. 26, No. 6.

Moore S.T., MacDouglas H.G., Gracies J.M., Cohen H.S. and Ondo W.G. (2007), "Long-term monitoring of gait in Parkinson's disease". *Gait Posture* ; 26:200–7.

Palit, A.K. and Popovic, D. (2005): Computational Intelligence in Time Series Forecasting: Theory and Engineering Applications. Springer-Verlag limited, London.

Petrofsky J., Macnider M., Navarro E., and Lee S. (2005): "Motor Control and Gait Characteristics in people with Type 1 and Type 2 Diabetes without sensory impairment in the foot". *Basic Applied Myol.*, 15 (2): 75-86.

Riker RR, Fraser GL, Richen P. (1997): "Movement disorders associated with withdrawal from high-dose intravenous haloperidol therapy in delirious ICU patients". *Chest* 1997;111: pp 1778–1781.

Zhang K., Gorijan A. and Lester K.D. (2006) "Gait change after local anesthetic of chronically arthritic knee". *Journal of Long-Term Effects of Medical Implants.* 16(3):223–234 (2006)