

**SIMULTANEOUS IMAGE AND SIGNAL ACQUISITION FOR FOOT
FORCE ANALYSIS**

A THESIS SUBMITTED IN PARTIAL FULFILLMENT
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By

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CERTIFICATE

This is to certify that the thesis entitled “**SIMULTANEOUS IMAGE AND SIGNAL ACQUISITION FOR FOOT FORCE ANALYSIS**” submitted by **MR. ANUP PURI** in partial fulfilment of the requirements for the degree of **Bachelor of Technology in Biomedical Engineering** embodies the bonafide work done by him in the final semester of his degree under the supervision of the undersigned. The thesis or any part of it has not been submitted earlier to any other University / Institute for the award of any Degree or Diploma.

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Contents	Page No.
Acknowledgment	i
List of Figures	ii
Abstract	iii
1. INTRODUCTION	1
2. LITERATURE REVIEW	2-10
2.1 GAIT ANALYSIS	2
2.2 METHODS OF GAIT ANALYSIS	3
2.2.1 VIDEO	3
2.2.2 MOTION CAPTURE SYSTEM	4
2.2.3 ELECTROGONIOMETERS	4
2.2.4 EMG (ELECTROMYOGRAPHY)	5
2.2.5 FORCE PLATE	5
2.2.6 TREADMILLS	7
2.2.7 FOOT PRESSURE ANALYSIS	7
2.3 STRAIN GAUGE SENSOR	8
2.3.1 STRAIN GAUGE	8
2.3.2 GAUGE FACTOR	9
2.3.3 STRAIN GAUGE MEASUREMENTS	9
2.4 FORCE PLATE DESIGN	10
3. AIM AND OBJECTIVE	11
4. SCOPE OF THE PROJECT	12
5. MATERIALS AND METHOD	13
6. RESULT AND DISCUSSION	15-24
6.1 CANTILEVER DESIGN	15
6.2 CANTILEVER CONSTRUCTION	16
6.3 FORCE PLATE DESIGN	16
6.4 STRAIN GAUGE FIXATION ON CANTILEVER	17
6.5 CIRCUIT FOR FORCE PLATE	18
6.6 FORCE PLATE OUTPUT	19
6.6.1 CALIBRATION CURVE	19
6.6.2 OUTPUT DATA	19

6.6.3 IMAGE CAPTURE	23
6.6.4 MULTI-THREADING	24
7. SYNCING DIGITAL SIGNAL WITH IMAGE	25
8. CONCLUSIONS	27
9. REFERENCES	28

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LIST OF FIGURES

Figure No	Title	Page No
Fig 1	Bonded Metallic Strain Gauge	8
Fig 2	Wheatstone bridge	9
Fig 3	Design of Cantilever	15
Fig 4	Cantilever Dimension	15
Fig 5	Initial constructed Force plate	16
Fig 6	Circuit for Force Plate	18
Fig 7	NI USB-6008 DAQ card	19
Fig 8	Web-camera used for the experimental setup	23
Fig 9	Schematic diagram of Multi-threading	25

ABSTRACT

Gait analysis is the study of locomotion. There are many applications of gait analysis, some of which are, treatment of the pathological conditions (Pathological gait), development of new prostheses and orthoses devices for rehabilitation, and in the field of biometrics for identifying an individual based on gait information. Main goal of most of the gait analysis is to study the kinematics (the position and motion of different joints) and kinetics (Force that causes the motion) of the joints. To analyze the kinematics and kinetics of the different joints during locomotion, many instruments are required such as a force plate. Force plate is used to measure the ground reaction force, the force exerted by body over the ground during locomotion. Using inverse dynamics approach we can measure the moment across the joints through the use of ground reaction forces. In this experiment, we are modifying an existing Force Plate design, which records ground reaction forces using the strain gauge, by fitting an integrated web-camera that will also record foot imprints from below the force plate instrument. The combination of the strain gauge signal and the image helps in determining the area of the foot in contact with the plate, and the type of strain gauge signal recorded at that moment. We hope that this low cost force plate instrument with the integrated web-camera can aid in the better analysis of gait using the force plate instrument.

CHAPTER 1

INTRODUCTION

Today in this world, health related problems are one of the most challenging problems to be solved, in which gait related problems are of great importance. Gait is the repetitive sequence of lower limb movement so that a person can walk with minimum energy expenditure. For proper execution of gait there should be good co-ordination between central nervous system and the neuromuscular system. In some pathological conditions a deviation in gait pattern is found. Gait analysis is the study of animal locomotion, including locomotion of human. The study includes quantification of measurable parameters of gaits, as well as drawing interpretation about the subject (health, weight, speed, etc.) from his/her gait. Gait analysis is done for two purposes, either for clinical research or for clinical testing. Clinical research differs from clinical testing because the reason is not to make clinical decisions for the individual patient, but to gather data about a pathological condition affecting a group of individuals. The main aim of most gait analysis is the study of joint kinematics and kinetics; other measurements are electromyography (EMG), oxygen intake and foot pressures. For foot pressure measurement either force plate or pressure foot is used, Force plate gives information about ground reaction force while pressure foot gives force field distribution of foot. Gait analysis can be used to extract the information that can be used to know the cause of symptom, in diagnosing the pathological condition, in rehabilitation engineering for new prostheses development and in the field of biometrics individual gait information can be used for identifying individuals. In the present study we are trying to make a low cost force plate which is capable of giving information about force field distribution as well as Ground reaction forces. The experiment makes use of the MATLAB software package for data acquisition from the strain gauges, and the webcam simultaneously for image acquisition from the bottom of the force plate instrument.

CHAPTER 2

LITERATURE REVIEW

2.1) GAIT ANALYSIS

Gait analysis includes study of measurable parameters of gait as well as interpreting the subject health from his/her gait pattern. According to **Brand et al** ^[3], there are four proposed reasons for performing any clinical test for gait analysis, these are

1. To distinguish Diagnosis between disease entities (diagnosis).
2. To determine severity of disease or injury (i.e. assessment or evaluation).
3. To select among treatment options
4. To predict prognosis

According to **Brand et al** ^[3], the monitoring of the progress of a patient's condition either following intervention or in its absence might be regarded as an additional reason, so brand modified the four reasons for performing any clinical test, these are

1. Diagnosis between disease entities.
2. Assessment of the severity, extent or nature of a disease or injury.
3. Monitoring progress in the presence or absence of intervention.
4. Prediction of the outcome of intervention (or the absence of intervention).

Brand et al ^[4], proposed the criteria for assessing the usefulness of biomechanical measurements, which can be used with some modification, as criteria for the usefulness of all clinical gait analysis.

These criteria should be

1. Reproducible
2. Stable (independent of mood, motivation and pain)
3. Accurate
4. Appropriately validated
5. Capable of distinguishing between normal and abnormal
6. Must not alter the function it is measuring
7. Reported in form analogous to accepted clinical concepts

Murray et al ^[5] studied the parameters of gait in normal men. He found that the average duration of the gait cycle was 1.03 seconds, cadence was 117 (90–20 steps) and the mean ergonomically walking speed was 2.8 miles per hour. The average stride length was 70-82 cm and the average stride width was 8 cm, with a foot angle of 6.7°.

Ostrosky et al ^[6], compared gait characteristics in young and old subjects and found that older people demonstrate less knee extension and a shorter stride length compared with Younger people.

2.2) METHODS OF GAIT ANALYSIS

A clinical gait laboratory will usually use these techniques for gait pattern analysis. These techniques can be used independently or in combination, these are:

2.2.1) VIDEO

It is a common method of recording an image digitally, it is used to augment in observational gait analysis and provide a degree of quality control. Slow motion or frame-by-frame playback can be used augment the observational gait analysis. This technique is used to enable an observer to make a decision about an individual's gait. It allows the clinician to record a person's gait before applying any instrumentation (EMG electrodes, footswitches, motion markers etc.) that might alter the gait patterns. Two cameras are used at least to view a patient Gait pattern, one for sagittal plane and one for coronal plane. These cameras are synchronized and camera views are integrated into a single image. Slow motion or frame-by-frame playback can be used augment the observational gait analysis enabling quick or imperceptible movements to be more readily detected. ^{[7][8][9]}

2.2.2) MOTION CAPTURE SYSTEM

If there are multiple images of the same object and 3-D position, orientation and Optical characteristics of the camera is known then 3-D position of object can be determined with the help of different 2-D images of same object. This system uses the Video camera and marker system. Video cameras are used to track down the Markers placed at different locations of the patient. Marker system is of two types Active and Passive. Infrared (IR) or light-emitting diodes (LEDs) markers are example of active markers while solid shapes covered with retroreflective tape are example of Passive. The horizontal and vertical coordinates of each marker are recorded from each camera. 3-D coordinates for each marker are calculated based upon the 2D data from two or more cameras and the known location of all cameras. Two or more cameras are needed because markers may become obscured from camera views because of movement of body parts during Gait cycle. In some cases single cameras are used with the assumption of that all motion is occurring perpendicular to the camera axis. But in this case there is loss of signal when any marker will placed outside of camera view. So this type of systems is not recommended for gait analysis and if used then it should be used in a very controlled situation. [7][9][10][11]

2.2.3) ELECTROGONIOMETERS

Electrogoniometers are electro-mechanical devices that span a joint to be measured, with attachments to the proximal and distal limb segments. These devices provide an output voltage proportional to the angular change between the two attachment surfaces. They operate on the assumption that the attachment surfaces move with (track) the midline of the limb segment onto which they are attached and, thereby, measure the actual angular change at the joint. This instrument gives better result for lean individuals than fleshy or muscular person due to skin and muscle movement. Accuracy of this device should be carefully evaluated before using for Gait analysis by testing them on individuals of various heights; this will give a general idea of the kinds of errors the clinician might encounter. Electrogoniometers available in market are either potentiometer type or Strain Gauge type. Potentiometer Electrogoniometers are designed to cause a potentiometer shaft to rotate proportionally to the joint angle being measured while Strain gauge Electrogoniometers are

consist of a small diameter, tightly coiled, flexible spring with plastic end blocks on each end. The strain gauge is housed inside the spring, whose electrical resistance changes proportionally to the change in angle between the longitudinal axes of the end blocks ^[7].

2.2.4) EMG (ELECTROMYOGRAPHY)

The electromyography (EMG) is used to record the activity of muscles during gait, this process is called as dynamic EMG. It can give the clinician an indication of what the muscles are doing during different activity of gait. EMG data can be very crucial because many surgical decisions are based on the EMG data. Therefore it is important to have instrumentation and techniques that provide high quality EMG signals. Two types of electrode are used in EMG Signal acquisition, surface electrode and intramuscular wire electrode. Surface electrodes have gained more acceptance due to their ease of application and because skin penetration is not required. EMG is generally recorded using either passive or active surface electrodes. Active electrodes have a built-in amplifier and are less susceptible to artifacts due to wire motion. EMG electrodes are usually interfaced with the data collection system via a data cable. Telemetered systems are used with some success, replacing the data cable with a small radio transmitter and power pack. The EMG system will typically be set up to monitor a number of muscles simultaneously. Eight- and 16-channel systems are common, and 32-channel systems are available. Surface electrodes cannot readily be used to detect the activity of deep muscles, e.g., the tibialis posterior. In addition, surface EMG is subject to cross-talk, particularly when a rather small muscle is adjacent to larger muscles with overlapping firing patterns. If the EMG of such muscles is required, fine wire electrodes are used. Like video recording, EMG may be captured simultaneously with motion capture or separately. Analysis of EMG can be done on several levels. The most basic level checking is the activity of the muscle is phasic (with clear on and off periods) or constant (either on or off indicating absence of useful control). The next level of analysis involves the checking of is the muscle activity occurring at the normal time in the gait cycle or not. ^{[7][12]}

2.2.5) FORCE PLATE

Kinetics is defined as the study of motion and its causes (forces which are responsible for the motion). Kinetic study of human locomotion can be helpful in determining and

measuring forces which are responsible for human locomotion. Kinetic study parameters can be categorized into internal moments and External moments, in external moment force acting on a joint is a result of ground reaction force. Newton's third law states that when a body exerts a force on a second body, then an equal and opposite force, called reaction, must act upon first body, so when a person walk on a surface or ground a force is applied by the body on ground and a equal and opposite reaction force is applied by the ground on that person, this reaction force is called ground reaction force. A force plate is used to measure the ground reaction force. Force plates have many application mainly theses are automobile crash tests, clinical gait analysis, and sports technique analysis.^[10]

A force plate is rectangular metal plate containing sensors at each corner which are sensing and measuring the applied load. Two types of sensors which are used in force plate are piezoelectric and strain gauge. When a load is applied to the plate it is detected by sensors and converted into electrical signal, from these signals the magnitude and direction of the force is measured. Generally force plates are designed such that it measures the components of ground reaction forces (X, Y, Z force and X, Y, Z moment).^[13]

Force plate has a contact surface area where person foot must contact during the ground reaction force measurement. Force plate measurements are generally done with floor fitted force plate to reduce the effect of surrounding vibrations. In order to measure the accurate ground reaction force of a subject, the subject need to place his or her foot or feet completely on the force plate but deliberate loading will give false data so to capture the correct data, starting point should be chosen such that subject foot during walking will be placed exactly on the force plate. At least two force plates are required to measure the ground reaction force because if subject stands on a single force plate then force plate output can't discriminate that ground reaction force is of which foot because force plate measures the total ground reaction force.^[14]

Selection of force plate depends on the applications. Chosen force plate must be of appropriate size and should have a linear response over a range of forces. Before recording any data the calibration should be done by placing a known weight at different locations that is similar in magnitude to the loads that will be applied during normal use. The same

vertical force should be recorded independently of the location and position of load should be detected accurately. ^[11]

2.2.6) TREADMILLS

Treadmills can be used to allow gait to be observed for prolonged times and at higher speeds than can be achieved on a gait laboratory walkway. Kinematics can be also obtained if the treadmill is positioned in the motion capture system viewing volume. Treadmills with instrumentation to measure the vertical component of the ground reaction force are commercially available. Recently, treadmill force plates have been developed, which may permit analysis of both the kinematics and kinetics of treadmill gait. ^[7]

2.2.7) FOOT PRESSURE ANALYSIS

Force plates measure the total force due to the contact of the foot with ground, but do not measure how the total weight pressure is distributed over the plantar surface of the foot. This information is necessary in dealing with patients with neuropathies and in defining the extent of and risks associated with foot deformities. ^[7]

Two technologies are used to measure the plantar surface load distribution.

- First is a floor mounted device similar in appearance to a force plate, but divided into many small regions. The vertical force applied to each region is measured and used to calculate the pressure on the portion of the plantar surface above that region. As with a force plate, the measurement is made only when the foot is on the plate.
- Second technology uses flexible inserts between the foot and the shoe. The insert is again subdivided into a number of regions and each region is instrumented to measure the local force. The resolution of these devices is generally lower than that of the fixed plates. The measurements are affected by how the foot, shoe, and insert fit, and the load sensors tend to be less precise and less uniform than those used in the floor-mounted platforms.

2.3) STRAIN GAUGE SENSOR

2.3.1) STRAIN GAUGE

A strain gage is simply a pattern of thin wires or foil. It works on the principle that when the wire is put under strain it either get elongated or shortened, so due to change in dimension it changes its electrical resistance. The resistance of a wire (R) is a function of three parameters, all of which are effected by strain.

$$R = \rho \cdot \frac{L}{A}$$

Most widely used gauge is the bonded metallic strain gauge. The metallic strain gauge consists of a very fine wire or, more commonly, metallic foil arranged in a grid pattern. The grid pattern maximizes the amount of metallic wire or foil subject to strain in the parallel direction (Figure 1). The cross sectional area of the grid is minimized to reduce the effect of shear strain and Poisson Strain. The grid is bonded to a thin backing, called the carrier, which is attached directly to the test specimen. Therefore, the strain experienced by the test specimen is transferred directly to the strain gauge, which responds with a linear change in electrical resistance. Strain gauges are available commercially with nominal resistance values from 30 to 3000 W, with 120, 350, and 1000 W being the most common values.

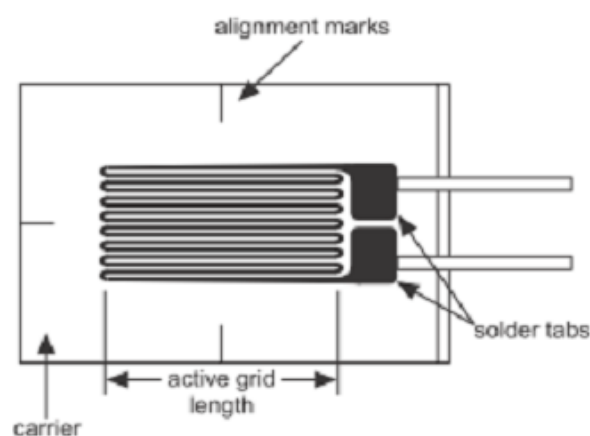


Fig 1: Bonded Metallic Strain Gauge

2.3.2) GAUGE FACTOR

A fundamental parameter of the strain gauge is its sensitivity to strain, expressed quantitatively as the gauge factor (GF). Gauge factor is defined as the ratio of fractional change in electrical resistance to the fractional change in length (strain)

$$GF = \frac{\Delta R/R}{\Delta L/L} = \frac{\Delta R/R}{\epsilon}$$

The Gauge Factor for metallic strain gauges is typically around 2.

2.3.3) STRAIN GAUGE MEASUREMENTS

Strain gauge used mainly for strain in the range larger than a few millistrains ($\epsilon * 10^{-3}$). Therefore, to measure the strain requires accurate measurement of very small changes in resistance. To measure such small changes in resistance, and compensate for the temperature sensitivity, strain gauges are almost always used in a Wheatstone bridge configuration (Fig 2) with a voltage or current excitation source. [15]

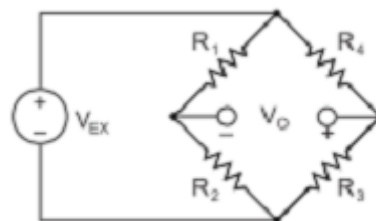


Fig 2: Wheatstone bridge

The output voltage of the bridge, V_O , will be equal to

$$V_O = \left[\frac{R_3}{R_3 + R_4} - \frac{R_2}{R_1 + R_2} \right] \cdot V_{EX}$$

An initial steady state voltage exists unless the numerator above is zero. Such a configuration with zero output voltage is termed a —Balanced Bridge|| and is provided when

$$R2 * R4 = R1 * R3$$

Any change in resistance in any arm of the bridge will result in a nonzero output voltage

2.4) FORCE PLATE DESIGN

Norman C. Heglund et al (1981) ^[16] proposed a simple inexpensive design of a force Plate which can measure Ground reaction force in two planes. In his design the transducer element is composed of two strain-gauge instrumented spring blades orientated at 90 ° to each other; the horizontal blade is sensitive to the vertical force, and the vertical blade is sensitive to the horizontal force.

CHAPTER 3

AIM AND OBJECTIVE

AIM

Simultaneous Image and Signal acquisition for foot force analysis

OBJECTIVE

- 1) Construction and Optimization of electrical circuit for Strain Gauge Sensor.
- 2) Calibration of Force Plate Instrument.
- 3) Acquiring the signals from the strain gauge using Data Acquisition card.
- 4) Capturing image frames that are of interest using the integrated webcam.

CHAPTER 4

SCOPE OF THE PROJECT

1st important point about project is that we are trying to develop low cost Force Plate because Force Plates available in market are costly.

2nd important point about project is that we are trying to measure the Ground Reaction Force as well as Foot print simultaneously (with help of Camera) because all the force Plates available in the market show only Ground Reaction Forces.

CHAPTER 5

MATERIALS AND METHOD

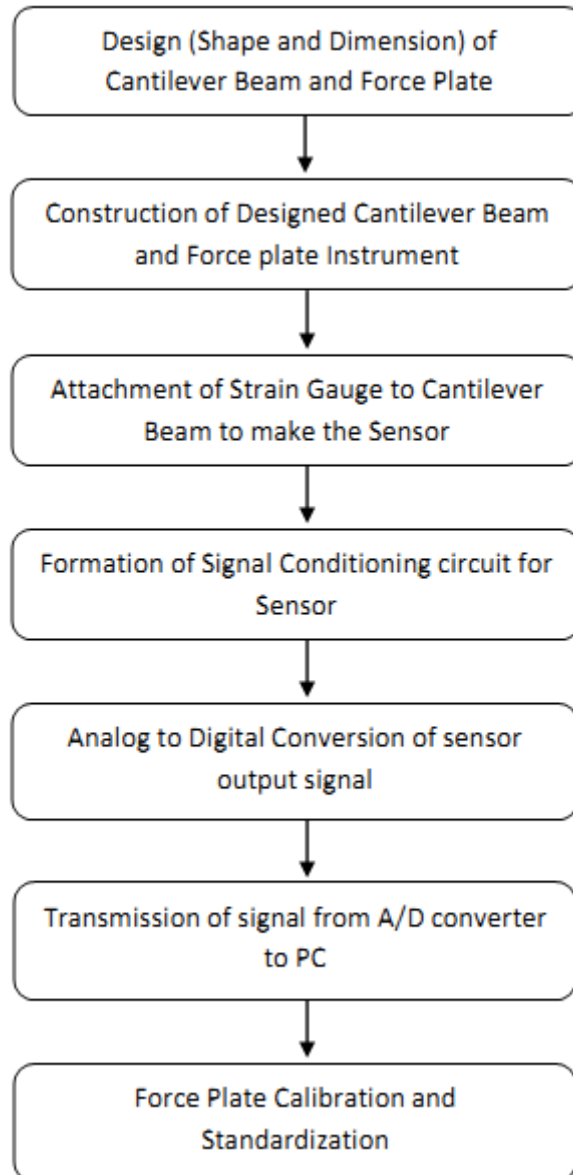
5.1) Materials

1. Stainless Steel 4 cm square rod (50 cm)
2. Stainless steel blade (4 mm height , 4 cm width, 100 cm)
3. Power saw blade
4. Welding electrode
5. Glass Sheet 18 mm
6. Stain gauge (360 ohm) (40 piece)

Power Supply Unit (+ 5v, + 12 v) (5 amp), O-PAMP (741), Resistors (1 - 1 M ohm), Bread Board, Vero Board(line), Multimeter, Hook up Wire, Soldering Unit, Electrolytic Capacitor(470uF/40V, 1000uF/40V, ,250uF/40V), Disc Capacitor(.01uF,.001uF,22 pf), Cutter, Twizer, Hand Drill, Solder Wire, Transistor(BC547,BC557,SL100), Microcontroller Atmega 8535, Crystal 8Mhz, LED -10, MAX-232(ic), TRIMPOT—(1K, 500 ohm).

5.2) Methodology

The cantilever has been designed and fabricated by my senior Mr. Chandan Kumar at the central workshop at National Institute of Technology, Rourkela. The force plate is suspended according to design, by attaching the one end of cantilever at force plate surface and other end at the fixed base end. A strain gauge has been fixed to the cantilever so that both combine to make a sensor. A strain gauge gives signal when it undergoes deflection due to load, these signal are then filtered, amplified and then passed to an Analog to Digital converter, which converts the analog signal to digital. These digital signals are transferred to PC where further processing of signal is done and then the force plate Instrument will be calibrated and standardized.



CHAPTER 6

RESULT AND DISCUSSION

6.1) CANTILEVER DESIGN

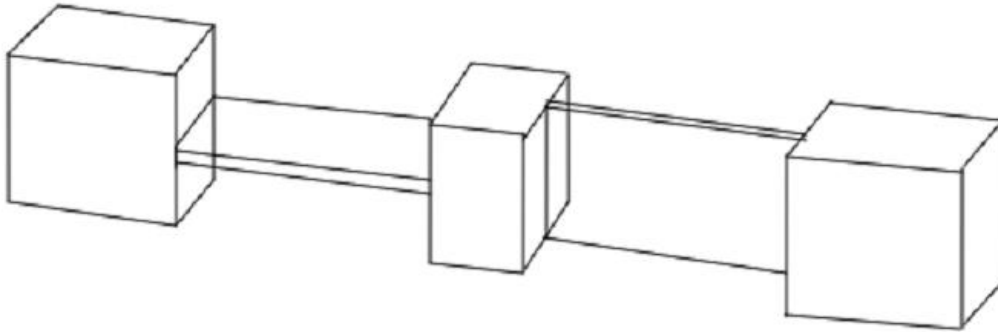


Fig 3: Design of Cantilever

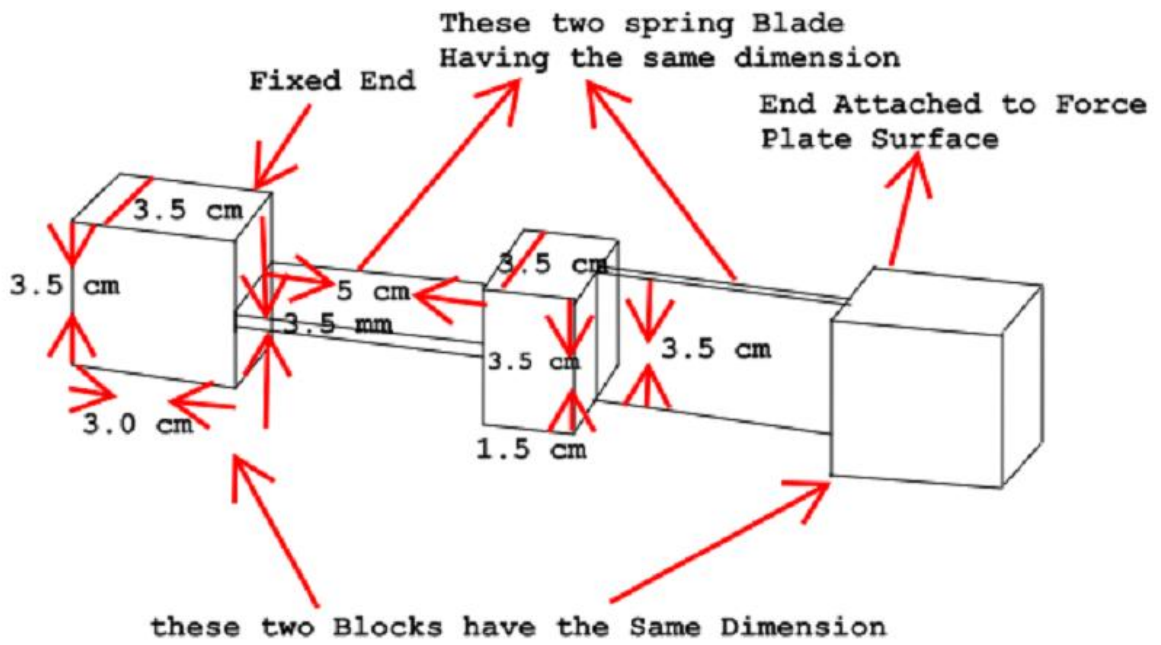


Fig 4: Cantilever Dimension

6.2) CANTILEVER CONSTRUCTION

Steps involved in cantilever construction:

1. Cut the stainless Steel rod and blade into 3.5 cm*3.0 cm, 3.5 cm*1.5 cm and 5 cm*3.5 mm size blocks using power saw machine.
2. Then drill the 3.5 cm*3.0 cm rod and 3.5 cm*1.5 cm Stainless Steel rod using drilling machine in workshop.
3. Then weld the Stainless Steel Rod and Blade According to Design.

6.3) FORCE PLATE DESIGN

This design is consisted of a rigid plate surface suspended at 4 points (4 corners) by a transducer element (Fig 5). The transducer element is composed of two strain-gauge instrumented spring blades orientated at 90 ° to each other; the horizontal blade is sensitive to the vertical force, and the vertical blade is sensitive to the horizontal force. Each spring blade is modelled as if it were two identical cantilevered beams joined at their distal ends.



Fig 5: Fabricated force plate

6.4) STRAIN GAUGE FIXATION ON CANTILEVER

Steps in strain gauge fixation

1. First clean the surface with acetone and water
2. Then place the Strain gauge at the appropriate place using Tweezers.
3. Now fixed the strain gauge with the araldite (fixing agent)
4. Place a cello tape over the strain gauge

Then leave it under a constant load for 24 hours.

6.5) CIRCUIT FOR FORCE PLATE

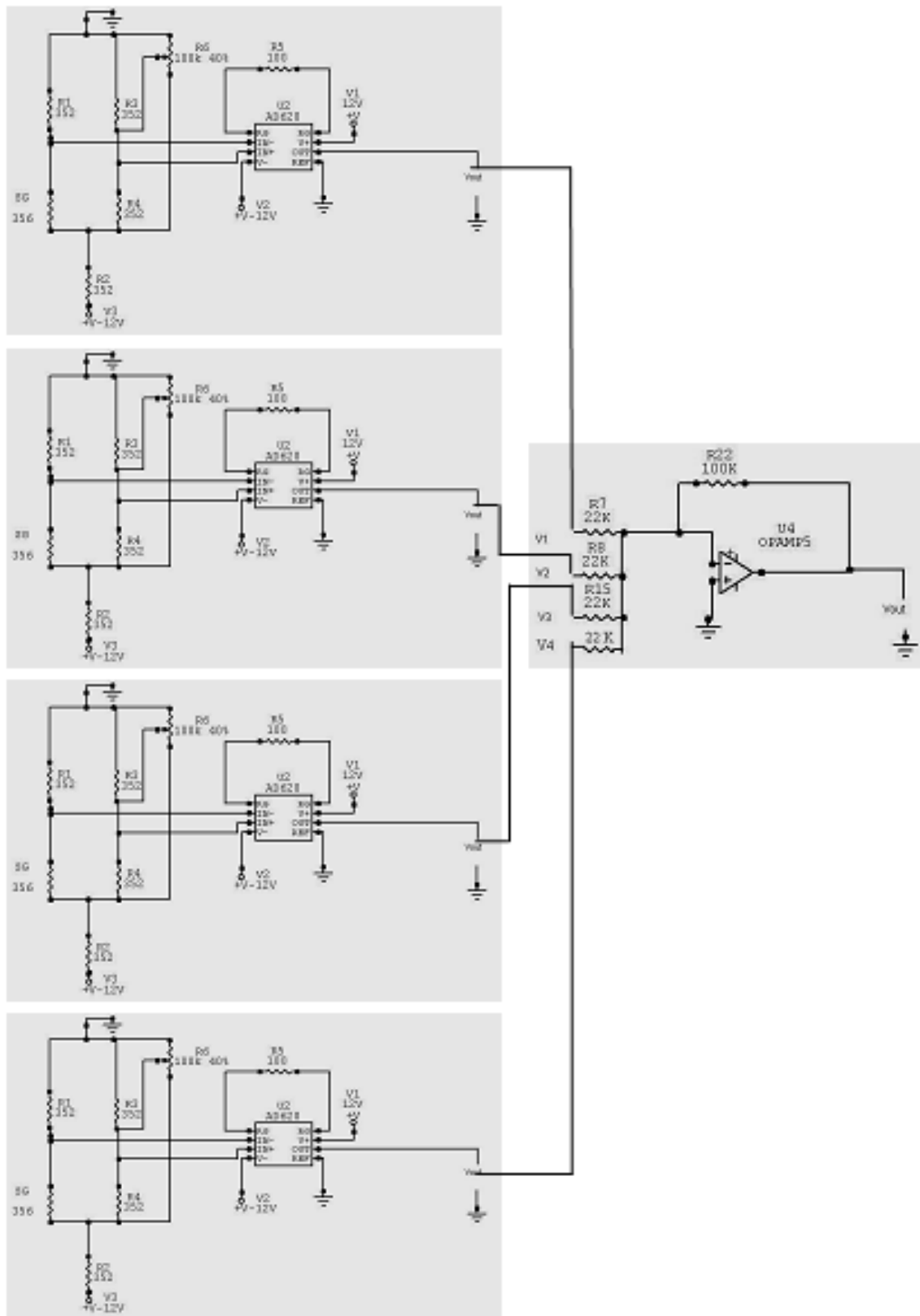


Fig 6: Circuit for Force Plate

Wheatstone bridge is used for measuring the change in resistance of strain gauge. Output of Wheatstone bridges are transferred to Instrumentation amplifier (AD620) for amplification of signal (Fig 6), we are using Instrumentation amplifier instead of op-amp for amplification because of Noise. Four Wheatstone bridge circuits are used because we are using four strain gauges in our force plate. Output of each Wheatstone bridge is transferred to separate AD620. Now we have four output signals so we have added these four signals with the help of adder. Output of the adder is the final output.

6.6) FORCE PLATE OUTPUT

6.6.1) OUT PUT DATA

Data was captured from the Wheatstone bridge circuit using the National Instruments (NI USB-6008) data acquisition (DAQ) card. The digital signals from the A/D converter were picked up by the DAQ card and I was able to access the data in real-time by feeding it into MATLAB through the Data Acquisition Toolbox.



Fig 7: NI USB-6008 DAQ card

To make the process easier and to be able to control the parameters during acquisition, I had written a MATLAB script (.m file) in which we can change the following parameters during Data Acquisition:

1. Sampling Frequency (Fs)
2. Blocksize (For showing data in real time)
3. Duration of acquisition
4. Logging mode (Disk/Memory or both)

The following MATLAB script was used for the data and video acquisition simultaneously.

```
clc
clear all
close all;
if (~isempty(daqfind))
    stop(daqfind)
end
daqhardwareinfo = daqhwinfo ; %toolbox name and matlab version
no
daqinstalledadaptors = daqhardwareinfo.InstalledAdaptors ;
%installed drivers (dll)
daqregister('nidaq') %'advantech' 'nidaq' 'parallel'
'winsound'

daqwinsoundinfo = daqhwinfo('nidaq')
```

```

ai =analoginput('nidaq','Dev1');
daqhwinfo(ai);
set(ai);
%For a complete listing of all object properties, with their
current settings, use the get function.
get(ai);

ao=analogoutput('nidaq','Dev1');
daqhwinfo(ao);

%Adding & Renaming Channels
%addchannel(ai,[1:2],{'ch0','ch1'});
addchannel(ai, 0,'ch0');

Fs = 1000;
Ts=1/Fs;
blocksize =2000;      % Specifying Sample Window size
duration=40
% Setting Engine Properties-----

set(ai,'SampleRate',Fs);
%Fs samples per second data will be acquired
set(ai,'SamplesPerTrigger',Fs*duration);
%Fs*duration no of samples will be acquired
set(ai,'TriggerType','immediate');
%ai.TriggerType = 'Immediate';
filename='file.daq';
%Assigning daq file name in variable filename
set(ai,'LogFileName',filename);
% Renaming the daq file name
set(ai,'LoggingMode','Disk&Memory');
% storing data in both Disk & Memory

% starting our engine
start(ai);

% Creating the data window
figure;

% Loop Structure for acquiring & displaying the data-----
vid = videoinput('winvideo',1,'YUY2_320x240');
set(vid, 'TriggerRepeat', Inf);
preview(vid);
start(vid);

```

```

i=1; prevE=0; prevmdb=0;
% initializing the loop
while ai.SamplesAcquired < ai.SamplesPerTrigger
% Loop condition
    while ai.SamplesAcquired < i*blocksize %
Ensuring optimum data
        end;

        odata=peekdata(ai, blocksize); %
Assingigning the latest available data to variable pd1
        fsHalf=Fs/2;

        lpf= fir1(30,10/fsHalf,'low');
        odata=filter(lpf,1,odata);

        hpf= fir1(30,1/fsHalf,'high');
        odata=filter(hpf,1,odata);

        data=odata(50:length(odata));

% peekdata function collects 'blocksize' amount of data
tmax=Ts*(length(data)-1);
tsec=0:Ts:tmax;
plot(tsec,-data,'-r'); grid on
% To plot the acquired data
xlabel('Seconds'); ylabel('Amplitude');
title('emg','FontSize',12);
axis([min(tsec) max(tsec) 1.5 2.5])
pt = 1.5*(length(data)/Fs);
% calculating pause time
pause(pt);
% applying pause time
drawnow; % To animate the data

i=i+1;
% incrementing the loop counter

end;

%% stopping the analog input engine-----

stop(ai)
stop(vid)

```

6.6.2) IMAGE CAPTURE

The webcam used for the experiment was “iBall Face2Face C12”



Fig 8: Webcamera used for the experimental setup

The webcam was configured to acquire image frames through the Image Acquisition Toolbox in MATLAB. The web-camera was placed below the force plate instrument for recording the images while the subject walks over the force plate instrument.

Following parameters were used for the configuration of the Webcamera:

1. TriggerRepeat: Infinite
2. TriggerDelay: Immediate
3. FrameRate: 60fps
4. Video Format: YUY2_320x240

The following code was used for the image acquisition process

```
vid = videoinput('winvideo',1,'YUY2_320x240');  
set(vid, 'TriggerRepeat', Inf);  
preview(vid);  
start(vid);
```

6.6.3) MULTI-THREADING

MATLAB support for multithreaded computation was first incorporated into MATLAB 2007a and is enabled by default in MATLAB 2008a and later. We have used MATLAB 2009a for our experiment, and hence had the advantage of using Multi-threading for running the code.

As mentioned in the MATLAB documentation, multithreading in MATLAB speeds up element wise computations such as those done by the sin and log functions, and computations that use the Basic Linear Algebra Subroutines (BLAS) library, such as matrix multiply. Multi-Threading is useful, if you have a cluster of machines that are available for processing, or if there are multiple processor cores on the same machine, or also on a single processor machine.

During multi-threading, the compiler breaks down the code into individual processes, which are each known as independent threads. The threads are capable of being processed by any processor, which is either a part of a cluster, or is one of the cores on the same machine. Due, to multi-threading, there is a possibility of executing programs such as ours, which requires the running of two Data Acquisitions systems at one and the same time.

Consequently, we have made use of MATLAB multi-threading for the execution of our code. The two Data Acquisition systems each share processor execution time among themselves. Due, to this, even though theoretically we have compiled a single program, the compiler breaks the code into a number of fragments specified, and takes up thread execution with a number of processors, or also a single processor. The end result, which matters for us, is that we were able to run two Data Acquisition systems (signal & image acquisition) at the same time which was essential for our experiment.

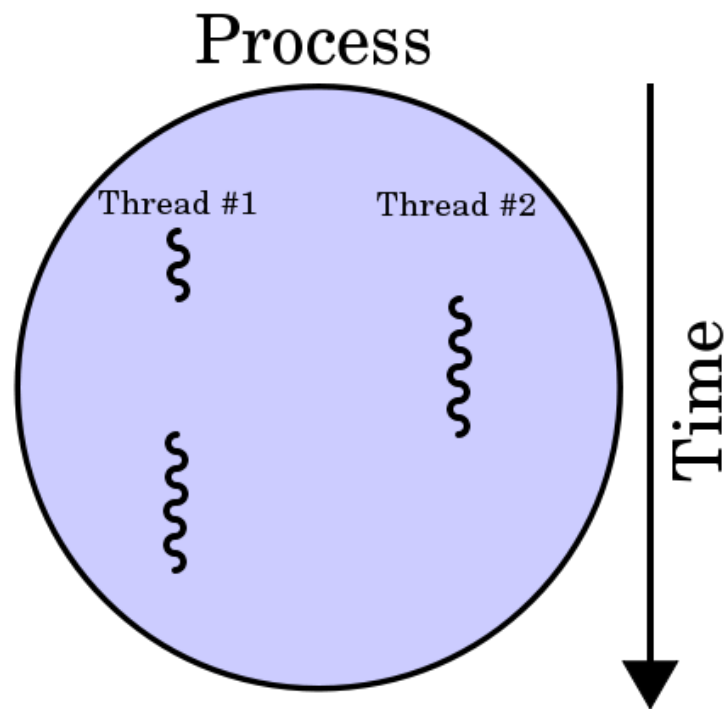


Fig 9: Schematic diagram of Multi-threading

7 . SYNCING DIGITAL SIGNAL WITH IMAGE

MATLAB data acquisition packages allow us to capture data from both systems (Digital signal from strain gauge, and image data from the web-camera) simultaneously. While using the Data Acquisition Toolbox (DAT) and the Image Acquisition Toolbox (IAT) in MATLAB, data can be logged into Memory, or on the Disk, or on both the mediums. It is however advised to use disk logging, for the purpose of data analysis for repeated number of experiments.

The EventLog function of both DAT & IAT provide timing for each event conducted by the toolboxes.


```
[data time ] = getdata(vid);
```

The variable `time` is a vector that contains the time each frame was logged, measured in seconds, relative to the execution of the first trigger. Check the first value in the `time` vector. It should reflect the duration of the delay before data logging started.

```
time
time =
    4.9987
    5.1587
    5.3188
    5.4465
    5.6065
    5.7665
    5.8945
    6.0544
    6.2143
    6.3424

trigdata =

    AbsTime: [2011 04 29 16 40 52.5990]
    FrameMemoryLimit: 139427840
    FrameMemoryUsed: 0
    FrameNumber: 0
    RelativeFrame: 0
    TriggerIndex: 1
```

The `time` vector is relative to the initial trigger (here, 1st frame). By adding the `time` vector to the `AbsTime` vector we can get the Absolute system time of each frame as it was acquired by the Image Acquisition Toolbox.

Similarly, we also get absolute time information for each digital data acquired by the Data Acquisition Toolbox. By correlating the absolute time of both the Toolboxes, we can come to know of each of the values at a particular time of the experiment. After the duration of the signal, where heel strike has occurred is identified, we can identify the image frames for this particular duration, and correlate the two data acquisition systems.

CHAPTER 8

CONCLUSION

Main objective of our experiment was to provide a low-cost alternative for foot force analysis. We developed the force plate with integrated imaging capabilities. In the market, the force plate instruments currently have only load measuring capabilities. Imaging systems in such force plate measurements are cameras that are located at a distance from the experimental setup, and measure joint movements with the help of specific imaging marker points on the limbs etc.

On the other hand, we have constructed this instrument with an integrated web-camera which is placed below the glass surface of the force plate instrument. This instrument helps us in obtaining the imprint of the foot while the subject is walking on the glass surface from below of the instrument. With suitable image registration algorithms, we can find out the area of contact of foot on the force plate, and associate it with the strain curves that we obtain. The combination of data and image simultaneously, gives a new method of conducting force plate experiments.

CHAPTER 4

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