MOTION ANALYSIS USING KINECT SENSOR

A PROJECT REPORT SUBMITTED IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE DEGREE OF

Bachelor of Engineering

in

Electronics and Telecommunication

Engineering

By

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2015-16

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This is to certify that

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have been admitted to the candidacy of Bachelor's degree of Electronics and Telecommunication Engineering in 2015-2016 and they have undertaken the dissertation entitled "Motion Analysis Using Kinect Sensor" which is approved for the degree of B.E. (Electronics and Telecommunication) under Goa University as it is found satisfactory.

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This is to certify that the final year project entitled

MOTION ANALYSIS USING KINECT SENSOR

submitted by

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has been satisfactorily completed in the academic year 2015-2016 as a partial fulfillment of the requirement of the degree course in BACHELOR OF ENGINEERING in Electronics and Telecommunication Engineering at Goa College of Engineering, Farmagudi, Goa.

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Dedication Sheet

This thesis is dedicated to our parents, teachers, friends and other acquaintances, who have been there for us in the thick and thin of the implementation of this project.

ACKNOWLEDGEMENT

Our project is a combined effort of not only the three of us but also of all those who have supported us in the completion of the project. While bringing out the project to its final form, we came across a number of people whose contributions in various ways helped in completion of project. It is a pleasure to convey our gratitude towards all of them.

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We would also wish to extend our special thanks to Sir Chiranjeev Singh, Director of Experiential Design Lab Pvt. Ltd, New Delhi for sharing with us vital information and essential knowledge about Microsoft Kinect Sensor.

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We also wish to thank entire staff of Electronics and Telecommunication Engineering Department for their help.

Last but not the least, we thank our parents, family members and friends for movtivating us.

ABSTRACT

With the advent of Microsoft Kinect sensor, a flexible low cost tool has been made available that enables marker less tracking of human motion in real time. The study explores the possibility of utilizing Microsoft's Kinect sensor to analyse the biomechanics of the shot put throw. It presents a software prototype capable of capturing, recording, analyzing and comparing movement patterns using three-dimensional vector angles. The goal of the present work is to ease the analysis of a shot put game for overcoming the difficulty of visual error detection in shot put game using a software prototype which compares an amateur's game to that of a professional to yield results, which is implemented by using the Kinect sensor. It combines both the Kinect motion capturing and biomechanics analysis and develops a shot put game improvement solution with coaching evaluation.

Contents

List of Figures

Chapter 1

Introduction

Launched in 2010, Microsoft Kinect is one of the most popular game controllers in recent years. Kinect allows users to naturally interact with a computer or game console with gestures and/or voice commands. Applications of Microsoft Kinect have been extended to many fields beyond video games, including sports, healthcare, education, retail, training, virtual reality and other areas. More over researchers have intensively studied fundamental techniques in computer vision-based human motion tracking and recognition using a Kinect sensor.

In late 2011, Microsoft released a Software Development Kit (SDK) for its Kinect sensors enabling users to develop sophisticated computer-based human motion tracking applications in C# and C++ programming languages. The immersive Kinect technology from both hardware design and the SDK makes it possible to detect, track and recognize human motion dynamically in real-time.

This project gets the advantage of both biomechanics analysis and Kinect motion capturing of a shot put player, and develops a sports improvement solution with coaching evaluation.

1.1 Motivation

Motion capture systems are gaining a lot of importance in different fields of research. In the field of biomechanics, marker-based systems have always been used as an accurate and precise method to capture motion. However, attaching markers on the subject is a time consuming and laborious method. As a consequence, this problem has given rise to a new concept of motion capture based on marker-less systems.

Current motion tracking software is not specifically designed for the purpose of extracting data for predictive modeling purposes. The complicated setup and cost factor, limit their applicability in empirical studies. Microsoft's Kinect Sensor is capable of providing skeletal tracking data without the need for a meticulous recording setup, making it ideal for deployment in empirical studies.

Our project is based on the analysis of a shot put throw using the Kinect sensor for coaching evaluation.The analysis of the game is very tedious by mere visual observation. Hence, we overcome this difficulty of visual error detection using a software prototype developed using Microsoft Kinect sensor.

1.2 Proposed Idea

To design and develop a specialized software prototype using motion tracking hardware that performs extraction and generation of quantitative data for shot put throw analysis, using Microsoft's Kinect sensor which studies the body motion of a shot put amateur and compares it with the numerical model of a professional's game for coaching evaluation.

1.3 Organisation of Report

Chapter 1 : Introduction

This chapter gives an overview of the idea of the project, motivation behind it and the evolution of the Microsoft Kinect sensor .

Chapter 2 : Introduction to Kinect Sensor

This chapter gives an overview of the Kinect Sensor structure, Skeletal Tracking implemented by the Kinect SDK, Left-hand coordinate system used by the Kinect and the Application of Kinect.

Chapter 3: Literature Survey

This chapter gives an overview of various existing methods which employ motion analysis systems and the Microsft Kinect sensor.

Chapter 4: Theory of Shot Put

This chapter provides a detailed explanation on the biomechanics of Shot Put, the Gliding Technique and the performance of Lanka(2000).

Chapter 5: Implementaion

This chapter discusses the tools used and the detailed methodology and analysis of our proposed idea.

Chapter 6: Conclusion

This chapter gives an overview of advantages, limitations, success factors to enhance the overall performance of the motion analysis system.

Chapter 7 : Future Work

This chapter gives different ideas to overcome the drawbacks and limitations of the designed software prototype system and also future possibilities to enhance the system.

Chapter 2

Introduction to Kinect Sensor

2.1 Kinect Sensor structure

Kinect sensor is a horizontal bar connected to a small base with a motorized pivot and is designed to be positioned lengthwise above or below the video display. The device features an RGB camera, depth sensor and multi-array microphone running proprietary software, which provide full-body 3D motion capture, facial recognition and voice recognition capabilities.

The depth sensor consists of an infrared laser projector combined with a monochrome CMOS sensor, which captures video data in 3D under any ambient light conditions. The sensing range of the depth sensor is adjustable, and Kinect software is capable of automatically calibrating the sensor based on game play and the player's physical environment, accommodating for the presence of furniture or other obstacles.

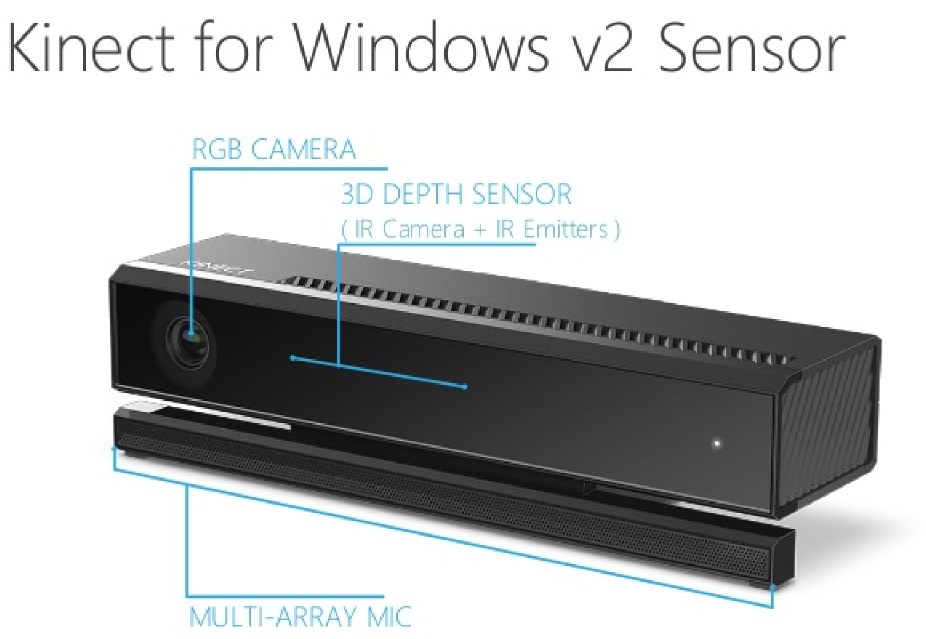

Figure 2.1: Microsoft Kinect V2 sensor

The Kinect must be kept at a height of 0.5 m to 1.1 m from the floor as shown in the figure 2.2. The technical specifications provided by Microsoft announces an operative measurement range of the Kinect sensor from 0.5 m to 4.5 m.

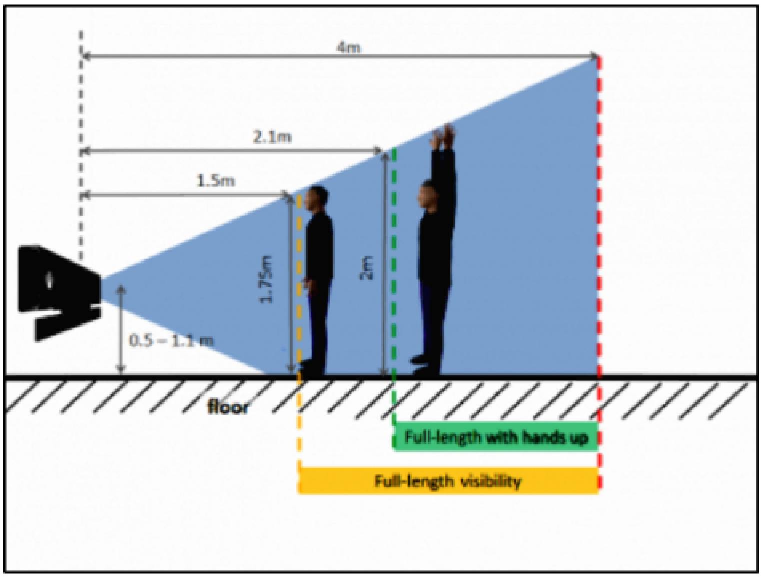

Figure 2.2: Placement and Range of the Kinect sensor

Another feature of the Kinect sensor is the field of view for depth sensing which is 70 degrees horizontally and 60 degrees vertically.

RGB camera captures color image frames of the player. With Kinect ColorImage library provided by Kinect SDK, we can choose the format and frame rate for our need.

All available formats are shown as below:

1. RgbResolution640x480Fps30

   This is default setting of ColorImage library of Kinect SDK, which has resolution if 640x480 pixels in RGB mode, with 30 frames per seconds.

2. RgbResolution1280x960Fps12

   This setting has higher resolution than default, which is 1280x960 pixels in RGB mode, but takes fewer frames per seconds as trade off, which is 12 frames per second.

3. RawYuvResolution640x480Fps15

   Image in raw, uncompressed YUV format with resolution of 640x480 pixels and frame rate of 15 per second.

4. YuvResolution640x480Fps15

   Image in YUV format with resolution of 640x480 pixels and frame rate of 15 per second.

In this project, since the quality of color image is less important than the accuracy of movements tracking, we choose default color image setting in order to get maximum frames per seconds.

The advantages of using Kinect compared to marker-based systems are portability, ease of set up, instantaneous data output. There is no calibration required as seen in marker based systems. Kinect based systems are field friendly, have high versatility and low cost. Kinect comes along with a free software development tool kit.

2.2 Skeleton Tracking

By using the depth stream, the Kinect SDK is able to detect the presence of the player in front of the sensor. Kinect is capable of simultaneously tracking up to six people, including two active players for motion analysis with a feature extraction of 25 joints per player. The number of people the device can ”see” (but not process as players) is only limited by how many will fit in the field-of-view of the camera. For each tracked person, Kinect SDK API provides a “skeleton” as a set of motion data. A skeleton contains 25 position sets, one for each “joint” of the body.

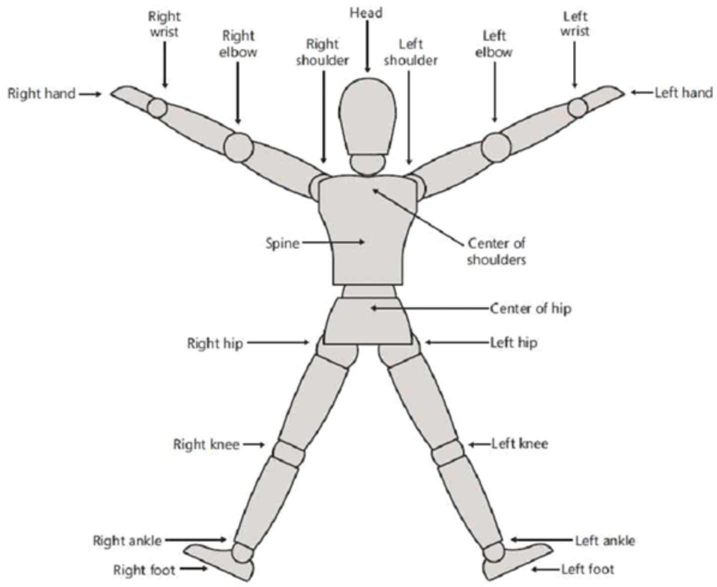

Figure 2.3: Joints Information

Each joint goes with its absolute position of X, Y, Z in play space in the unit of meters.

Kinect SDK provides each joint data set with X, Y, Z values as below :

- The 25 joints set is in a sequence that starts from joint HipCenter, goes up to the Spine then up till the Head, and then goes left from ShoulderCenter till the HandLeft. It goes to the right in the same way, then goes down to the left till FootLeft, and further goes to the right till FootRight as an end.
- The absolute X, Y, Z position refers to the distance from joint point to Kinect sensor in X, Y, Z axis respectively.

2.3 Data Format

Kinect applies the left handed coordinate system for position and absolute rotation tracking. This system has its Z axis originating from the Kinect sensor facing towards the player. The Y axis points upward in the vertical direction. And X axis points to the left along the direction of the horizontal axis. The figure 2.4 shows the left handed coordinate system.

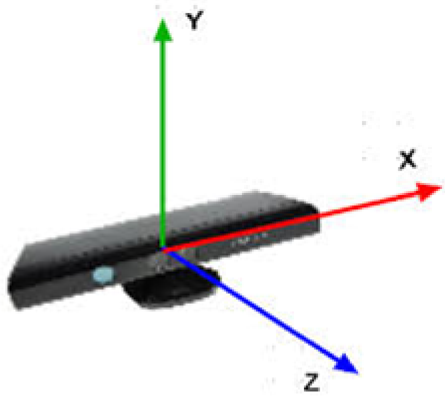

Figure 2.4: Left Hand Coordinate System

2.4 Applications of Kinect

Microsoft Kinect Sensor was initially marketed to add motion control to games and is used as a peripheral for Xbox 360. Kinect is used in the field of medicine and surgery,robotics, general health care, physiotherapy. It is widely used in the field of sports biomechanics.

Some of the applications are as follows :

1. Produce High-Quality 3D Scans
2. Help with Stroke Recovery
3. Translate Sign Language
4. Retrieve Data via Gesture
5. Turn Any Surface Touchscreen-Enabled
6. Virtual Clothes Fitting
7. Control Robots with Body movement

Chapter 3

Literature Review

3.1 Evaluation of Body Position Measurement and Analysis using Kinect – At the example of Golf swings

1. Authors:

   Andreas Elm, Rikard König, Henrik Linusson

2. Abstract :

   Modern motion capturing technologies are capable of collecting quantitative, biomechanical data on golf swings that can help to improve our understanding of golf theory and facilitate the establishing of new, optimized swing paradigms. This study explored the possibility of utilizing Microsoft's Kinect sensor to analyze the biomechanics of golf swings. Following design-science research principles, it presents a software prototype capable of capturing, recording, analyzing and comparing movement patterns using three-dimensional vector angles. The tracking accuracy and data validity of the software were then evaluated in a set of experiments in optimal and real-world conditions using actual golf swing recordings. The results indicate that the software is providing accurate data on joint vector angles with a clear profile view, while visually occluded and frontal angles are more difficult to determine precisely. The employed position detection algorithm demonstrated good results in both optimal and real-world environments. Overall, the presented software and its approach to position analysis and detection show great potential for use in further research efforts.

3. Hardware used :

   Microsoft's Kinect Xbox 360 console.

4. Methodology :

   The central contribution of this thesis is the software developed for the Kinect sensor, enabling the comparison between two movement patterns and allowing data to be extracted for predictive modelling purposes. The software prototype of this thesis realizes this technique by including a keyframe selection feature. The use case for golf swings includes the recording of an 'optimal' benchmark swing to establish a ground truth, which is then used to compare and analyse subsequent recordings with. Once the swing has been captured with the software, the user interface allows for dynamic frame-by-frame browsing through the entire recording, with both visual and quantitative vector angle data at display. Once the desired comparison position has been found, it can be added to the list of keyframes.

This permits for a dynamic approach to motion comparison, as there are no boundaries to the number of keyframes in the array.

5. Conclusion :

   This thesis set out to develop a software prototype capable of tracking, recording and analysing biomechanical data utilizing Microsoft's Kinect sensor and prepare it for predictive modelling purposes. Following the design-science in information systems research methodology, the study was focused on golf swing analysis. Therefore, the research objective of this study was to develop and evaluate a software artefact usable for predictive modelling.

3.2 Biomechanical Study of the Shotput and Analysis of the Flight Phase

1. Authors :

Daniel Vecchio, Carmen Muller-Karger (Biomechanics Research Group, University Simon Bolivar, Caracas, Venezuela)

Edgar Salazar (National Institute of Sport, Biomechanics Laboratory, Caracas, Venezuela)

2. Abstract :

In this research a biomechanical study of an athlete during a shot put competition was conducted. The aim of the study was to gain understanding of the athlete performance and to communicate the knowledge to the coaches to generate accurate recommendations.

The main biomechanical aspects of the shot put were analyzed; results are presented for joints angles and velocities, as well as the trajectory of the shot. Subsequently, the release conditions that dictate the flight phase in each attempt were obtained. A numerical model of the flight phase was developed as a problem of initial conditions. A comparison between the numerical results and experimental values is presented. A sensitivity analysis of the parameters that affect the flight and distance of the shot put was performed.

3. Conclusion :

The numerical results confirm that the parameter that most affects the final result is the release velocity, the higher it is, the greater the distance reached. The same applies to the release height but the improvement is not very significant. Regarding the biomechanical analysis, the initial position taken by the national athlete generates losses in velocity and linearity of the trajectory of the shot in the hand. The result of the numerical model showed a maximum relative error of 7.35% respect to the experimental values with a conservative approximation always less than the real value. The numerical results confirm that the parameter that most affect the final result is the release velocity.

3.3 Animation of 3D Human Model Using Markerless Motion Capture Applied To Sports

1. Authors :

   Ashish Shingade and Archana Ghotkar, Department of Computer Engineering, Pune Institute of Computer Technology, Pune, India.

2. Abstract :

   Markerless motion capture is an active research in 3D virtualization. In proposed work we presented a system for markerless motion capture for 3D human character animation, paper presents a survey on motion and skeleton tracking techniques which are developed or are under development. The paper proposed a method to transform the motion of a performer to a 3D human character (model), the 3D human character performs similar movements as that of a performer in real time. In the proposed work, human model data will be captured by Kinect camera, processed data will be applied on 3D human model for animation. 3D human model is created using open source software (MakeHuman). Anticipated dataset for sport activity is considered as input which can be applied to any HCI application.

3. Hardware used :

   Microsoft Kinect Sensor.

4. Project Plan :

   Kinect camera allows us to produce depth, texture, user and skeleton information. The depth information is obtained from IR cameras on kinect. The texture information is the RGB color map of the scene which can be obtained through the RGB camera on the kinect. The user information is obtained from the binary images which includes the detected people in the scene. To obtain the skeleton information the person has to stand in front of kinect camera, as we are using MS kinect SDK calibration pose is not required and kinect tracks the human skeleton in real time. The MS kinect SDK is a middle ware framework supported by kinect camera. We get 20 joint positions. using MS kinect SDK. The skeleton joint positions obtained from kinect camera are shown in figure 1. The major steps involved in the proposed system are: Skeleton Recognition and Tracking ,3D Human Model Creation, Rigging ,Application of Motion Data to Rig.

5. Conclusion :

   After conducting a survey on different motion capture and skeleton tracking technique, it is found that there is lot of scope for the development of such system. Hence, we proposed a system using markerless motion capture for 3D human character animation using kinect camera, which takes comparatively less development and processing time, this technique can widely be applied for gaming and film industry. We have also done survey on various depth cameras available and different NUI libraries available for development with these cameras.

3.4 Marker-less Motion Capture for Biomechanical Analysis using the Kinect Sensor

1. Author :

   Ting TingAnShen

2. Abstract :

   Motion capture systems are gaining more and more importance in different fields of research. In the field of biomechanics, marker-based systems have always been used as an accurate and precise method to capture motion. However, attaching markers on the subject is a time-consuming and laborious method. As a consequence, this problem has given rise to a new concept of motion capture based on marker-less system. By means of these systems, motion can be recorded without attaching any markers to the skin of the subject and capturing colour-depth data of the subject in movement.

   The current thesis has researched on marker-less motion capture using the Kinect sensor, and has compared the two motion capture systems, marker-based and marker-less, by analysing the results of several captured motions. In this thesis, two takes have been recorded and only motion of the pelvis and lower limb segments have been analysed. The methodology has consisted of capturing the motions using the marker-based and marker-less systems simultaneously and then processing the data by using specific software. At the end, the angles of hip flexion, hip adduction, knee and ankle obtained through the two systems have been compared. In order to obtain the three-dimensional joint angles using the marker-less system, a new software named iPi Soft has been introduced to process the data from the Kinect sensor. Finally, the results of two systems have been compared and thoroughly discussed, so as to assess the accuracy of the Kinect system.

3. Conclusion :

   As it was said in the introduction, the Kinect system is less accurate than the marker-based system. However, once finished the analysis and obtained the results, it has been verified that Kinect system is able to capture with enough accuracy the human motion with a reduction of time in the capture process. From the graphics obtained, it can be verified that, as expected, Kinect did not obtain exactly the same results as the marker-based system. However, by means of the data obtained from Kinect, it is observed that the system is able to provide a good approximation of the movement. Given the NRMSEs of each case, the most reliable results refer to the hip flexion and knee angles and the results of hip adduction and ankle angles are not accurate enough to be relied on. This suggests that Kinect is better for capturing the rotation pattern of the joints with a large range of motion.

   In conclusion, Kinect system is a reliable system which permits to obtain acceptable kinematics results. Moreover, Kinect system saves significantly the time consuming process of attaching markers on the skin of the subject (which can take 15 to 20 minutes).

3.5 A Comparative Study of Human Motion Capture and Computational Analysis Tools

1. Author :

Seung-kook Jun, Xiaobo Zhou, Daniel K. Ramsey and Venkat N. Krovi , Mechanical & Aerospace Engineering, SUNY at Buffalo, Buffalo, NY 14260 USA.

2. Abstract :

Human motion-capture and computational analysis tools have played a significant role in a variety of product-design and ergonomics settings for over a quarter-century. In moving beyond traditional kinematic (and its dual-static) settings, advances in biomechanics and multibody dynamics have led up to computational analysis tools that can provide significant insights into the functional performance. Such tools now offer the ability to perform numerous what-if type analyses to help virtually-evaluate scenarios, thereby providing enormous cost- and time-savings. However, there exist significant differences in the capabilities and ease-of-use between these tools, necessitating a careful evaluation. Hence, in this paper, we perform comparative analysis of motion data from two alternate human motion-capture systems (ViconvsKinect) processed using state-of-the-art computational-analysis systems (AnyBodyModeling System/Visual3D). The quantitative evaluation of a clinically relevant task (squatting) facilitates an objective evaluation of functional performance including effects of motion capture fidelity (from various sources) and the role of pre-processing and post-processing (calibration, latent dynamics estimation).

3. Project Plan :

Our study beings with motion capture of squatting using two alternate synchronized systems – a high-fidelity Vicon MX System (Vicon 2013) together with a low-cost commercial-off-the-shelf Kinect sensor. The Vicon motion capture system uses high-speed (120Hz) digital cameras to track retro-reflective markers placed over body segments (head, neck, trunk, pelvis, arms, forearms, thighs and feet), from which 3D human movement is inferred using reconstructed 3D maker trajectories. We employ an 8 camera Vicon MX system that is synchronized with Kinect system via a video synchronizer.

4. Conclusion :

Two motion capture systems : a low-fidelity and low-cost Kinect framework and the more expensive, higher fidelity Vicon were examined to aid quantitative knee-angle estimation in a clinically-focused squatting study. In particular, we sought to compare the systems in terms of quantitative performance criteria including workspace, sampling rate, accuracy and portability. The combination of Vicon Motion-capture with AMS/Visual-3D post-processing yields outstanding performance (with huge workspace, high resolution and sampling rate) but with limited portability and high cost. The commercial-off-the-shelf Kinect system offers an ultra-mobile (2.2 kg) solution costing less than $100 but has small workspace, relatively low resolution. Thus direct application of the Kinect system to clinical or research work (without post-processing of raw data) tends to be limited. However, we noted that with suitable post processing offers potential for applicability for clinically relevant us.

Chapter 4

Theory of Shot Put

4.1 Biomechanics of Shot Put

The science devoted to study the performance of an athlete, through the analysis of the human movement using the laws of physics, is the sport biomechanics. To comply with optimal release characteristics, the athlete must perform a set of previous specifics movements that requires a high physical preparation and technique. The study of biomechanics is critical for understanding the way in which the human body moves when engaging with a multitude of different activities.

The biomechanical factors determine whether the performance will be successful or not are given as follows:

4.1.1 The Kinetic Chain

Shot put requires all of the joints in the kinetic chain to move simultaneously in one single movement. A push-like movement pattern is best in shot put for many reasons, one of significance being that simultaneous motion will result in a more accurate movement due to the body travelling in a straight-line, a push-like movement pattern helps control the accuracy of shot put throw.

To execute successful movement in shot put the individual needs to have a solid stable base of support. The individual rotates their torso and their back knee is bent. There is an upward motion that relies on the power to be generated through extending the knee that is bent, the individual would apply force to the ground with the leg that is bent, Newton's Laws of Motion state that for every action there is an equal but opposite reaction. As the individual extents the force moves into the arm as the shot put is released. The front leg remains straight and the shot is pushed from the tips of the finger at an optimal angle.

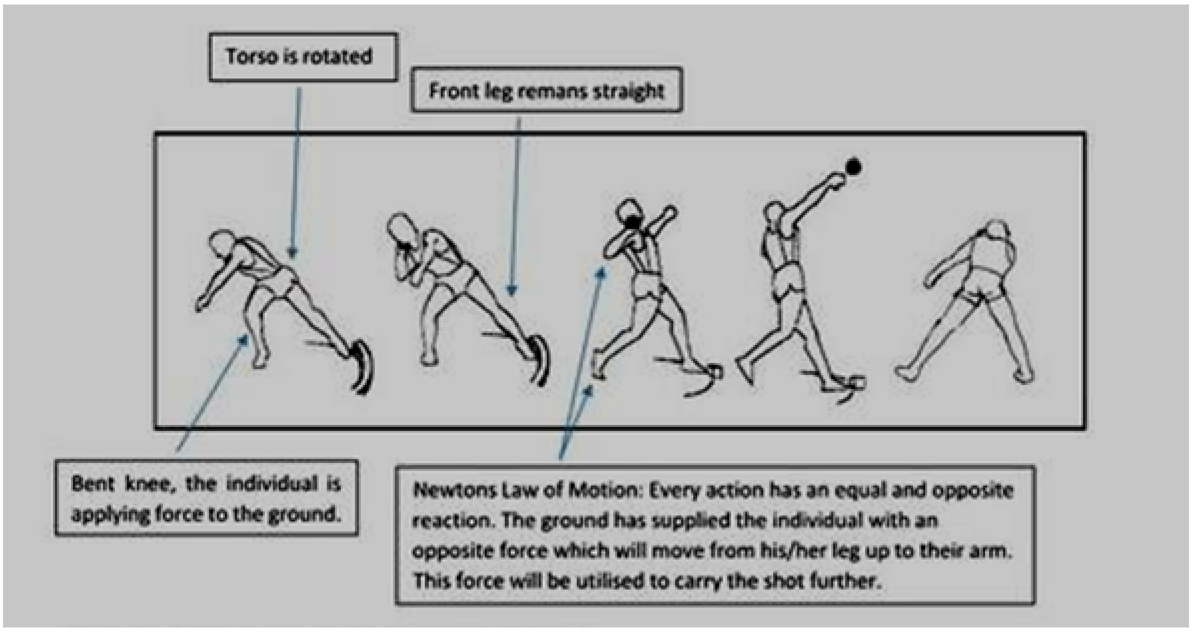

Figure 4.1: Push like movement in Shot Put

4.1.2 Optimum Angle/Height of Release

The angle of release and height of release both play a significant role in determining how far the shot will be carried and the distance is ultimately determined by the way in which force is applied. The optimum angle of release for an individual is the ratio between the horizontal and vertical velocity. In order to attain the maximum projectile range the angle of release of the shot needs to be between 90 ° and 0 °. The best release angle is 45 °, when horizontal velocity and vertical velocity are equal and the shot has the ability to reach its maximum distance.

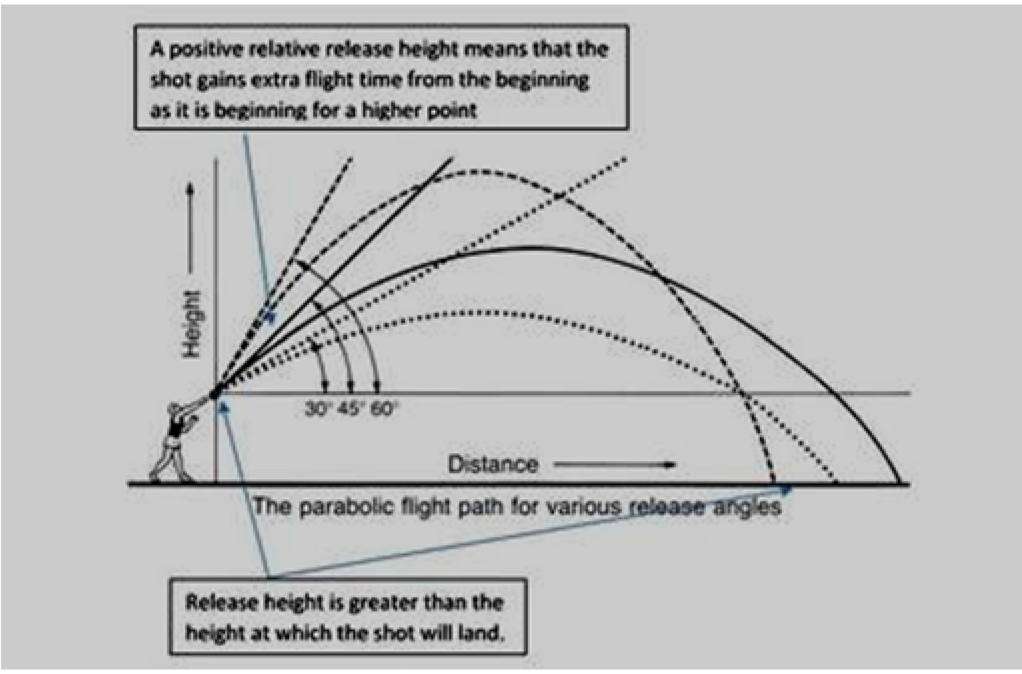

Figure 4.2: Optimal angle of release in relation to a positive relative release height

Optimal angle of release is determined by two factors, these being when the landing point is lower than the height of release and when the height of release is lower than the landing point. In the case of shot put, the landing point is lower than that of the release height, this means that the relative release height is positive. When the relative release height is positive it means that the object, in this case the shot, is starting from a higher point and from the beginning has extra flight time which ultimately means that the angle of release can be less than 45 °. The height of the individual is also a determining factor that should be considered when calculating the optimum angle of release.

4.1.3 Speed Dynamics

Speed dynamics refers to the changes in the individuals speed whilst they are going through the movements .The speed at which the individual is moving when performing a shot put throw will greatly influence the distance at which it will carry the shot and therefore the speed dynamics play a critical role in the analysis of a shot put throw. Athletes should build up their speed gradually along the different phases of the shot put throw rather than having a burst of speed at the beginning. It is important that the individuals build up speed gradually, as it allows the player to have greater control over the throw.

4.1.4 Throwing Technique : Gliding Technique

At the start the shot is placed on the neck, under the jaw with the thumb touching the collar-bone. The ideal path of the shot is straight as possible from starting position to the release, with a gradual increase in the height of the ball from the start of the glide. The purpose of the start is to enable the thrower to get in to a good power position with more speed on the ball than from a standing put. The thrower faces the rear of the ring in an upright position with the feet together. Then the upper body is bent slightly over the right leg, knees are together and the left foot is slightly behind the right foot at the starting position. The lower body falls back or unseats from the waist, then the left leg is stretched and kept low as it extends across the ring. The right heel leaves the rear of the ring after the left leg is extended. The left arm is down and relaxed, the upper body remains passive, the thrower's eyes and head remain back.

Most of the force to get across the ring is generated by unseating and driving the left leg to the toe board. The right leg is picked up and place near the centre of the ring. The upper body remains passive and back, for most throwers the left arm will remain back and over the right leg. Once the athlete starts the glide across the ring, the thrower must keep the ball and body moving toward the throw. Shot-putters need to increase the speed of the throw during this movement and set up a proper throwing position. The shot remains over the right leg, the upper body is still passive, and however, some athletes actively open the left arm as the athlete reaches the power position, but the shot is always kept back over the right foot with good technical throwers. The left leg braces with a blocking action, as the left arm opens to the middle of the throwing sector. Then, the right side begins the throwing action with a high arm strike, the elbow up near the ear, the left arm pulled towards the chest. The thrower should keep the body weight back over the right side as the right foot continues to turn. The momentum created by driving across the ring is then converted into a vertical lift. Finally, during the final putting action, the legs lift off the ground and the put is finished at a throwing angle between 37°- 42 °.

The glide seems better suited for tall, largely built athletes. The glide has more consistent results and is easier to execute. On the negative side, the glide has a limited force application and speed development across the ring.

The factors that have been examined here are very significant and influential to a successful shot put performance. Each of them influence the performance at an individual level, however, when connected they are the factors that will determine the overall distance of the shot. It is important that all shot putters and coaches keep these factors in their minds when training for shot put, biomechanics has a significant role in this sport and if this is acknowledged, individuals will ultimately experience greater success.

In our project we have considered the Gliding Technique of the shot put throw. We will be examining the four biomechanical phases: Initial phase, Sliding phase, Transition phase and Flight phase (Final phase).The angle of release of the shot and the trajectory of the shot is determined. The performance of shot put amateur is compared to the performance of a professional shot putter Lanka(2000) and a coaching evaluation is provided.

The figures below shows the performance of Lanka(2000) :

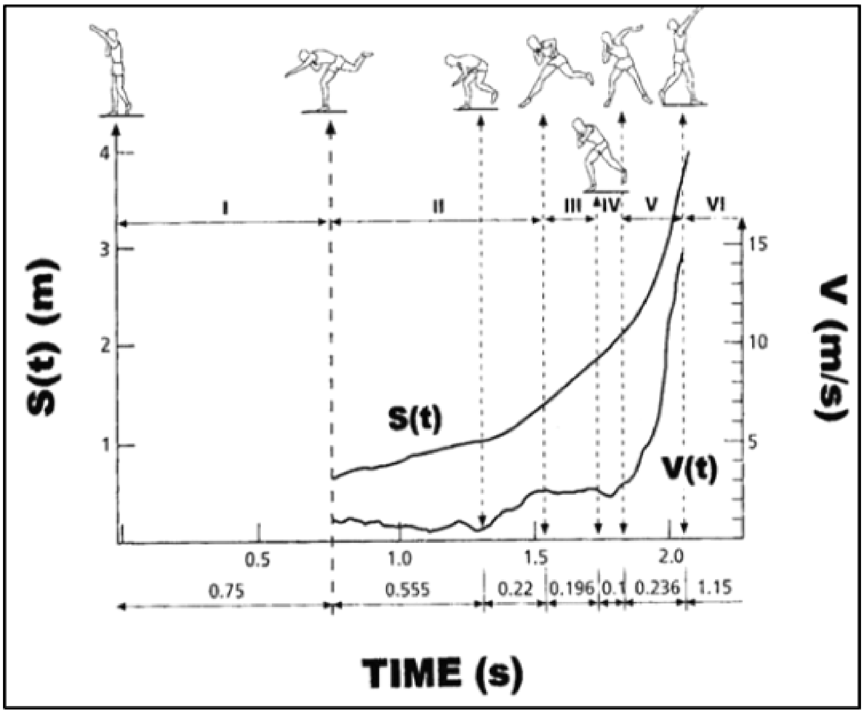

Figure 4.3: Path length s(t) and speed of the shot v(t) ,of an elite shot putter (Lanka, 2000)

Figure 4.3 shows the Path length s(t) and speed of the shot v(t) ,of an elite shot putter (Lanka, 2000) at the different phases of a shot put throw which are preparatory phase(I), starting phase(II), glide phase(III), Transition phase(IV),delivery phase(V), and the final phase(VI)

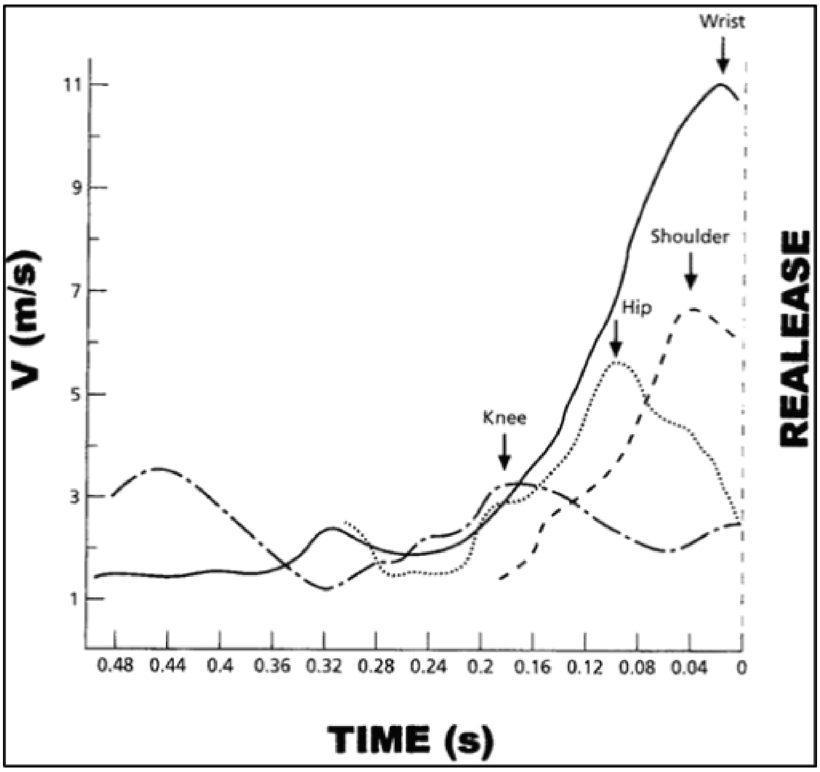

Figure 4.4: Resultant speed of the main joints in Shot-Putting obtained using the motion analysis techniques used by Lanka(2000)

Figure 4.4 demonstrates that there is no coincidence of muscle activation for shot putting. Clearly, there is a sequential transfer of power from proximal to distal body segments: the legs and hips are the engine, the arms and hands the transmission system. Resultant speed of main joints (right side of the body) in shot-putting is obtained using the motion analysis techniques. Arrows indicate the maximum joint speeds and show that deceleration begins at the knee and proceeds progressively upwards to the hip, shoulder, and wrist (Lanka, 2000)

Chapter 5

Implementation

5.1 Tools used

1. Microsoft Kinectv2 sensor :

   The Kinectv2 sensor is a 3-D motion sensing input device operating at frame rate of 30 frames per second(fps) and provides 25 vital joints coordinates of the human skeleton in its field view. It is a markerless technique which makes the overall operation user friendly. The Kinect for Windows SDK provides the tools and APIs, both native and managed, that assists developing Kinect-enabled applications for Microsoft Windows.

2. Visual studio 2013 :

   The Kinect for Windows SDK provides the tools and APIs, both native and managed, that you need to develop Kinect-enabled applications for Microsoft Windows. It can produce both native code and managed code. Visual Studio supports different programming languages and allows the code editor and debugger to support (to varying degrees) nearly any programming language, provided a language-specific service exists. Built-in languages include C, C++and C++/CLI (via VisualC++), VB.NET (via VisualBasic.NET), C# (via Visual C#), and F# (as of Visual Studio 2010). Support for other languages such as Python, Ruby, Node.js, and M among others is available via language services installed separately.

3. Excel 2013 :

   Microsoft Excel has the basic features of all spreadsheets, using a grid of cells arranged in numbered rows and letter-named columns to organize data manipulations like arithmetic operations. It has a battery of supplied functions to answer statistical, engineering and financial needs. In addition, it can display data as line graphs, histograms and charts, and with a very limited three-dimensional graphical display.

4. Windows 8 :

   Windows 8 is a personal computer operating system developed by Microsoft as part of the Windows NT family of operating systems. Windows 8 introduced a number of new features across various aspects of the operating system. Among these included a greater focus on optimizing the operating system for touch screen-based devices (such as tablets) and cloud computing. Kinect v2 is compatible to windows 8 and 8.1 only.

5.2 Detailed Methodology and Analysis

Shotput is a game involving many complex motions simultaneously which includes rotational, translational and lateral motions. For any beginner, it gets very difficult to detect the stage of the throw which needs an improvement. Existing methods involve a coach trying to evaluate the stage of flaw in the game by observation.

This has 2 major drawbacks:

- The presence of a skilled trainer is inevitable for every throw of the beginners practice session.
- The accuracy level would be lower than desired, since the correction of flaw in the game is manual method.

To overcome the above difficulties ,we have developed a software prototype for which could detect the flaw in the beginners game without constant physical presence for the busy trainer.

Gliding technique and spin technique are the 2 major techniques of the shot put throw followed by majority on the national and international shot put champions each having equal share of its advantages and disadvantages. The glide technique has consistent results and is easier to execute whereas the rhythm of spin technique is a difficult to master especially for athletes with limited practice schedules. Also, in spin technique the path of the shot is not as linear as the glide causing inconsistent release patterns. Therefore, our software prototype is a glide technique shot put game analyzer for beginners.

Before developing the software prototype, following are few activities undertaken:

- A thorough understanding of the Kinect SDK and glide technique of shot put game was carried out.
- After much considerations, Lanka (2000 Olympic gold medalist) was chosen as our reference / ideal case in shot put game analysis since she has been used as a reference in various experiments giving successful results.

There are two possibilities as to how the power generated by muscles is applied to the shot:

1. Power is maximized through the temporal coincidence of the trunk and arm movements.
2. Power is maximized through a sequential activation of body segments: typically from proximal to distal, i.e. legs → pelvis → back → shoulders → arm → shot.

Height and energy contained are relatively constant for an individual athlete and, from a practical point of view, cannot be changed to improve performance. Thus, increased performance must come from increasing release velocity as the range is directly proportional to the square of release velocity.
Velocity is inversely proportional to time. Therefore, time is an important factor for consideration for improving performance.
The angles made by the joints at the start of the initial stage have maximum impact in building energy for the shot put throw. When these are well within the limits, a player with a given amount of energy can use it to its optimum, to have maximum release velocity.

The method of developing the prototype has been described below.

In our study we have considered 15 necessary joints of the skeleton. They are as shown in the following figure :

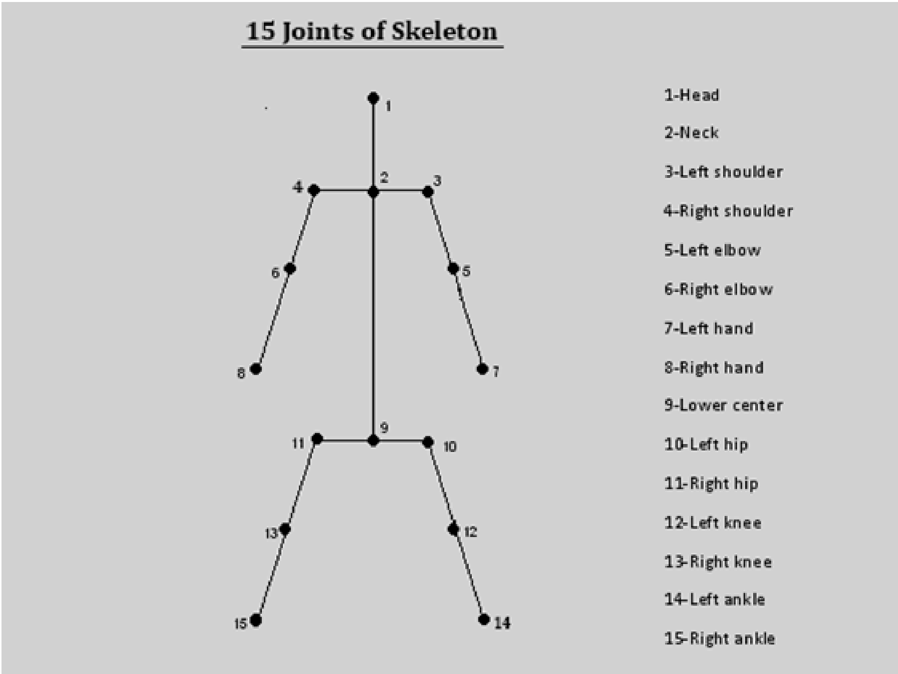

Figure 5.1: 15 Joints of the Skeleton

The shot put throw using glide technique was divided into 4 stages namely :

- Initial stage
- Sliding stage
- Transition stage
- Release stage

The software takes care of mainly 3 important parameters in the game :

1. The time duration at each phase :

   It must be well within the range of our reference lanka for maximum release velocity.

2. The following angles at the start of the initial phase :

   - Right knee
   - Left Knee
   - Right hip
   - Right elbow

   If these angles are well within our reference angles, it results in higher build up energy to have an increased release velocity.

3. The release angle of the player :
   When release angle is within the range of 38°- 42 °, maximum range is attained.

Kinect is capable of throwing a continuous stream 3D coordinates of 25 joints in a text file. However, data analysis of such a large amount of data becomes cumbersome due to the limitations offered by the Kinect. A more effective way of dealing with this problem would be to set triggers which would send data only at the trigger points. Having acquired the desired data in a text file, data analysis can be performed separately.

Following is the algorithm for throwing the coordinates at trigger points to the text file :

1. At start and trigger points like F0, F1 , F2, F3, F4, send the time in milliseconds and the 3D coordinates of 15 joints which include head, neck, left shoulder, right shoulder, left wrist, right wrist, Spine base, left hip, right hip, left knee, right knee, left ankle, right ankle, left foot, right foot to the text file .
2. At every frame arriving check if left knee if at the maximum position. When the maximum position is reaches, noted time and coordinates at F0 trigger are sent to the text file.
3. Next, when right foot leaves the floor, F1 is triggered and the time and coordinates are sent to the text file.
4. When the right foot hits the ground again, F2 is triggered set and the time and coordinates are sent to the text file.
5. When the left foot hits the ground again, F3 is triggered and the time and coordinates are sent to the text file.
6. When the right wrist reaches the maximum position, F4 is triggered and the time and coordinates are sent to the text file.

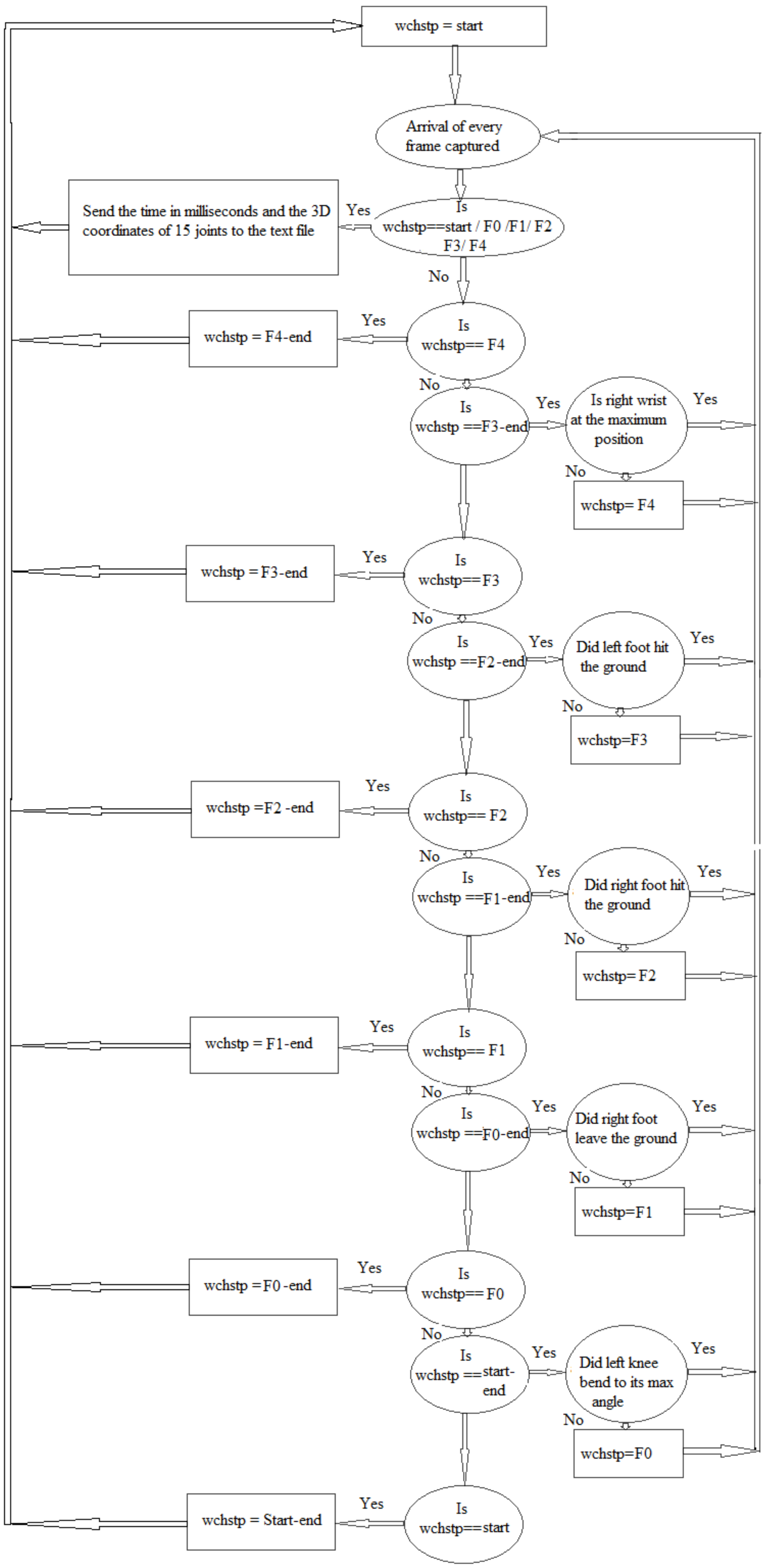

Figure 5.2: Flowchart depicting the Algorithm in brief

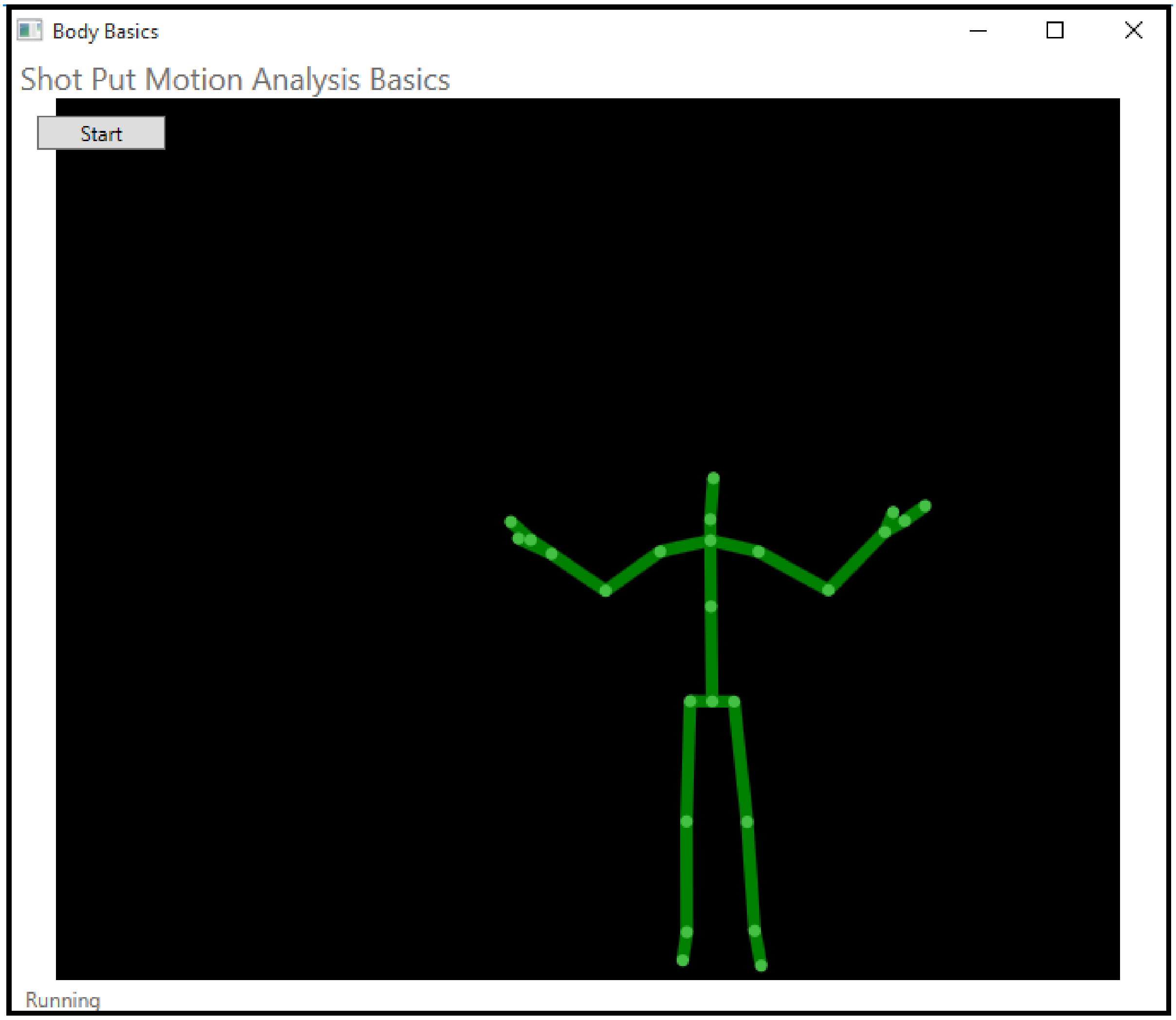

Figure 5.3: Output of the Kinect code

Figure 5.3 is a screenshot showing the output of the Kinect code. On clicking the start button, the player will start the motion of the shot put throw. Once the shot put throw motion is completed the code stores the essential data in the text file for further data analysis to be carried out and this text file is updated every time a player throws the shot put.

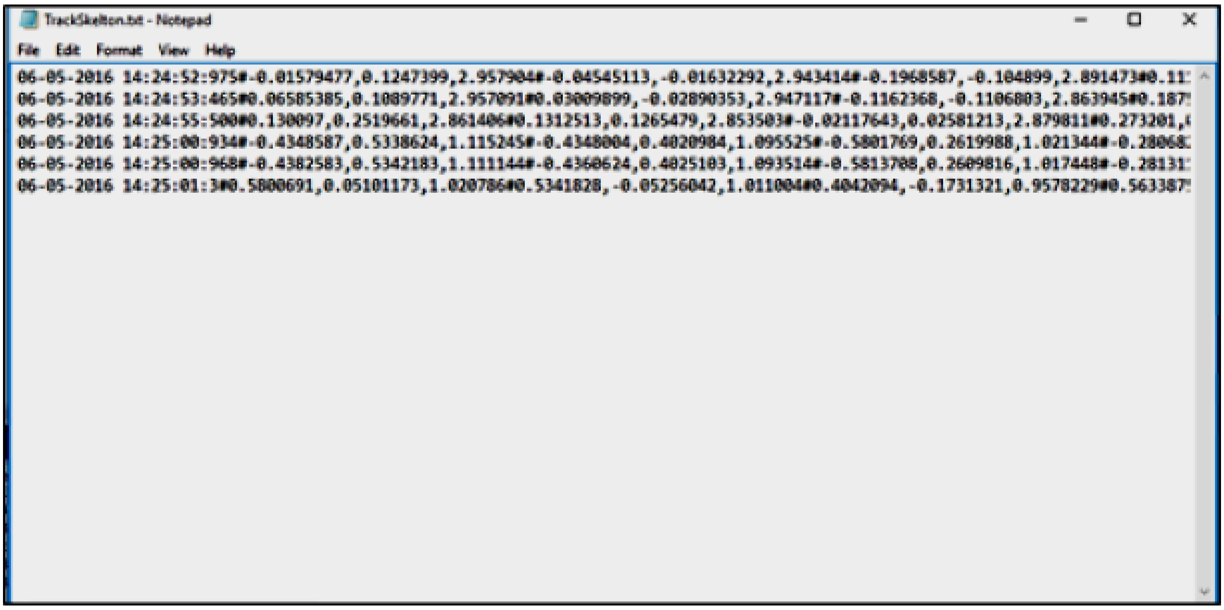

Figure 5.4: Format of the Text file

The text file as shown in the figure 5.4 has a particular format : Each line of the text file has date, time, timing of particular phase in milliseconds, and coordinates of the skeleton joints in the order of joint number 1 to joint number 15 separated by hash tag symbols.

A Data analysis is performed using the coordinates of these joints and timing details of each player. In this data analysis, we display the timings in each phase of the shot put throw, calculate and display the four important angles in phase F0 and the angle of release of the shot for each player. The four important angles in the phase F0 are :

- Right knee angle :
  Formed using the coordinates of the right hip, the right knee and the right ankle joint.
- Left knee angle :
  Formed using the coordinates of the left hip, the left knee and the left ankle joint.
- Right hip angle :
  Formed using the coordinates of the right shoulder, the right hip and the right knee joint.
- Right elbow angle :
  Formed using the coordinates of the right shoulder, the right elbow and the right hand joint.

The angle of release is calculated as the angle between 2 vectors : one vector formed by the right hand joint and right shoulder joint and the other vector formed by the joint at the neck and the joint at the lower centre.

Algorithm for data analysis of a single player is given below :

1. Extracting the timing data from the text file we display the timings of each phase of the shot put throw.

2. Extract the coordinates of the 3 joints : right hip, right knee and right ankle joint in F0 phase which are required for the calculating the Right knee angle and throw it into variables having suitable names.

3. From these variables we create two 3-D vectors between 3 joints: one vector is "Righthip-knee" formed by subtracting the corresponding x, y, z coordinates of the right hip and right knee joints and the other vector is "Rightkneeankle" formed by subtracting the corresponding x, y, z coordinates of the right knee and right ankle joints so that both the vectors point in the same direction.

4. We then call a user defined function "GetAngle", by passing values of the two vectors as arguments in order to calculate the Right knee angle between two vectors and display it. This function performs the same operation as used in 3-D geometry for calculating an angle between two 3-D vectors.

5. We then repeat step 2 to step 4 for Left knee angle, Right hip angle, Right elbow angle in the phase F0. We also find the angle of release using the function "GetAngle".

6. Displays the Right Knee angle, Left knee angle, Right hip angle, Right elbow angle and the angle of release.

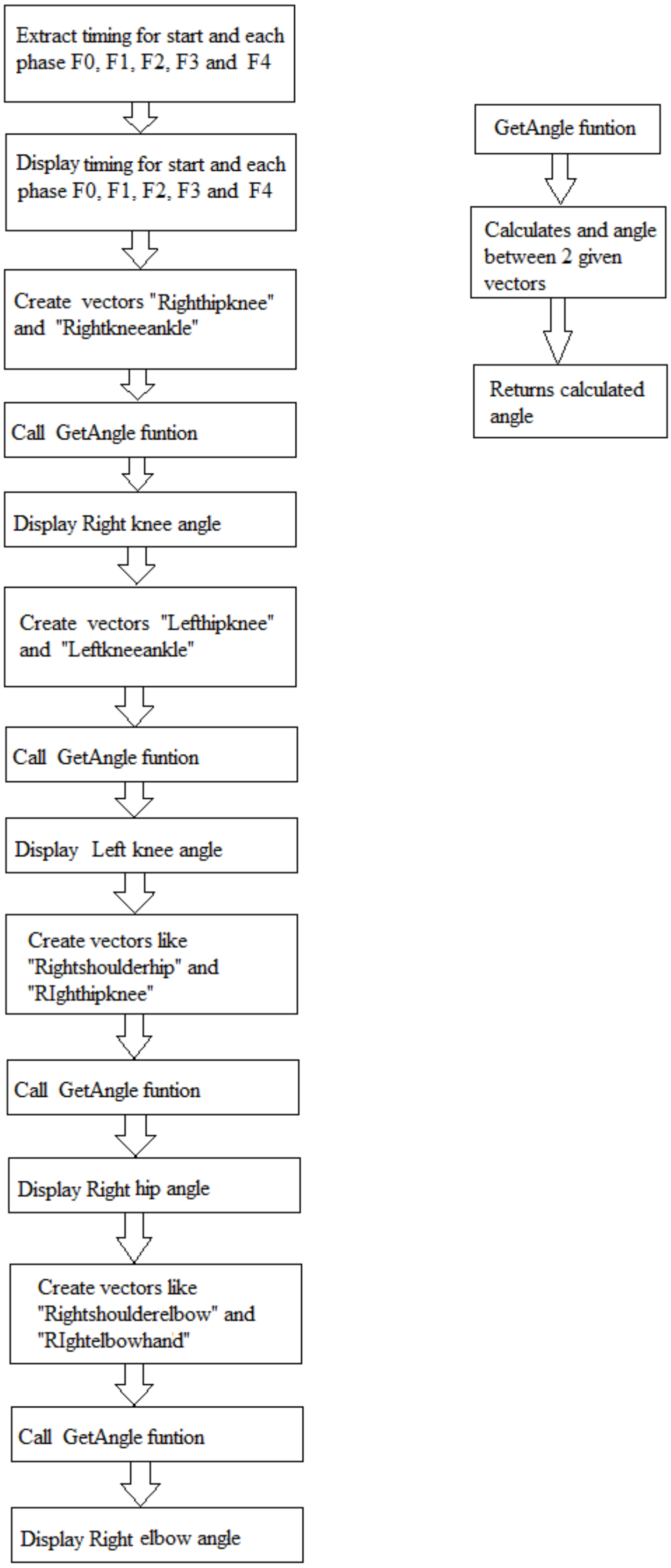

Figure 5.5: Flowchart for Data Analysis carried out on each player

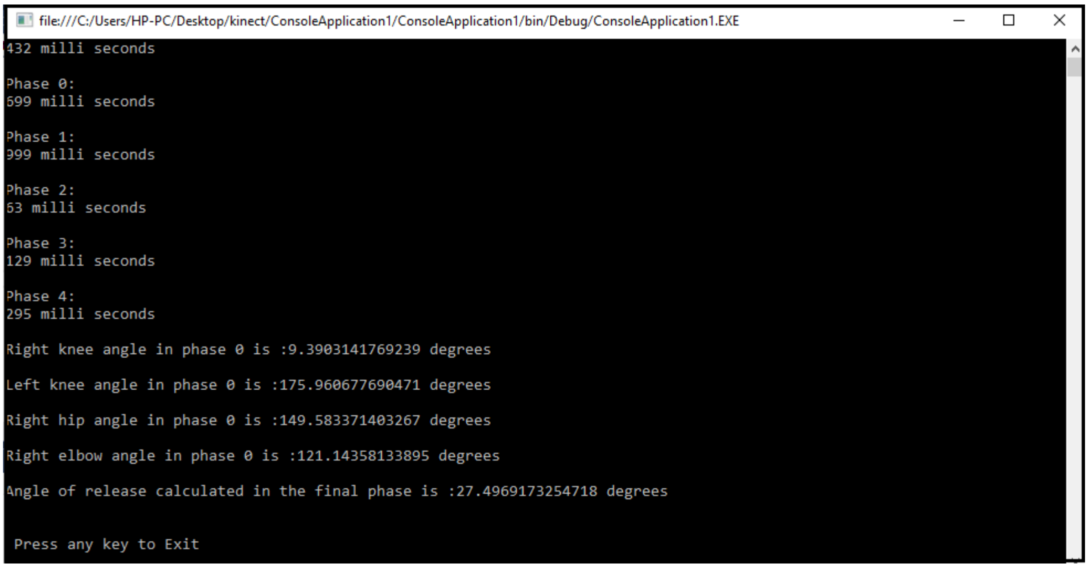

Figure 5.6: Output of the Data Analysis code

The overall steps for carrying out the entire process are explained below :

1. Shot put player is standing at a distance of 4 meters from the Kinect, which is placed at height of 1.5 meters from the ground level.

2. The whole skeleton of the player is visible on the screen without distortion of any part.

3. Click on start button on the screen by any person other than the player (need not be the coach).

4. Kinect captures the 3D coordinates at different trigger points and stores them in a text file.

5. Code to carry out data analysis of the text file is executed, which generates an output screen depicting the calculated angles and time durations.

6. Each player throws a set of 15 throws of shot put.

7. The average values of the angles and time duration of all the throws is calculated and a final graph is plotted along with the values of Lanka(2000).

8. This graph helps the player realize the erroneous stage which would help him improve his performance.

This software was tested upon three shot put amateurs who followed the glide technique of shot put throw. Each player threw a minimum of 15 shots which were recorded using Kinect and the overall average for his performance was calculated and depicted using graphs for comparison with our reference Lanka(2000).

Following are the results of every player's performance depicted graphically :

Player 1 :

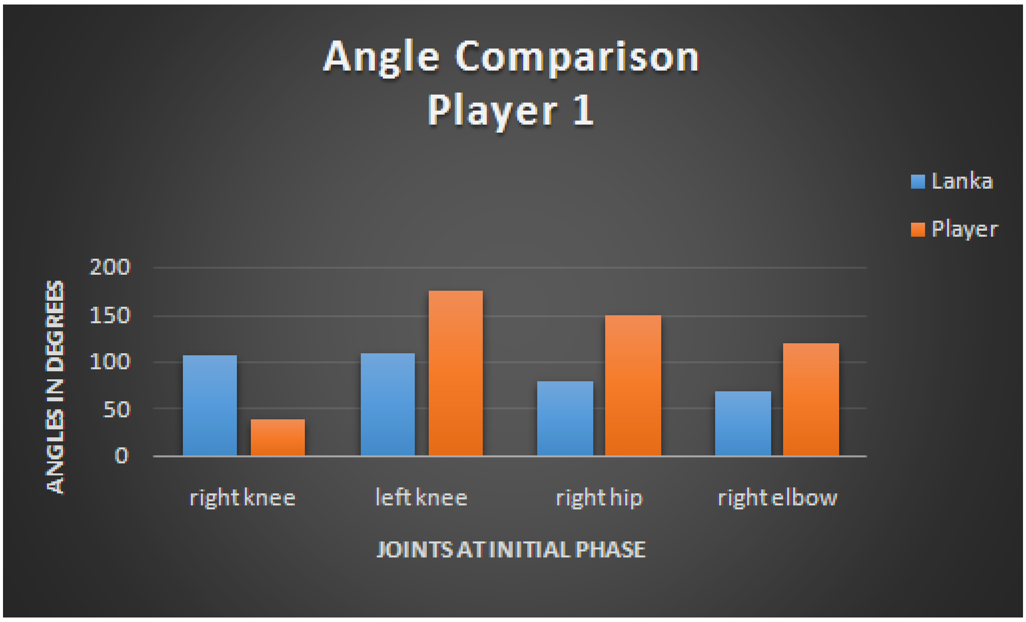

Figure 5.7: Angle comparison of Player1 with the reference values of Lanka(2000)

Figure 5.7 shows the graph depicting the angles of 4 important joints at phase F0 for player 1 along with the reference value for comparison.

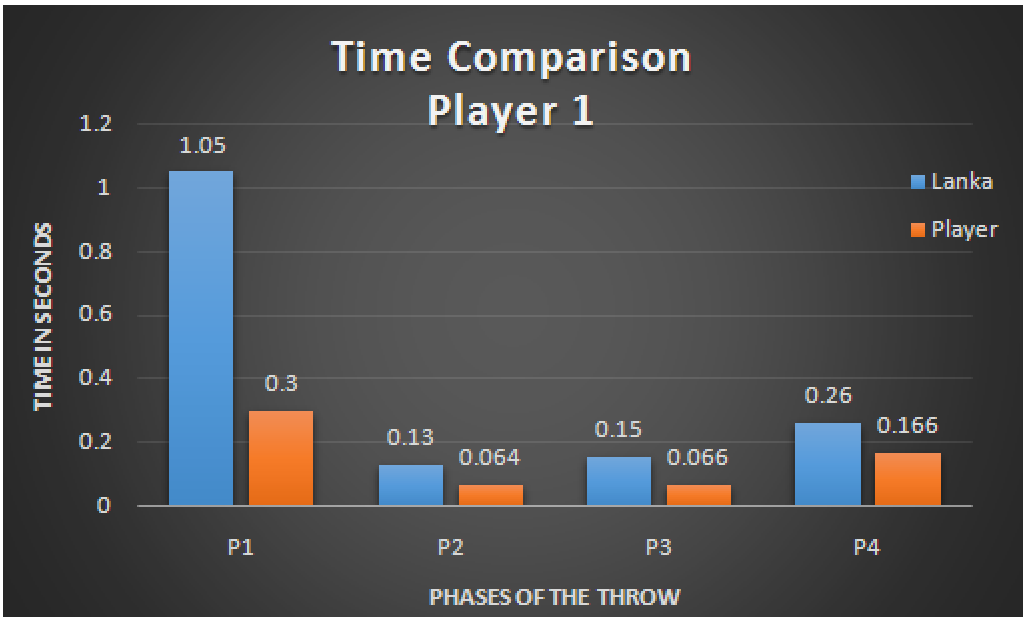

Figure 5.8: Comparison of Time Duration of Player1 with the reference values of Lanka(2000)

Figure 5.8 shows the graph depicting the time duration in each phase of the shot put throw along with the reference value of Lanka for comparison. In this figure P1 is the initial phase, P2 is the sliding phase, P3 is the transition phase, and P4 is the release phase.

Player 2 :

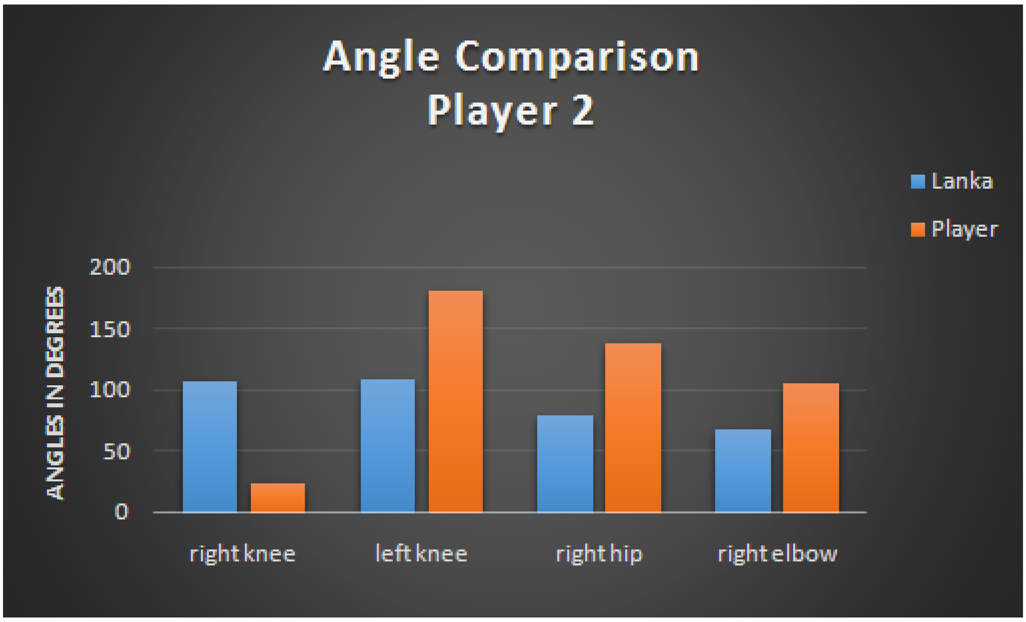

Figure 5.9: Angle comparison of Player2 with the reference values of Lanka(2000)

Figure 5.9 shows the graph depicting the angles of 4 important joints at phase F0 for player 2 along with the reference value for comparison.

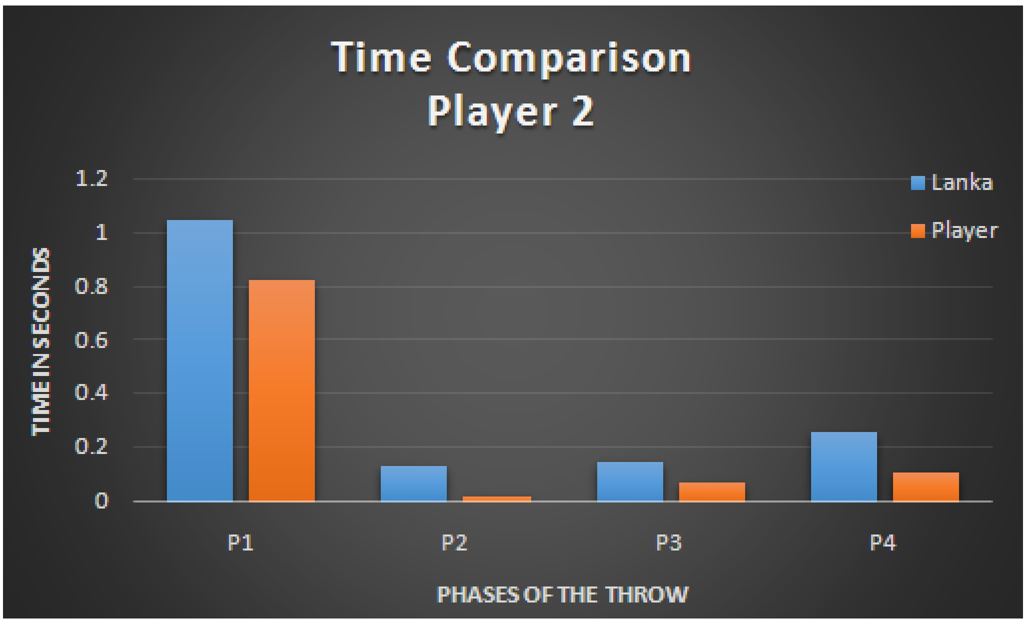

Figure 5.10: Comparison of Time Duration of Player2 with the reference values of Lanka(2000)

Figure 5.10 shows the graph depicting the time duration in each phase of the shot put throw along with the reference value of Lanka for comparison. In this figure P1 is the initial phase, P2 is the sliding phase, P3 is the transition phase, and P4 is the release phase.

Player 3 :

Figure 5.11: Angle comparison of Player3 with the reference values of Lanka(2000)

Figure 5.11 shows the graph depicting the angles of 4 important joints at phase F0 for player 3 along with the reference value for comparison.

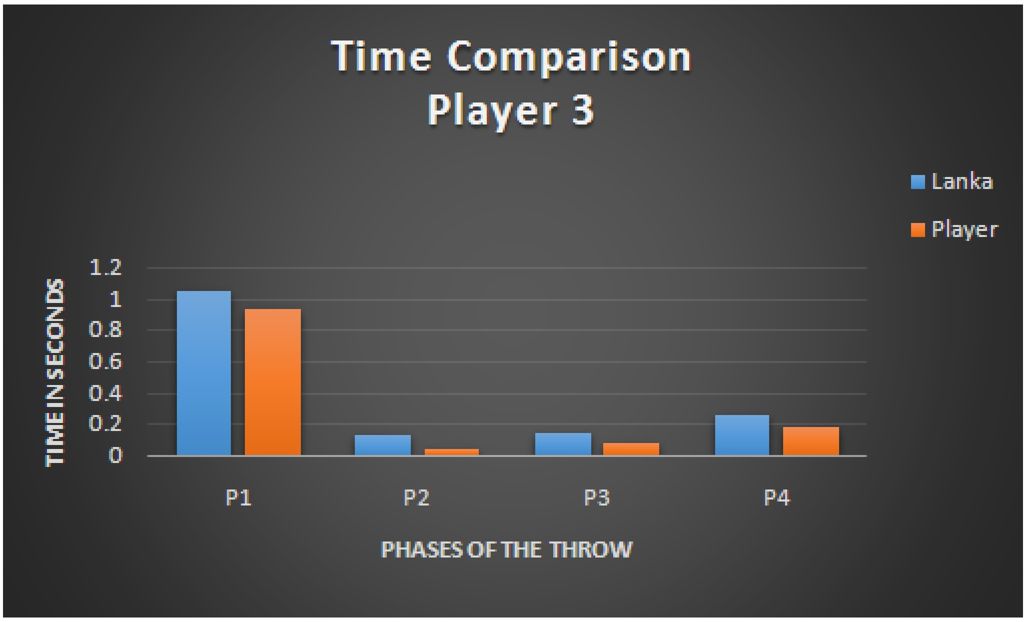

Figure 5.12: Comparison of Time Duration of Player3 with the reference values of Lanka(2000)

Figure 5.12 shows the graph depicting the time duration in each phase of the shot put throw along with the reference value of Lanka for comparison. In this figure P1 is the initial phase, P2 is the sliding phase, P3 is the transition phase, and P4 is the release phase.

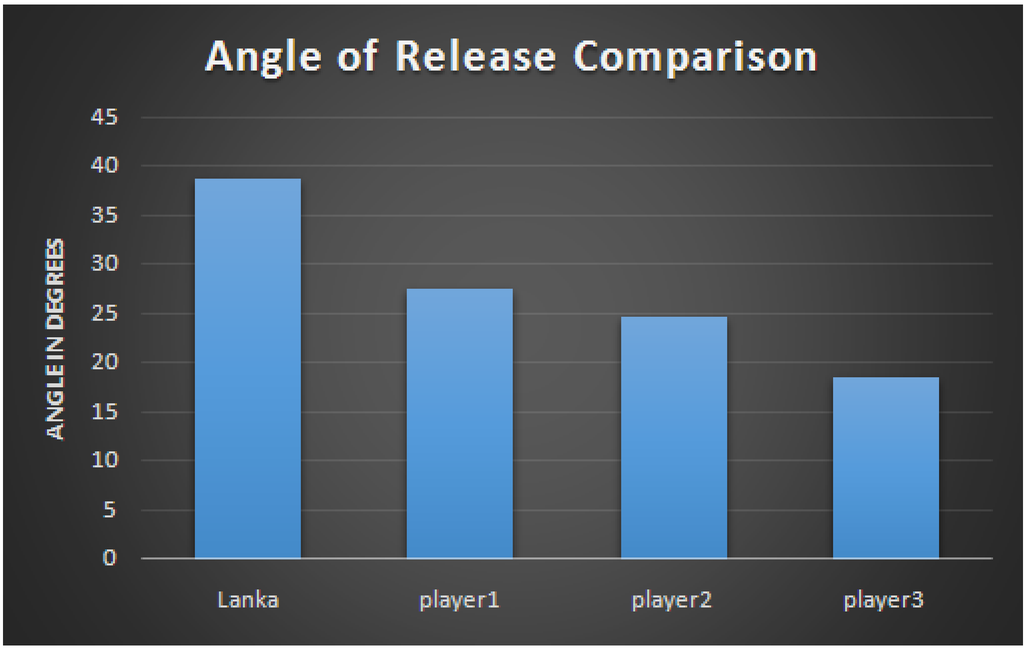

Figure 5.13: Comparison of the Angle of Release

Figure 5.13 depicts the angle of release for the three players and compares it with the ideal value of Lanka(2000).

Trajectory of Shot Put :

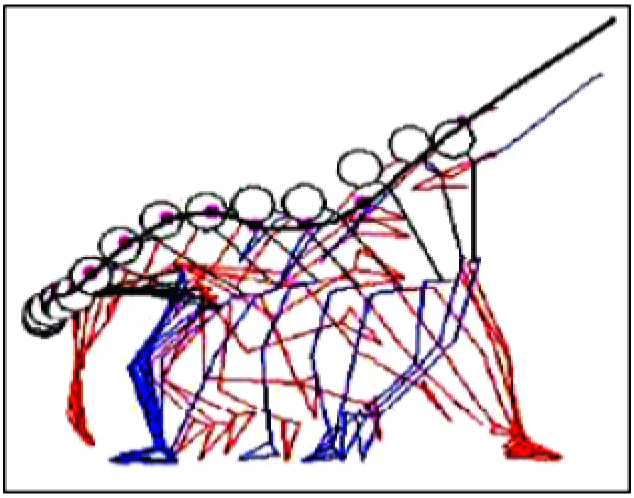

Figure 5.14: Trajectory of the Shot of Lanka(2000)

The approximate trajectory of the shot of our reference Lanka (2000) is shown in the figure 5.14. This initial position represents losses in release velocity due to an angular displacement of the trunk respect to the horizontal, losing the linearity of the trajectory of the shot in the hand. Due to these differences in the relative angular position of the joints, the trajectory of the shot in the hand is not linear and does not comply with the principle of the optimal acceleration, leading to losses in the release velocity of the shot.

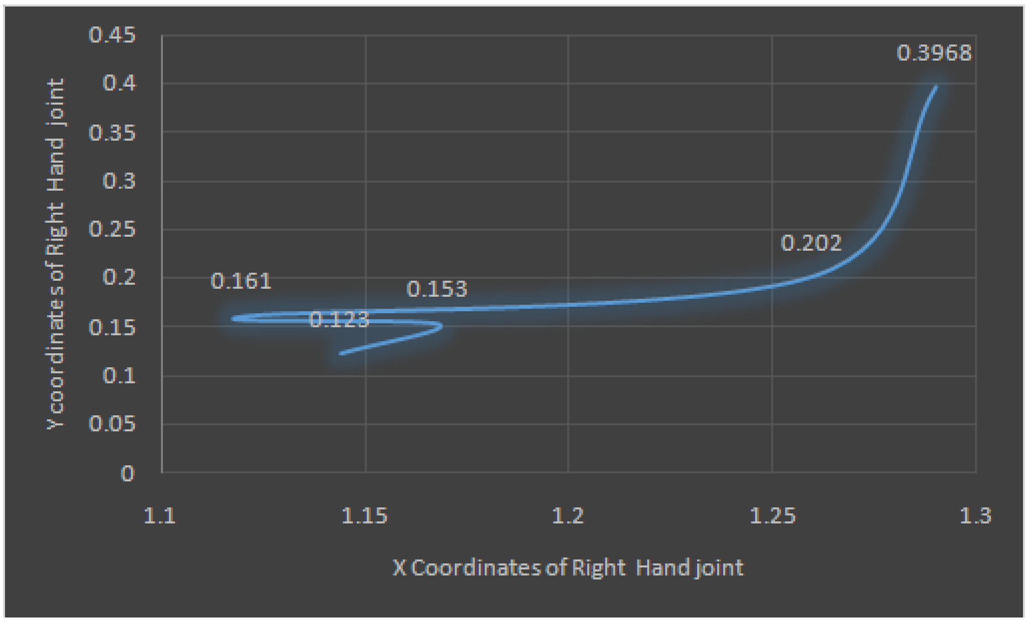

Figure 5.15: Trajectory of the Shot of an Amateur

Figure 5.15 shows the trajectory of a shot of an amateur obtained by plotting absolute values of x coordinates of the Right Hand joint versus the absolute values of y coordinates of the Right Hand joint through the different phases of the throw.

Chapter 6

Conclusion

In this project we have successfully examined the four biomechanical phases of the shot put throw and evaluated the necessary angles of the joints, the angle of release of the shot and the trajectory of the shot of an amateur. A shot put game improvement solution was achieved by developing a software prototype using the Kinect sensor which compared the performance of an amateur to that of a professional. The Kinect system being a marker-less system, is able to capture the human motion with a reduction in time.

Although our software prototype could be used in a shot put game to provide coaching evaluation, the results cannot be completely relied upon, as the accuracy was limited due to decreased resolution of Kinect sensor. A few drawbacks of this sensing technology were the fixed location of the sensor with a range of capture of only roughly ten meters, a difficulty in fine movement capture, and shoulder joint biomechanical accuracy.

In conclusion, the Kinect system is a reliable system which permits to obtain acceptable kinematics results.

Chapter 7

Future Work

The Kinect sensor offers an unlimited number of opportunities for old and new applications. Thus far, additional research areas include hand-gesture recognition, human-activity recognition, body biometrics estimation (such as weight, gender, or height), 3-D surface reconstruction, and healthcare applications. Based on our review of the literature, we have reported a summary of critical issues and suggestions for future work in this domain.

Future research could investigate the possibility of using more than one Kinect sensor to track the motion of the shot put throw. Given the fact that the joint vector angle readings were comparably precise and coherent with real-world values when the sensor had a profile view on the respective angle, using two Kinect sensors might improve the accuracy during the complex shot put throw motion.

From a software-based perspective, enhancing the base skeletal tracking algorithm of the Kinect with the specific shot put throw motion data could provide an increase in joint tracking accuracy.

More hardware-based improvements could be observed after the utilization of the next-generation Kinect sensor as it has more functions such as the supporting of seated skeleton and multi-language speech recognition. This framework can be widely used for development of many applications based on 3-D motion.

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