INTRODUCTION: A BRIEF HISTORY OF BASKETBALL

The Sport of Basketball was created in early December 1891 by Canadian Dr. James Naismith, a physical education professor and instructor at the International Young Men's Christian Association Training School (YMCA). Basketball has evolved so much today and spread world wide becoming one of the world's most popular and widely viewed sports. The National Basketball Association (NBA) is the most popular and widely considered to be the highest level of professional basketball in the world and NBA players are the world's best paid sportsmen, by average annual salary per player.

The first Basketball game ever played was in the YMCA gymnasium in 1892 and ended with a score of 1-0, the highest scoring NBA basketball game of all time ended with a 186-184 “Detroit Pistons” victory; this shows exactly how difficult it was for the pioneers of basketball to properly adjust factors that were playing impact on their shot accuracy and precision. Over the years in the Basketball world, proper training from “Human Coaches” has been allocated to basketball prayers to improve on these key factors and help them develop the necessary skills for better performance during Basketball games. The coaches are experienced Basketball professionals and are classified at different training levels. Basketball Coaches and other professional trainers first categorise players into 5 different positions (Point Guard, Shooting Guard, Power Forward, Small Forward, Center) based on height, weight, and then skill level. Coaches then try to promote in prayers training in skills necessary for the position such as:

- Ball-Handling and Dribbling
- Defense and agility
- Footwork
- Offense
- Offensive Moves
- Passing
- Post Play
- Press Breaker
- Rebounding
- Shooting
- Transition and Fastbreak

This system of training has been around for over 100 years and should be obsolete today. In this old system the Basketball player is assigned a position based on height and trained to attain skills that he is not able to perform because he is weak at points in that position and stronger in another position. A comprehensive analysis is necessary in order to determine a players abilities and properly place them in their right position to make better and stronger teams.
TECHNOLOGY APPLICATIONS TO BASKETBALL

Computer technology has improved the way we see the world today. One of the most important fields to look at where technology has made impact is medicine. Centuries ago diseases were only grouped in four categories and treated based on the fluid that was present in the body that was believed to be causing the disease, the disease was either called a black, red, yellow, or white illness; regardless of the disease found, it was grouped into one of these colors and all diseases were treated in the same way. But over time it was realized that the stakes were too high people were dying and medicine wasn't so effective. So doctors got smarter and used technology and all the resources available at hand to group diseases instead by the actual characteristics of the illness and then focused on learning how to diagnose and how to treat each disease; we need to do the same with Basketball. The game of basketball has not changed since it was first introduced in 1891.

Coaches have failed to realize that there are more than 5 positions in basketball and have improperly categorized players who could better play at other positions. No two players in basketball have ever played the same whether, point guard, shooting guard, power forward, small forward, or center. If Computer-Aided Player Analysis of every athlete is adapted into basketball, we can now begin to group players in their right positions and begin to design a better offense and defense around every team. Training of basketball players would start from their skill level and not height or other arbitrary categories. With Computer-Aided Player Analysis, when given a Starting line-up with 5 players, we can now custom design an offensive play that fits that specific 5 men line-up the best. We can create a better offense for every 5 men line-up as opposed to treating every offense the same way. We can also work the line-up from inside out; Instead of starting with a 5 man line-up and building an offensive play based on them, we can start with checking the coaches play books for an offense or defense play that we want to run for example the “triangle offense” and
then the computer program can create the positions that fit that offense the best. For years we have described the triangle offense by being run by a Point Guard, Shooting Guard, Power Forward, Small Forward, and Center; but that doesn't truly mean anything to us. With Computer-Aided Player Analysis and the new understanding of positions that it brings, we can go through history and analyze the teams that ran the triangle offense successfully and figure out exactly what positions they ran the triangle offense with, and thereby giving us the ingredients or the recipe for the best triangle offense. We can do this for every offense and find the ingredients that teams used to run the offense successfully and save them as ingredients for future Owners and General Managers to construct their own teams and for coaches and trainers to train their players.

We started out with an example of the first basketball game ever played and the best basketball game ever played because in basketball we still try to believe that there is really only 5 ways to play the game, even though currently our players are better, faster, stronger, and more unique than any other players we've had in the past, so it's time to discard our old arbitrary scheme and regard a new one. By using Computer-Aided Player Analysis we can take basketball training and playing to the next level. For the rest of this report, we will draw a parallel between the system we are introducing and the purpose we are proposing by briefly explaining some aspects of basketball that will be working on to improve with this system.

**“DBT #22” - DIGITAL BASKETBALL TRAINER**

“DBT #22” is a Computerized Basketball Training System. Guided by computer intelligence we are designing a system that will take Basketball training to the next level. In this system of training, we start by analysing the athlete that wants undergo basketball training and then build them to reach a professional level of training, grading them on their skill level as they progress; determining their true position and at the same time helping them advance to an All-Star level.
TRI-MODE SYSTEM

To help us achieve the goals that we have set for “DBT #22”, we have created Tri-Mode system. This three mode system includes Learning Mode, Training Mode, and Coaching Mode. With this system we can better understand how the athlete plays and then begin training them and determining at every stage which position they truly play so that in coaching mode we can be able to place the right players together for each offensive or defensive play. We'll start by describing each mode separately to get a better understanding of the role each mode is playing in the training.

LEARNING MODE:

Our entire system is build up from this fundamental stage. Learning mode is the stage at which the system is studying how the athlete plays.
To create this mode we are developing a Low Energy **Motion Capturing System** that we are designing to break the barrier between the “Virtual World” and the “Real world”. The system begins analyzing the athlete by answering questions such as;

**How does the player shoot?** By studying how the athlete shoots the system first learns which parts of the court the athlete is able to shoot from, the athletes range in shooting, their body form when they shoot to properly help them correct any mistakes they may be doing, and their accuracy levels.

**What key factors contribute to Athletes accuracy?** By studying the factors contributing to the Athletes accuracy such as height, strength, energy level, stamina, weather, body temperature, we will be able to know the athlete better and they can also know themselves better in what conditions they play best, what exercises they can do to improve on strength, stamina, and endurance. This important because we have to keep in mind that every athlete is different, to give better advice you have to know your players.

**What moves is the player able to execute?** Another important part of getting to know our athletes skill level is by analyzing the skills that they are able to perform. We imagine that this system can be built to analyze the data received through the motion capture to compare this data with the stored data that we’ll train this system to recognize and also train our players with. This is a challenging part of our system currently because it involves precise and accurate calculations but we hope we can program the system with data within a certain range by repetitive trials from different subjects storing this valuable data into the system. Since each player also plays differently, we also want to analyze successful manoeuvres that are made by each individual player and give them the option of
storing their moves by repetitive trials to the **Player Profile Management System (PPMS)**.  

**TRAINNING MODE:**  

After the “athlete analysis” phase is complete, the system now knows this subject as a “basketball player”. The digital trainer is now ready to condition this player. The trainer monitors the progress of the player while training them perform all the moves in the system step by step and constantly updates the Player’s profile in the **PPMS**. In training mode the player undergoes offensive tanning as well as defense strategies. On offense we also train a player on moves that will help them drive past their opponents. This “digital-trainer” will adapt the principles human basketball trainers have used to train the basketball players with such as;  

- Ball-Handling and Dribbling  
- Defense and agility  
- Footwork- Offense  
- Offensive Moves  
- Passing  
- Post Play  
- Press Breaker  
- Rebounding  
- Shooting  
- Transition and Fastbreak  

With Computer-Aided training, we believe the system will help the player develop these skills much better, because of analysis methods the system will use to develop Players. We imagine this system can be trained by professional athletes and through software updates, it will advance on skills that players can be trained to develop. An average NBA basketball Players career lasts for 5 years, with this system we can store his valuable skills and methods of training and conditioning before he retires, and train the new players with these skills to develop better, stronger, and faster
basketball players.

**COACHING MODE:**

In Player coaching mode, the system begins coaching players on gameplay. Once the training process is initialized and the system has updated the **PPMS** (Player Profile Management System), the Players profile containing records of the each Players exercised skills can be loaded in coaching mode to give the player gameplay strategies and teach them how to apply these skills during games. “Coaching Mode” is a multi-player setting, with this mode the system begins by identifying every player on the field and each players profile is loaded; the coach can then give “Over-Air” pointers to each player based on the position the player can play accurately. The coach will help the player learn to know his surrounding and knowledge him to identify “Open” team-mates who are also able to execute their skills from particularly identified positions. In this mode players are also trained on “team-playing”, they learn passing techniques, court visualization, timing, drive past opponents, crossover moves, and develop the confidence to shoot from spots on the court under pressure in order to master the skills they exercised during training. Most basketball players are able to shoot on an open court, but learning to shoot while under pressure is the focus of coaching mode. Another important part coaching mode helps us to make possible is the problem of identifying the key ingredients for an offensive/defensive play in the coach’s playbook, In this system the right combinations are automatically put together for an offensive and defensive play to create stronger match-ups during games.

![Hot Zones for LeBron James “NBA 2K15” Video Game](image)

Training modes and strategic guiding are common in videogames including the NBA 2k series and Madden series but are not common methods of training players today. These computer training methods along with the Virtual Reality hardware can be the solution to the best training players can receive, computers are able to make calculations much faster than players and with this training, players will be more alert of their surroundings and develop strategic skills from a computers perspective, which will be more advanced than skills, techniques, and fitness exercises human coaches will advise on. With this system, coaches can simply focus on operating these systems to help them develop much better and stronger teams.
PLAYER PROFILE MANAGEMENT SYSTEM

PPMS is a method of keeping updated records of data relating to every player under training with “DBT #22”. As observed, the PPMS is important in all three modes of the system because it identifies each player. The PPMS is responsible for storing the players necessary information (i.e. Name, height, position), his shot statistics from every point/angle on the field (i.e. goal percentages, jump shot percentage, post-up percentage), and record / identify the players exercised moves. After the system gathers all necessary data about a player, this system can grade the player on average and identify a Teams “Starting Line-up” and bench players who can substitute after the system reads low energy levels from an active player. The PPMS is automatically loaded when a player logs-in and can be utilized in both training and coaching modes. This system is also responsible for identifying the Games MVP (Most Valuable Player) based on outstanding performance during a Teams basketball season, the system also keeps records of total game points, total rebounds, assists, total career points, and other important records. Every Skill/ move in the PPMS is saved and can be named to be identified during both training and coaching mode.
Videogames have implemented a similar system of storing a player's records including “Player Charts”. With this method of recording data automatically based on a Player's statistics, we can easily identify key players for each position and construct the right combinations of them. This system of calculating is fully computerized and requires no external calculations making “player ranks” accurate and “player identification” easier to access.

**OPERATING SYSTEM**

DBT#22 is currently being developed by utilizing standard and improving non-standard softwares/hardware that have been developed by known vendors and third party sources. After a lengthened amount of research, we have come up with a number of hardware and software platforms that we will be developing this project on.

**RESEARCH MOCAP SYSTEM:**

To achieve the motion capture function for the system, I began by researching on developed MOCAP suits/systems including; “BodySense”, “PRIORVR”, “SouVR”, “Microsoft Kinnect” and many other, each of these systems was priced beyond this project's budget and was bigger than we wanted in order to make it less visible and with no effect on the athletes' game. These sources did give me some pointers on what to look for and I ended up on youtube through some search results unto a successful cheap motion capture system developed by a person named “Thiagesh”; not a recognized source but his video was impressive to me and I wanted to develop his system and make it better to fit “DBT #22”. After inquiring from “Thiagesh” to assist me by providing the code for the project and along with the design of the system, he responded that his “Guide” for the project was not allowing him to share this information, then I simply asked him to explain a little bit more about the
system so I can understand.

His systems hardware consisted of two devices:
1. **GY80**, which is the IMU (Inertial measurement Unit) with three sensors; accelerometer, magnetometer, and gyroscope. This device has also been adapted in modern day smartphones, and to control RC planes or a self balancing robot. It is also known as a 9Dof (nine degrees of freedom) device with each sensor consisting of 3-axis (X,Y,Z) to calculate motion on each rotational axis upto 3-Degrees totaling 9 Degrees of freedom.

2. **ESP8266** To get the reading from the sensor and transmit the reading over to the laptop, Thiageshs' system uses the ESP8266 which is a processor/ wifi module. The device gets the sensor values from the IMU sensor and transmits the data to the laptop over tcp. A java processor in laptop gets the value and sends it to 3ds Max via a virtual serial port. A utility is created in 3Ds Max to read the values and to move the bones of the character accordingly. Each node on the body would need to be linked to a separate capturing device.
3. Java Utility/ Autodesk 3ds Max

Utilities to perform operations on the character in 3Ds Max can be developed using the most common communications using maxscript; a language for 3ds Max. After Thiageshs group tested using maxscript to directly pull the data from the sensors using tcp/ip, they realized the reading was very slow and resulted in creating an intermediate java program that constantly reads the data from the sensor and sends the data to 3ds Max using a virtual serial port.

From this source came the idea for the “MOCAP” system on “DBT #22”. After more research the final hardware components of “DBT #22” were discovered and the design of the system was drawn to meet the conditions of the outdoor/indoor operating environment.

HARDWARE

1. GY-87
For “DBT #22”, we discovered the latest Gy-series IMU available on the market is the GY-87, which is only an advanced version of the GY-80 + 1 Degree, because this device can also measure temperature/ humidity/ pressure totalling upto 10dof (Ten Degrees of Freedom). This component is also equipped with three sensors; triaxial accelerometer (MPU6050), three-axis magnetometer (HMC5883L), and three-axis gyroscope/ pressure sensor (BMP180). This component has 10 Degrees of Freedom and outputs data for three axis (X,Y,Z) on each sensor via the I2C protocol. It also requires a low energy input of 3-5 Volts and is compact sized with dimensions of 2.2cm x 1.7cm therefore making it more than ideal for the design we're trying develop.

2. BLUETOOTH TECHNOLOGY
To transmit data from the 10DOF IMU device “GY-87”, after a generous amount of reasearch I concluded that this system would operate efficiently if all wireless data was sent via bluetooth technology. While designing a rough idea of the system, I discovered that using WI-FI to communicate with the IMU sensor would simply require a lot more power and make the system much more larger and complicated, making the MOCAP system not much better than using “Kinnect” or other devices. After researching on “Infrared” technology; also used in “Kinnect”, I also found that this technology is more efficient if developed on indoor systems and not good on outdoor system because it can be easily interfered with by daylight and any objects in front of the transmission; it also requires the receiver to be directly infront of the transmitter. I discovered most
of the outdoor systems for sports and fitness have been developed using bluetooth technology. The 94-Fifty Smart Sensor Basketball is one such example that is designed with bluetooth technology to communicate a basketball players shooting and ball handling data directly to an iOS Smart Phone or Android app.

[94-Fifty Smart Sensor Basketball]

**BLUETOOTH LOW ENERGY (BLE)**

Bluetooth technology is now the easiest channel to communicate with the most recent computer systems including smartphones and “Bluetooth Low Energy” (BLE) is the most recent development of wireless connectivity. Known as Bluetooth Low Energy (Bluetooth LE, BLE, marketed as Bluetooth Smart) is a wireless personal area network technology designed and marketed by the Bluetooth Special Interest Group aimed at novel applications in the healthcare, fitness, beacons, security, and home entertainment industries. Compared to Classic Bluetooth, Bluetooth Smart is intended to provide considerably reduced power consumption (3-5 Volts) and cost while maintaining a similar communication range.
After thorough research on various systems using Bluetooth Low Energy such as the 94-Fifty, Texas Instruments is the common supplier of most BLE RF transceiver chips. I discovered the system that we're designing “DBT #22”, “Bluetooth Low Energy” would be the best choice for wireless communication between the sensors and the PC simply because it was developed for outdoor fitness systems among other applications. The CC2xxx series from TI are among the most used BLE devices on fitness products on the market today. I discovered from a similarly developed BLE system “TI Sensor Tag” that the CC2541(SimpleLink Bluetooth Smart and Proprietary Wireless MCU) BLE Module would be compatible for sending data from the 10DOF IMU to the laptop over the air. The CC2541 uses a 2.4-GHz Bluetooth low energy Compliant and Supports 250-kbps, 500-kbps, 1-Mbps, 2-Mbps Data Rates using the I2C communication interface and a Wide Supply-Voltage Range of (2 V–3.6 V). The CC254X has Excellent Link Budget (up to 97 dB), Enabling Long-Range and this makes it compatible for this “DBT#22” outdoor system.
The CC2541 BLE Module communicates to the PC by transmitting data to the CC2540 USB Dongle which enables “Bluetooth Low Energy” on both Windows and MAC operating systems. After purchasing and testing the device I discovered that I was able to connect this BLE Module to my PC via the bluetooth channel (2.4Ghz) throught the CC2540 USB Dongle. This BLE Module is able to communicate via I2C protocol to the IMU 10DOF Sensor. This technology will be sufficient for our design, it has low power consumption and Long-Range propagation allowing us to design a system that doesn't interfere with the athletes game as we analyze his skill level. With this device we're able to detect all motion from the IMU 10DOF sensors and receive all the data using the I2C Interface through the Software applications we're now designing.

**SOFTWARE:**

1. **Autodesk 3Ds Max**
   3ds Max software provides a comprehensive 3D modeling, animation, rendering, and compositing solution for games, film, and motion graphics artists. 3ds Max has tools for crowd generation, particle animation, and perspective matching, as well as support for DirectX 11 shaders. The Motion Capture utility drives your animation using peripheral devices, such as MIDI keyboards, joysticks, and the mouse. While driving the animation, you can record it in real time.
For this system “DBT #22”, we will be using functions of the 3ds Max to model our player, analyze the motion capture to store important moves into the PPMS database, and to create a 3-Dimensional virtual basketball court to model a real time court configuration and obtain important calculations during gameplay such as the players shot release positon, the players relative location on the court, players shooting range, help the system realize offensive play from defense playing, locate each player seperately on their position on the court. 3Ds Max will be responsive for saving the motion data that will help train the athletes to become All-Star players. We can create programs in 3ds max using a language called maxscript to store this important data and also collect motion data via a virtual serial port through an application or directly from the sensors depending on the speed of the processor when we try both methods. The data we collect into 3ds Max will help us monitor player motion, train players in different game modes, help us monitor any improveants and train players players using recorded data. 3Ds Max will be the main interface we'll use to monitor all important information we need about the player or the game play.

2. C# Application/ Java application
To send the raw data from the mocap IMU device into 3ds Max, we are also developing a secondary software. This software would simply convert the raw motion capture data from each of the 11 total IMU devices into motion data to move the character in 3ds Max through virtual serial ports. Currently we have obtained a sample application written in C# from Texas Instruments that works with the TI sensor tag “TI SensorTag/Keyfobs Diagnostics” to convert all raw data into X,Y,Z plane 3-dimensional motion. We're working on developing this software to enable us to connect to all bluetooth devices and create a virtual serial port for each device to transmit the motion data and location data into 3ds max so we can use this data . This software could also be developed to manage the PPMS and store the raw data directly for data analyzation.
3. DBT#22 MOBILE APP

The features packed in the 3Ds Max software allow us to display even the current game points and players game statistics in the same software. We can the send this important data through the BLE module back out to a mobile application we wish to develop at a later point to let players learn using their mobile phone and monitor their game play, progress, game statistics when they are off the court. Instead of sitting on the bench bored during substitutions or timeouts, a player can monitor their game points, shot statistics to play better when they get back into the game. This mobile application will also allow us to control and load the players profile and monitor progress and learn moves directly from the phone. We will work to develop an app that will be able to access the main server containing the database to player training skills and monitor player records, skill level and other important information through the PPMS, from mobile phones players can also upload and share game play data.

PLAYERS DISPLAY:

As we have already proposed, we imagine the players notification display to be a mobile phone. With bluetooth support and popular demand, mobile phones are the best microcomputers to incorporate the “DBT#22” system on. The player display will be connected directly to a computer/server via bluetooth or wifi to access live game play data, game scores, player profiles, shot statistics, player statistics, Skills Trainer, and many other programs.

PROJECT BUDGET:

This project is being designed and developed by 3 group members including me the Project Manager. To complete this project the following are the resources that are required.
Skills/ People Required:
Hardware Designer(s)
C++, C#/Java Programmer(s)

APPROXIMATED PROJECT COST  =~ 1000 RMB
- 11x GY-87 IMU Sensor (43.35Rmb)  = 476 RMB
- 17x 4.0 BLE Module  (23.38Rmb)  = 397.46 RMB
- 1x CC2540 USB Dongle  = 47.00 RMB
- 2x Arduino Micro  = 50 RMB
- 2x Arduino Nano  = 50 RMB
- 1x Digital distance sensor  = 25 RMB
- 1x Quad alphanumeric display  = 10 RMB
- 1x Circuit board  = 10 RMB

APPROX TIME  =~ 2 YEARS

Significance and Innovation:
As a basketball player, i've learned most of my game skills and moves from playing videogames. In developing this system of training I believe much better guiding will be given to each athlete with or without a third party. “DBT#22” is the only Smart Digital Basketball Trainer/ Coach that deals with the Players moves along with improving the players shooting accuracy – fast. Learns and adapts to any player’s skill level.

Sources:
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