Construction of a kinetic analysis unit by using sensors as an instrument for bio kinematic analysis

prof. Amr soliman mohamed
biomechanics professor - Department of Movement Science - Minia University
Dr. Khaled –abd Elmowgoud abd Elazeem
Lecturer in Department of Sport Training and Movement Sciences- assuit University

Introduction and the research problem :-

Once the sporting field with various activities has become a square for developed technological application even levels of its achievement has accelerated in a continuous Processive and the elite found their itself in a permanent race with development which its progress wheel has rushed by impact from the momentum which gained it as a result of its depending on a scientific methods in measuring ، planning، implementation with help of many devices and tools high objectivity extreme precision and which work on evaluate the kinetic performances inside the diversity sports activities.

And that the foundation in kinetic performances analyzes lies in registration the movement of player's body while performing skill an accurate registration by video cameras where his movement attributed to monitor point fixed ،in order to determine the engineering tracks for the body or its parts in one hand and the time of performance on the other hand ، then account its variables (1: 406).

And the research problem crystallize in two main axis thy are :-

Requirements of imaging process and kinetic performances analyze.

Impact of changing angels the imaging vision in light of kinetic capture techniques.

First: requirements of imaging process "imaging process and kinetic performances analyzes require more procedures including those related to the preparation and equipping inspected from raising their physical measurements and distinguish points of their anatomical bodies as well determine the centers of gravity ،of bodies parts accurately and by reflectors to ensure the validity of deduced data Also it ،and that require a specialist on a high degree of competence and experience takes a large period of time where takes into account determining the position set of cameras vertically on the vacuum level to the phenomenon being studied and requires cover it a number at least three cameras of the same type and distributed in a way ensures that it see all monitored points together and may be difficult to calculate the height of cameras and its dimension from track of the performance so that it cover the photography space and this procedure exceeds the researcher abilities sometimes or didn't agree with their potential materialism because of the high cost of this cameras and the imaging process subsequent of transaction film process for ،at other sometimes analyzes after cutting it by the parts required to analyze and what's wrong with this change of synthetics architecture for those films and the effect on the camera frequency speed fig (1) (2:22- 23), which consequent on it the image isn't purity and there were just expect the ،then difficult on the analyst to determine the point position and after the completion of processing comes analysis using software ،place of point moment by moment even if ،its arduous process requires from who do it follow up it and begin to do a major file containing build the ،the analyzes was automatically model special of analyzes process with access the calibration unit(drawing measures) which requires a special characteristics and captures a picture of him in the field of

performance and then has called it inside the program when equip analyzes model and this takes a lot of time and concomitant this human error due to the analysts needed to register the anatomical points replace of monitoring and that not less than (18 anatomical point) image image until the end of the film, also we add to that correlation of the photography field with dimension of the calibration cube that the individual t exit from it and this consider a problem make us unable to shoot kinetic ‘can performance needed to extent of bigger kinetic.

Fig (1)

Second: **The influence of the view angles of the camera in view of the technologies of motion capture :**

Microsoft company has made an experimental study about connecting the technology of (Kinect) with the filming cameras, to know the range of the distance between monitored points according to the difference of its positions in the 3D Space. It is shown in fig (2) that the monitored body, which appears in the things filmed by the color camera, seemed to be near by the bodies surrounded it, and the depth is not clear opposing to the real fact. Nevertheless, when using a night vision camera (shape 3), the situation has changed, as the body sounded far from the surrounding bodies because of the change of the distances inside the photo in light of the reality.

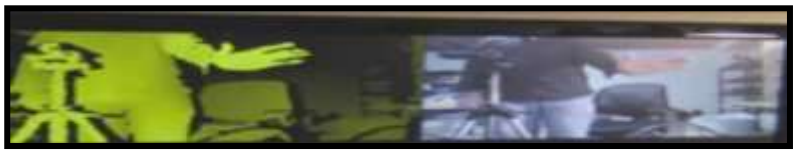


Fig (3) Fig (2)

It appears more clearly by drawing a 3D Scheme for the photo taken by the night vision camera fig (4) , the range and size of the depths of the photo, and the ability to see the dimensions(3:6-10).

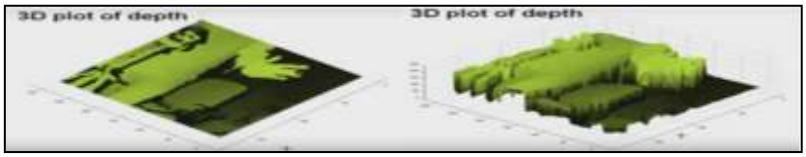
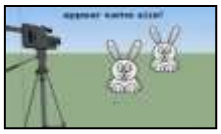


Fig (4)

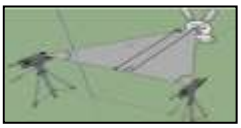
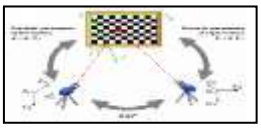
Therefore, if we assume putting two bodies as targets for filming fig (5, 6) using one camera, knowing that the body, which is closer in the reality, appears in fig (5) smaller than the other one and located in front of it. However, in fig (6), the two targets has the same size despite the difference between their sizes, as it was mentioned. It has shown in fig (7, 8) the affect of the distance of the camera on the poles that have similar height. In fig (7) where the difference in the height between the poles is clear when filming from 3 meters distance. Nevertheless, fig (8) shows a clear symmetry in the height of the same poles, however, the filming this time was 20 meters distance. So, if we need to specify the real height, and the range of the fairness

of the bodies that are filmed by the camera, the question is; how can we know the difference between the bigger body and the smaller one, while they have similar size and different heights contradicting with the reality? So, this is considered the first problem when using just one camera.(2:19).

Fig(5) fig(6) fig(7) fig(8)

Here comes the function of the second camera trying to solve this problem. So, if we draw a base of triangle between the cameras, and the vertex of the triangle is located in some point at the monitored target, fig (9) we will be able, using trigonometry, to count the distance between the point and the cameras in view of the angle between the filming cameras and the point. However, we find the second problem in this method, which is the difficulty to make sure that the incident rays coming from the cameras are located on the same point fig (10). That difficulty will increase if monitoring two points is required fig (11),(6) because of the difference between the vision angles of the camera. Therefore, how can we count the different dimensions in the presence of this problem?.


Fig(9) fig(10) fig(11)

In view of this, the researchers have made exploratory experiments based on their experience in that field, to face the problems of the process of photography;

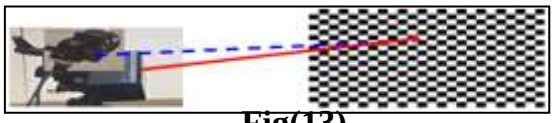
- In case of deviation the observed target side away from the its track appears shorter than the real length of 2.7% of the real length per meter away from its track and on the camera, while in deviation the body away from its track near to the camera that it appears longer than the real length by 3.64% of the real length per meter distant from the path toward the camera.
- When the body rotation on its track with angel (45 degree) in the front of and behind mild- point of the track perpendicular with the camera it appears closer from its length and amount of its angel differ in the image than the real in the middle

In light of the above studies were conducted to try to resolve these problems and has been reached to technique the (Kinect) fig (12) where this technique has dealt with these problems through use of video camera and infrared.


Fig (12)

To illustrate this has been painted a scene with invisible signs and has been reached to video camera with technique the (Kinect) that the camera fig (13) seen those signs but they can't measure the dimensions if the camera saw a point on the line that the technique (Kinect) see this point on the farthest line at an angel different vision but it agree with the real fact fig (10) and then ability to measure the dimension

if the location of point different in the vacuum changed directly with it the vision angel.



Fig(13)

Although the technique of (kinetic) has overcome the problem of measure the dimensions but in this technique problems also and most important of which that should be shooting inside the dark rooms and inability to shoot outside it in the presence of the sunlight which overlap with infrared which weakness angels of monitored points and inability to measure the real dimensions ,as we add to this inability to see the hidden point in human body when photography some movement or mathematical skills where it doesn't see except points of apparent parts in front of it only.

In light of the foregoing presentation of the problems, whether in the imaging requirements or angels of imaging vision that has come forward to the researcher's minds trying to find solution is from their point of view the perfect way to avoid these problems and by research and study the researchers reached to a way they hope in building it and it is about construction of Unit kinetic analysis depend on use a combination of inertia sensors to determine the coordinates of different positions of each point of the trace points that being to the moving body and this on three axes (x . where this sensors are installing on the positions of rigid bodies for human body ،y .z) where this sensors connected to unit of central control by using microcontroller and as these sensors can be connected ،install on human body concerned by measuring weird to central unit that this unit hold wirelessly with computer unit (station) where through it made observation and using different transaction. And to accuracy follow the movement will use sensors with high precision so that can trace any movement in parts of melee meter and that will use unit of central control with high speed where it can receive data from all sensors at each operating cycle and send it to the central computer unit with high speed from which can follow dynamic movement and and including packages of analyzes unit which ،monitor all biomechanical variables targeted by design as follow:

- Build a variety group of program to carry out variety functions required in the proposed observation control system.
- Implementation group of the organization system for communication processes between the sensors and the unity of the microcontroller.
- Build various transactions account programs from reading sensors.
- Build interaction with the user programs (user interface) to facilitate communication process and extraction data.

Aim of the research:-

The research aims to build kinetic analyzes unit by using inertia sensors

Research questions

- Can inertia sensors determine the different positions coordinates for each point of the tracking points (Yaw. Pitch. Roll)(X.Y.Z)?
- Are there significant differences between the inertia sensors and optical system in values of mechanical variables measured?

Research procedures:

Research method:

The researcher used the experimental method due to its relevance to the research nature.

Research sample

The research sample selected by purposively way and which represented in number (1) boxer individual has performance a group of movements which made in and axe ، axe (pitch) top and bottom ،three axes and they are (Yaw) front and behind (Roll) pronation and superstition in order to identify the values of certain kinematic variables to link (hand – forearm – upper arm).

The Instruments and tools used in the research:

3An inertial measurement unit (IMU)
(ARDUINO BOARD)
FTDI-Adapter
Lab VIEW Software
- 2 camera (pasler)120 HZ
- 3Markers

Parts of the devices and its geometrical dimensions:

The parts of the equipment will be clarified in the form of items containing the framework of the idea of the equipment:(4 : 1-65)

Definitions (sensors and soft wares):

The first element:(IMU)

An inertial measurement unit (IMU) is an electronic device that measures and reports a body's specific force, angular rate, and sometimes the magnetic field surrounding the body, using a combination of accelerometers and gyroscopes, sometimes also magnetometers. IMU type used is 9 Degrees of Freedom - Razor IMU - SEN-10736 - Spark Fun Electronics (combined of accelerometer, gyroscope and magnetometer).fig (14)

The second element::(An accelerometer)

is a device that measures proper acceleration; proper acceleration is not the same as coordinate acceleration (rate of change of velocity). For example, an accelerometer at rest on the surface of the Earth will measure acceleration due to Earth's gravity, straight upwards (by definition) of g ≈ 9.81 m/s2. By contrast, accelerometers in free fall (falling toward the center of the Earth at a rate of about 9.81 m/s2) will measure zero.

The Third Element :(A gyroscope)

is a spinning wheel or disc in which the axis of rotation is free to assume any orientation by itself. When rotating, the orientation of this axis is unaffected by tilting or rotation of the mounting, according to the conservation of angular momentum.

***The Forth Element :*(A magnetometer)**

is an instrument that measures magnetism—either magnetization of magnetic material like a ferromagnetic, or the strength and, in some cases, direction of the magnetic field at a point in space.

The Fifth Element :(Unity 3d)

Unity is a game development platform. Used to build high-quality 3D and 2D games, deploy them across mobile, desktop. fig (15)

The sixth element:(Mono Develop)

Is the *integrated development environment* (IDE) supplied with Unity. An IDE combines the familiar operation of a text editor with additional features for debugging and other project management tasks.

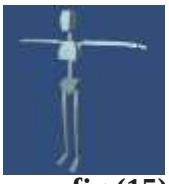


fig (15)

The seventh element:(Lab VIEW Software)

Laboratory Virtual Instrument Engineering Workbench (LabVIEW) is a system-design platform and development environment for a visual programming language from National Instruments.

The eighth element: (ARDUINO BOARD)

Arduino senses the environment by receiving inputs from many sensors, and affects its surroundings by controlling lights, motors, and other actuators. (IMU is one type of Arduino).fig 16

Fig(16)

ARDUINO SOFTWARE IDE :

Used to program Arduino by writing code in the Arduino programming language and using the Arduino development environment.

Processing:

Is an open source computer programming language and integrated development environment (IDE) built for the electronic arts, is used magnetometer calibration.

Virtual Serial Port Driver :

Virtual Serial Port Driver creates virtual serial ports and connects them in pairs via virtual null modem cable. Applications on both ends of the pair will be able to exchange data in such a way, that everything written to the first port will appear in the second one and backwards.

The neunte Theory of work:

IMU is the sensor installed on the human body limps to measure its orientation in 3D It will be preprogrammed and calibrated before use using the processing software for calibrating the magnetometer and Arduino IDE software for calibrating the accelerometer, gyroscope and entering the calibrated magnetometer data then programming the IMU. Three IMU are used and attached to the arm one on the Upper arm, one on the Forearm and one on the Hand. The IMUs sends the data to the computer through a FTDI board which will transform the IMU sensor to a protocol compatible with the computer USB port. The computer will read the signals(ROLL,PITCH and YAW) from the sensors by cable through serial port (USB) and send these data to Mono Develop C# software editor that will pass these data through equations and orders that will allow unity 3d to indicate these signal on a 3D human skeleton . The Unity 3D will send these data to the Labview to calculate the angle ratio per second omega and calculate the angle acceleration. The calculated results will be sent the angles to an excel sheet after stopping the labview application running.

The scientific calibration followed for sensors inertia system:-

The system calibrated by using depend on optical system on the cameras and where the sensors ،this in conjunction with inertia sensors designed by researchers

put on arm bodies (hand – forearm – upper arm) also have been put reflectors on top of each sensor and have been monitored each point in three directions (x . y . z).

Table (1)
Scientific calibration to identify the correlation between the inertia sensor and optical system

frame	Time (S)	optical		inertial		Differ Prec (%)		Dev.Std		Correlation	
		Up AR (Deg)		Up AR (Deg)							
		YAW	Pitch	YAW	Pitch	YAW	Pitch	YAW	Pitch	YAW	Pitch
1	0.00	0.0°	89°	0.0°	92°	0.0	3.3	0.0	2.1		
2	0.2	42°	80°	47°	87°	10.6	8.0	3.5	4.9		
3	0.4	75°	69°	84°	76°	10.7	9.2	6.4	4.9		
4	0.6	93°	53°	101°	59°	7.9	10.2	5.7	4.2		
5	0.8	104°	41°	110°	44°	5.5	6.8	4.2	2.1		
6	1.00	113°	32°	120°	35°	5.8	8.6	4.9	2.1	0.998	0.998
7	1.2	118°	27°	124°	31°	4.8	12.9	4.2	2.8		
8	1.4	123°	24°	129°	26°	4.7	7.7	4.2	1.4		
9	1.6	125°	18°	132°	20°	5.3	10.0	4.9	1.4		
10	2.26	127°	15°	138°	17°	8.0	11.8	7.8	1.4		

show From table (1) values of rotation angels around axe (z) (Yaw) and rotate around axe (y) (Pitch) which their measuring abilities ranges between (180° … 180°) and show from table the difference percent between sensors ،for inertia sensors system and optical where the maximum value of difference amounted 12.9% in rotation angel around axe (y) (Pitch) also the maximum value of deviation amounted and the type of correlation relationship ،7.8% in rotation angel around axe (z) (Yaw) has came positive and proportional where the values amounted (0.998) and it's a very strong relationship between two system and this appear in fig (17 .18) where whenever the rotation angel increase in system (optical) comparable increase in other system (inertia sensor) which designed by researcher.

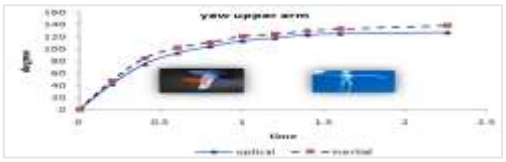


fig (17)
The angle of rotation axis(Yaw)

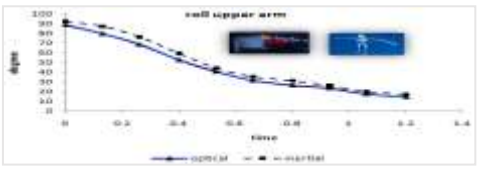


fig (18)
The angle of rotation axis(Pitch)

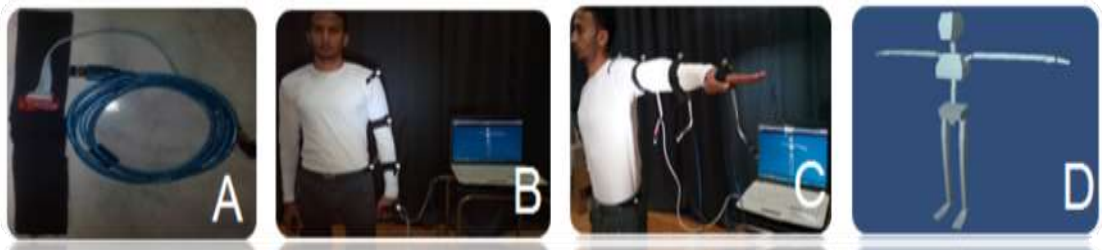
Presentation and discussion of the search results:

First : Is it possible determine the coordinates of different positions for each point from points trace on the human body and it's on (x.y.z).

An inertial measurement unit works by detecting the current rate of acceleration using one or more accelerometers, and detects changes in rotational attributes like pitch, roll and yaw using one or more gyroscopes. And some also include a magnetometer, mostly to assist calibration against orientation drift. Inertial navigation systems contain IMUs which have angular and linear accelerometers (for changes in position); some IMUs include a gyroscopic element (for maintaining an absolute angular reference). Angular accelerometers measure how the vehicle is rotating in space. Generally, there is at least one sensor for each of the three axes: pitch (nose up and down), yaw (nose left and right) and roll (clockwise or counter-clockwise from the cockpit) .(4:1).

Accelerometer sensor is designed to measure the acceleration and tilt, the gyroscopic sensor measures the angular velocity and orientation. The IMU sensor is a special one designed to combine the features of an accelerometer and gyroscope in order to display complete information about the acceleration, position, orientation, speed, etc. for a robot.(4:1).

In light of the foregoing the researcher enable from install these sensors on the links of rigid bodies to human body (Rigid bodies) and its (hand . fore arm .upper arm) fig (19) where these sensors connect to central control unit by using also these ،microcontroller and installed on the human body concerned by measuring sensors has connected wired to central unit as to hold with computer unit (station) where through it has observed movement and use different transaction. And for accurate follow the movement has used sensors with high precision so that can trace any movement in parts of melee meter and so that has used central control unit with high speed where it can receive data from all sensors at each operating cycle and send it to the central computer unit with high speed from which can follow dynamic movement and monitor all its kinematic variables.



Fig(19) The positioning of inertia sensors on the links with the appearance of three-dimensional model

In light of table (2,3,4) the researcher can answer to the second question where the results refers to ruthless the presence of significant differences between inertia sensors and optical system for some kinematic variables (angular velocity – angular acceleration) on axe (yaw, pitch) where the values of standard deviation ranged between two system for upper arm body between (0.05 : 0.51) on axe (yaw) ،(0.15: 0.50)on axe (pitch) for variable of angular velocity and with correlation coefficient (0.995) ، and the standard deviation amount between (0.14 : 0.89) on axe (yaw)، (0.16 : 1.05) on axe (pitch) for variable of angular acceleration and in correlation coefficient (0.998) and this results refers to success of researcher in reach to system depend on inertia sensors where don't presence differences with significant between two system also the correlation relationship between two system used refers to presence of correlation relationship positive where it amounted the less value correlation (0.927) and maximum value correlation (0.998) and this values refers to presence of strong relationship if happened increase or decrease in two direction positive and negative in values of kinematic variables measured in optical system synchronize with it inertia sensors which the researcher reached to it by increasing and decrease and in two direction positive and negative with ability of determine movement directions which describe transformation between photos that Two-dimensional and each other and the researcher could in recent system overcome on the problem of movement which done in vacuum by correct engineering projection three – dimensional (photo) and that deals with measuring units by pixel (pixel) the element component to digital photographs.

The conclusions:

Within the limit of the research objective and in light of question and used methods the researcher enable as follow:

- The researchers reached to build kinetic analyzes unit depend on inertia sensors
- The researchers enable from connect these sensors wired to central unit as to hold with computer unit (station).
- Ability to trace any movement in part of melee meter and also used central control unit once high speed for receiving data from three sensors at each operating cycle and sent it to central control unit with high speed (real Tim).
- The researcher reached to simulation the human body in three dimensions photo synchronize in its movement with human movement in the real time.
- There are strong correlation relationship and positive between inertia sensors system and optical system in values of kinematics variables measured to standard system used between two systems.
- There aren’t complicated standard systems for inertia sensors as what fined in other systems which depend on using imaging cameras.
- Lacks of time factor spent on inertia sensors which don’t exceeds seconds in trace the movement and get the immediate report.
- Lack costs of inertia sensors which the researcher reached to it and that beat the rest of other systems.

Recommendation

- Indispensability complements of inertia Sensors system on the rest of the parts and links of human body in light of engineering build and technical followed by researchers.
- the need to rely on the current regime in kinetic analysis procedures when embarking on the study and analysis of sports movements or evaluate the movements in rehabilitation system after injuries of sports .

Research References:

First: Arabic References:

1- **Talha Hussain Hossam Eddin:** Biomechanics fundamentals theoretical and applied**, T**he house of the Arab Thought, Cairo, Arab Republic of Egypt**,** the first edition,1993.

Second: English References:

2- **CARLJ .PAYTON AND ROGER M .BARTLATT**: Biomechanical Evaluation of Movement in Sport and Exercise. The British Association of Sport and Exercise Sciences Guidelines , 2008.

3- **John Mac Cormick** : How does the Kinect work, 2006.

4- **Gordon Wetzstein!:** Introduction to Inertial Measurement Units!, Stanford University!,2016.

5- **Zhuxin Dong1 , Guanglie Zhang1 , Yilun Luo1 , Chi Chiu Tsang , Guangyi Shi1 , Sze Yin Kwok1 Wen J. Li1,*, Philip H. W. Leong** , and Ming Yiu Wong3 : A Calibration Method for MEMS Inertial Sensors Based on Optical Tracking , Center for Micro and Nano Systems, The Chinese University of Hong Kong, Hong Kong SAR

Third: Websites from the internet:

6- **https://www.reddit.com/r/videogamescience/comments/4u5td3/how_the_kinect_depth_sensor_works_in_2_minutes/**

7- **https://www.researchgate.net/figure/224698432_fig3_Figure-7-Schematics-of-multiple-camera-calibration-experimental-setup.**