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Design of a Software for a Novel Inertial Data Logger to Measure High Kinematic Parameters of Soccer Instep Kick

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Abstract. In sports biomechanics, videography provided an indirect method for measuring kinematic parameters. However, these techniques are expensive, bulky and not portable. In contrast, the current sensor module and data logger is light, robust and cheap and applicable in the field for directly measuring high linear and rotational kinematics. In this project a data logger and computer software were designed to measure the high kinematic parameters (linear and angular accelerations and velocities) and compute the kinetic parameters (force, torque, angular momentum, impulse and angular power) of the instep kick and compare the right and left legs during trials of a subject or in the group. This novel technique is also suitable in many of other sports or in the low range movements (e.g. gait, dance, etc) using low range accelerometers.

Keywords: Software, Data Logger, Accelerometer, Soccer, Instep Kick

1. Introduction

Development of a suitable data logger and software system for direct measurement of high kinematic and kinetic parameters of an instep kick in soccer has received no attention over the years. Hitherto, the complex high kinematic and kinetic parameters of an instep kick was measured using the indirect methods of 2-dimensional (Asai, 2002; Barfield, 2002; Dorge, 2002; Van Deursen, 2001) and 3-dimensional videography (Levanon and Dapena, 1998; Nunome, et al., 2002; Nunome, et al., 2006a; Nunome, et al., 2006b; Rodano and Tavana, 1993). However, the 3-dimensional videography method has recently been reported not to be accurate in measuring the movements of the shank near to the impact with the ball due to the low sampling rate of the cameras, coupled with attendant filtering methods to derive the high kinematic and kinetic parameters of instep kick (Nunome, et al., 2006a; Nunome, et al., 2006b).

Further, the high cost of acquiring videography equipment coupled with its bulkiness makes the equipment unwieldy to be easily used in the field. Hence, there is need for an alternative technique that can directly measure the soccer instep kick in the field. Such a device must be inexpensive, easy to use by coaches and its data logger system should be able to record, store and process the data for later downloading into a computer for computations either in the field or in the laboratory. To the best of our knowledge, presently, no direct measurement technology is available for measuring the high kinematic and kinetic parameters of the soccer instep kick in the field.

Consequently, in the present study, a new sensor module configuration and data logger was designed and fabricated to directly measure angular acceleration in three axes as well as the shank angular velocity in two axes. The current design therefore is in contrasts with previous data logger systems that used triaxial accelerometer together with triaxial gyroscope (±300 - ±1200 °/s) to measure low range human locomotion. It is therefore obvious that such devices will be incapable of measuring the high kinematic and kinetic parameters as seen in an instep kick (i.e., angular velocity >1900 °/s). It is therefore not surprising that the

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previous data logger systems were only used for low range motion analysis like gait analysis (Currie, et al., 1992; Evans, et al., 1991; Foerster and Fahrenberg, 2000) and ambulatory movement monitoring (Aminian, et al., 1998; Aminian and Najafi, 2004; Aminian, et al., 2001).

Other disadvantages of previous inertial data loggers are high cost, size and weight of these data logger systems (e.g. XSENSE, MEMSENSE and MicroStrain companies). The high costs might make it difficult for coaches to acquire such a device for the measurement of low kinematics. Consequently, the current data logger system offers a relatively cheap and affordable device for coaches to purchase, use in the field and easily download results on a laptop computer. This enables quick way to assess the technique performed by the footballer and get immediate feedback for skill correction. Application of present data logger is not limited to the soccer alone and it can be used in many other sporting activities.

2. Methodology

2.1. Hardware

In the design of the current sensor module, seven (7) axes of five accelerometer sensors with high ranges (±100g) were arranged in a specific geometric configuration with complimentary axes X, Y, Z, opposite and parallel to each other. This enabled the sensor module to be responsive to rotational and linear acceleration and velocity in any direction in space and function it as a "gyroscope-free system".

2.2. Software

The present design offers a novel simultaneous and independent extraction of the two-dimensional magnitude of angular velocity and angular acceleration of the shank in three axes. This provides a simple algorithm for computing angular velocity in two planes (i.e., flexion/extension and abduction/adduction) using rotational acceleration values.

Fig. 1: Overall flow chart for data acquisition

Software programming for this project was done using two different programming languages for the microcontroller (C language) and PC software (Delphi™). In the PC software, many utilities are available for data chart presentation and reports. These were utilized for the evaluation of the hardware, comparative studies and field tests. No filtering methods were used. In the designed software, the data logger was initially programmed to enable it to acquire the measured data and then transfer the data to the computer. The computer PC software, in turn, conducts modular testing procedures and request for debugging, evaluation and calibration processes. In this way, the PC software fully communicates with the data logger software, manages the database, computes kinematic and kinetic parameters and analyses the kicking data and finally presents the data in charts and reports.

Hence, the backbone of the PC software is to provide an algorithm capable of computing rotational kinematics from the accelerometer data, differentiate the linear and rotational kinematics and process the instep kick data. In addition, the software recognizes the instep kick stages based on the angular velocity and angular acceleration in the X axis. The instant stages of leg toe-off, back swing and impact with the ball are distinguished by the software and the rotational velocity in the X-axis and Z-axis is then computed using the angular acceleration in the X, and Z axis respectively.

1.1.1 Overall Data Acquisition Process

Acceleration data generated by the movement of the shank and thigh during the instep kick was recorded by the sensor module and data logger accelerometers. The analog acceleration output data registered in the X, Y and Z axis of the sensor module and data logger were simultaneously digitised and fed into the microcontroller for storage in a memory card in binary format. The computer software was used to retrieve the binary data from the memory card. When the data processed, the final output was displayed in graphs or reports (Fig. 2). The data logger can also be used in a network by connecting it to other data loggers and sensor modules attached to other body segments, after synchronizing the time.

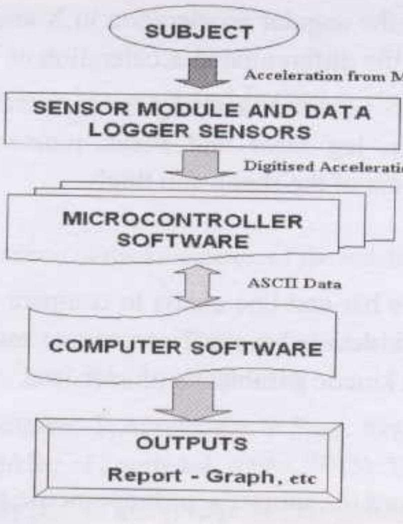


Fig. 2: Overall flow chart for data acquisition

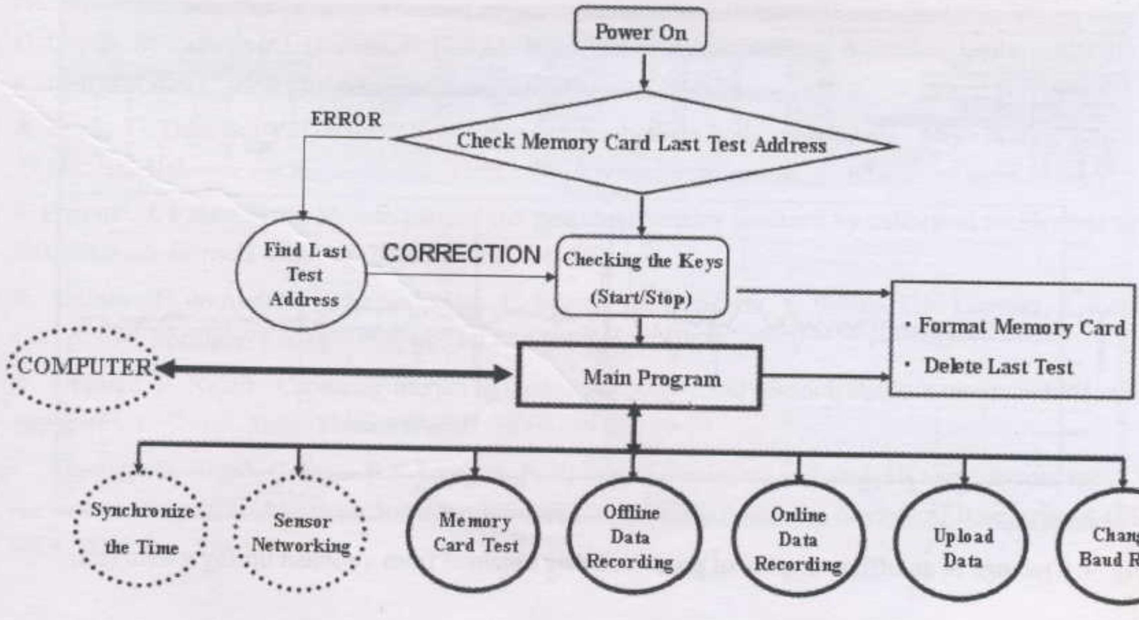


Fig. 3: Flow chart for the microcontroller software

1.1.2 Computer Software Design

The computer software was designed to acquire data in the field. In this regard, an interface was designed to communicate with the microcontroller through a serial port named "Data Logger Remote Control". The retrieved data was processed under "Data Processing Unit" and used for either Online or Offline data acquisition.

Both Online and Offline data acquisition programs were developed to create and manage databases, display the processed data either in simple reports or advanced graphical format. The Online data acquisition was mostly used during the development of the data logger, sensor calibration and verification of the sensors before and after the field test. Offline data acquisition was used for retrieval of data from the data logger.

1.1.3 Data processing

In real time data processing, time and digitised acceleration data from ten (10) axes of the accelerometers were processed by the "Data Processing Unit". Calculation of acceleration in "g" unit used linear approximation formula for each axis and was based on the calibration data from calibration database. After conversion of the digital data to acceleration in "g", the mean acceleration value of each parallel axis (e.g. X1, X2) of the sensor module was used to calculate the linear acceleration of the shank. Differentiation of the acceleration data obtained from two parallel axes for X and Z, divided by the distance between the sensor module accelerometers was used to compute the angular acceleration in X and Z axes. Magnitude of angular velocity was calculated by the square root of the differentiated acceleration of Y1 and Y2 axis.

After calculating the kinematic parameters i.e. linear and angular accelerations and magnitude of angular velocity (XZ), shank mass + foot + shoe, leg mass and shank moment of inertia were taken into consideration to compute the kinetic parameters of the shank and thigh.

1.1.4 Data demonstration

To present the data the software employs bar and line charts to compare the results of the field tests for each subject and in the group. To perform a detailed comparison of test results, other special utilities and reports provided details of the kinematic and kinetic parameters of each test.

3. Results

The designed software enabled us to record the subject's anthropometric parameters, and date of the field test. Test results for each subject were saved separately in the database. By selecting each subject's test, the kinematic and kinetic parameters are processed and the results displayed graphically, or in other graphical formats or exported to Excel format.

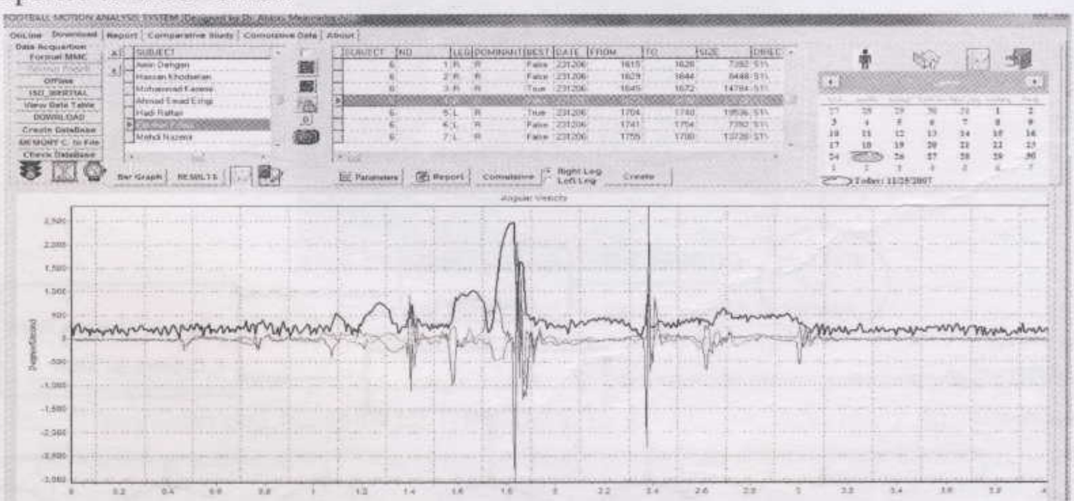
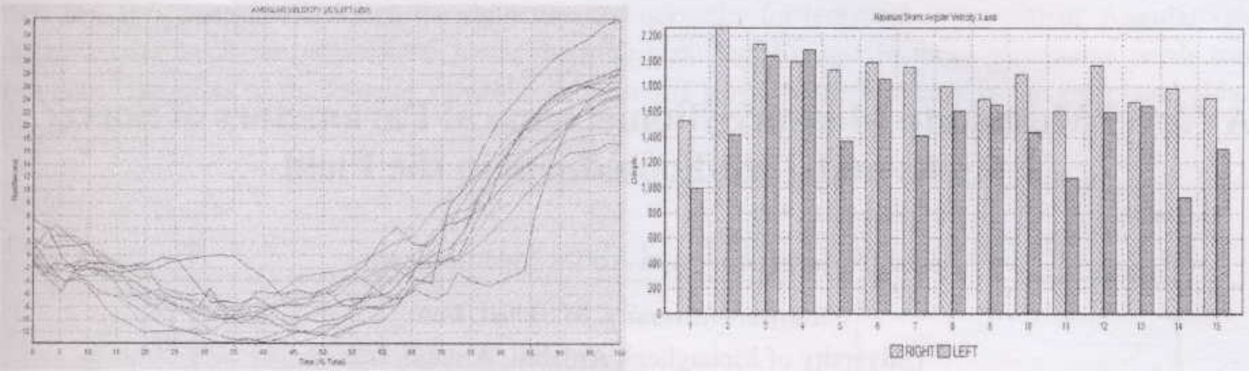


Fig. 4: Tracings of an offline display of processed data obtained from a subject during a field test

Comparison of the right and left leg kinematic or kinetic parameters can be evaluated by bar graph (Fig. 5.b). Another utility of the software is demonstration of the kinematic data of the subjects in a line graph normalized from toe-off until impact with the ball in time percent (Fig. 5.a) for the dominant or non-dominant leg.



(a) (b)

Fig. 5: Cumulative (a) and comparison of (b) data from fifteen subjects

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