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Design and research on the information collection system of digitized discus throwing

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Abstract. Information collection system of digitized discus throwing is designed to achieve the diagnosis and analysis of the mechanical information about athletic technical movements. Firstly, upper and lower covers and circle of the digitized discus as well as other parts are drawn according to the general structure of discus measuring system, physical connection among all devices, object appearance and its structural design. And then, hardware and software design are made for information collection system of digitized discus throw. The achievement for hardware circuit system function of digitized discus is depended on the software design. Hardware consists of power source, SCM, sensor, A/D transformation, wireless communication and RS232 serial communication. And anti-interference design is also made to hardware system. Lastly, throwing experiment is carried out. Data collected in practical throwing is compared with data collected in the experiment, combined with discus movement rules, which testifies the feasibility of hardware circuit system design of digitized discus. And with stable equipment job, diagnosis and analysis of mechanical information is made to athletic technical movements.

Key words. Digitized discus, information collection, wireless launch, sensor.

1. Introduction

In the throwing events, athletic discus performance needs to be improved through technical means improvement as athletic break-out force is hard to improve. Before throwing the discus, acting force applied on the discus by hands and discus posture at that time all influence the athletic throwing performance to some extent. Therefore, a research is made from the discus posture in the throwing process and forced direction of discus [1]. At present, interaction force between human beings and ground can be acquired by 3-D force platform. However, the acting force applied on the discus by hands cannot be acquired directly. Yet, there is no ideal equipment for measuring discus throwing events. The present research method for measuring discus is by means of dynamical information [2]. In view of this situation,

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a hardware circuit system of digitized discus is designed to acquire the dynamical information when the athlete is throwing the discus, which is fully prepared for the further research of discus posture angle.

2. Literature review

In the throwing events, electric resistance gauge, used to measure the force [3], which hardly achieve the discus without discrimination; with the acceleration of social modernization, the demand for sensor technology in industrial production and in daily life is increasing, and the demand for accuracy becomes higher and higher. And the sensor technology is indispensable in the throwing events and becomes an important part of information technology. Application level of sensor technology directly affects the automation development. Since 1980s, sensor technology has developed rapidly in Japan, USA and other countries, and the sensor technology has been extended to some field, such as defense technology and industrial production control. Since that, China has paid more and more attention to the development of sensor technology and taken it as one of priorities in national high-tech development.

According to the international standard, the discus structure of built-in circuit board is designed by the hardware circuit system of digitized discus, and a discus with 3-D accelerated velocity and 3-D angular velocity in the whole discus throwing process can be developed based on the acceleration sensor and angular sensor. And the acquired data can be sent by wireless transmitter module and received by wireless receiving module. Eventually, the discus motion parameter is dealt with by the computer to fulfill the real-time acquisition of dynamical information [4]. Computer can handle the data and store useful information; this system can be used alone or matched with other instrument and equipment. Researchers working for sports can take advantage of this measuring means to get the data and search for new theories and rules about discus throwing.

3. Methods

3.1. Overall design of digitized discus

Digitized discus mainly consists of upper and lower discus covers, stand column, nut and discus circle that connects with upper and lower covers as well as circuit board with relative function.

It is functional circuit board is small enough in the experiment that it can be put into discus. Functional circuit board is put in the central place of discus by the stand column, which can narrow the error brought by vibration in the throwing process [5].

Overall design for hardware circuit system of digitized discus is shown in Fig. 1.

In the discus throwing, digitized discus system is used to get 3-D acceleration velocity and 3-D acceleration velocity information in the throwing. And the force, posture velocity and other parameters of discus can be worked out through integra-

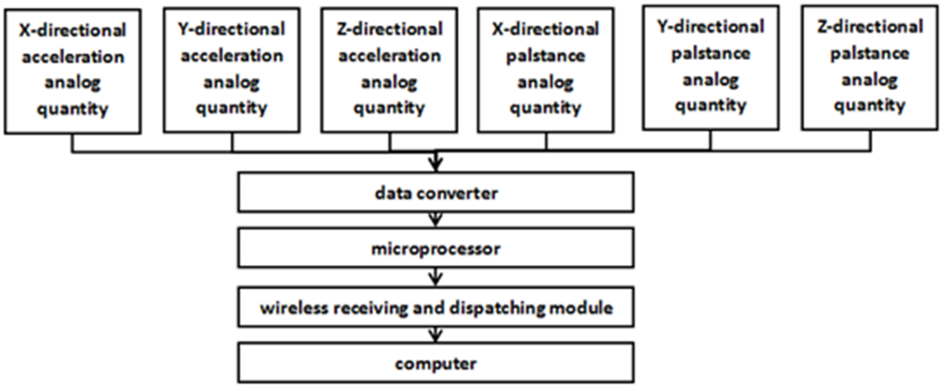

Fig. 1. Overall design for hardware circuit system of digitized discus

tion and INS. After throwing the discus, 3-D information is collected respectively by three-axis acceleration sensor and angular velocity sensor; sensor is driven by analog-digital converter to collect that analog quantity that is turned into 12 figures with digital quantity; digital signals that are turned by microprocessor are sent to launching cache. And then the wireless transmitter module is launched. Finally, digital signals are received and stored by the computer through the receiving module [6].

The circuit board in the discus is integrated by the ADXL78 acceleration sensor, ADXL278 acceleration sensor, Tri-Rate free-velocity sensor, TLC2543 A/D converter, C8051F320 SCM, AT26F004 storage, LTC4602 battery charging IC, MAX 1760 boost IC, lithium battery, PTR6000PA wireless transmitter module and other main devices; PTR6000PA wireless receiving module integrated with C8051F320 SCM as one unit are inserted into computer.

3.2. Hardware structure and function of digitized discus system

3.2.1. Power source. C8051F320 SCM system needs to be supplied power by relatively stable 4 V–5.25 V power source; LTC4062 battery charging is adopted in the circuit design of digitized discus hardware structure. Interface and socket of lithium ion battery is supplied with direct voltage 3.6 V from external power source. Voltage of power source is increased to 5 V by MAX1760, which can provide a stable 5 V voltage for SCM, spinning top, acceleration sensor, A/D and other components and parts to use.

3.2.2. SCM. There are several ports used in SM, such as P0.0 (SCK), P0.1 (MISO), P0.2 (MOSI), P0.6 (IRQ_nRF24L01), P0.7 (IRQ_LTC2543C), P1.0 (CS_ nRF24L01), P1.1 (CS_FLASH), P1.2 (CS_LTC2543), P1.7 (CE_nRF24L01) and so on. RST/C2CK and P3.0/C2D are used for restoration and system debugging. When VBUS inputs 5 V voltage and the USB is surly connected, REGIN is voltage stabilizer input in SCM, VDD is 3.3 V voltage stabilizer output, D– and D+ are the data output and input.

3.2.3. Sensor. (1) ADXL278(AD22285) is a double-axis acceleration sensor whose measurement range is ±50,g. ADXL278 measures the value of accelerated velocity in X, Y direction and its volume is 5 mm×5 mm×2 mm. When the accelerated velocity is 0 g, the frequency is 100 Hz. When VCC is 5 V, the value of VOUT—VCC/2 is between –150 mV and 150 mV, and its sensitivity is 36.1–39.9 mV/g.

(2) ADXL78 (AD22280) is a double-axis acceleration sensor whose measurement range is ±50,g. ADXL78 measures the value of accelerated velocity in Z direction and its volume is 5 mm×5 mm×2 mm. When the accelerated velocity is 0 g, the frequency is 100 Hz. When VCC is 5 V, the value of VOUT—VCC/2 is between –150 mV and 1150 mV,, and its sensitivity is 36.1–39.9 mV/g [7].

(3) TriRate (TR1200S050) is a three-axis angular velocity sensor whose measurement range is ± 12000/s. TriRate measures the values of angular velocity in X, Y, and Z directions and its volume is 0.70 in×0.70 in×0.40 in. When the angular velocity is 0, the voltage output value is 2.5 V, and its sensitivity is 1.25 mV/°/s.

3.2.4. A/D converter. TLC2543 is a 12-figure analog-digital conversion chip. First and foremost, TLC2543 configuration is connected to the two corresponding pins of SCM: pin EOC is corresponded to the SCM P0.7, pin CLK is corresponded to SCM P0.0, pin DIN to the SCM P0.2, and pin CS to the SCM P1.2. Thus, SCM is attached to the TLC2543 through SPI. And SCM data conversion comes to end by interruption (EOC is high level). Because SCM has no specialized SPI port, it uses software to achieve SPI function in order to have a communication with TLC2543. It takes time-delayed method to collect data. Mode configuration register is output through port 0 and P0.0, P0.1 and P0.2 is set up as push-pull output. 8-bit data is serially input from DIN port (00000001), which is called control word. Analog channel (0-8) is controlled by the high-four figure of 8-bit data to use. Output length of 12-bit data is achieved the third and second configurations. The first one stands for high order is first sent out. Number 0 controlling achievement is output with 2 complement form [8].

3.2.5. Wireless communication. Receiving module of wireless launch adopts nRF24L01 as its core component, which can fulfill wireless communication in six channels [9–10]. Major operating modes and pin functions of nRF24L01 are shown in following Tables 1 and 2.

In the Shock Burst mode, SPI port is provided for nRF24L01 to be linked together with bradytelic acceleration sensor and angular sensor. After sending data, the IRQ becomes high level to inform SCM. And SCM can read out the data that received by RXFIFO register. In the data launching and receiving process, nRF24L01 can share with one channel to launch and receive data from six different channels. All the data from channels can be set up as enhancement mode to recover the lost data without increasing SCM workload.

Table 1. Thermophysical properties of regular fluid and nanoparticles

Mode	Receiving mode	Sending mode	Sending mode	Standby mode II	Standby mode I	Power down mode
PWR_UP	1	1	1	1	1	0
PRIM_RX	1	0	0	0		
CE	1	1	10	1	0	
FIFO register state		Data is put into TX FIFO register	Sending mode, until data is sent out	TX FIFO has no data	Data is not transmitted	

Table 2. Pin function of nRF24L01

<table>
<tr><td>Pin name</td><td>CE</td><td>CSN</td><td>SCK</td><td>MOSI</td><td>MISO</td><td>IRQ</td></tr>
<tr><td>Direction</td><td>Input</td><td>Input</td><td>Input</td><td>Input</td><td>Three-state output</td><td>Output</td></tr>
<tr><td>Sending mode</td><td>High level 10 us</td><td rowspan="4">SPI chip selection enabling, low level enabling</td><td rowspan="4">SPI clock</td><td rowspan="4">SPI serial input</td><td rowspan="4">SPI serial output</td><td rowspan="4">Interruption, low level enabling</td></tr>
<tr><td>Receiving mode</td><td>High level</td></tr>
<tr><td>Standby mode</td><td>Low level</td></tr>
<tr><td>Power down mode</td><td></td></tr>
</table>

When some data in SCM needs to be sent out, MOSI will receive node address (TX_ADDR) and valid data (TX_PLD) written into nRF24L01. And the length of emit data (bytes) are written into TX FIFO from SCM. When CS_nRF24L01 is in low level, chip begins in a work state and nRF24L01 is written into [11]. When CE_nRF24L01 is in high level, launching mode starts and duration time should last for 10 s or more in a high level state. After sending out the data, channel 0 is set up as receiving mode to receive answering signals. Both receiving answering signals and retransmission outnumbers the set value result in interruption. And then TX FIFO is eliminated, which makes preparation for next set of data to be launched.

3.2.6. RS232 Serial communication. RS-232 is a widespread serial interface, using P0.4 and P0.5 of SCM. RS-232 serial communication interface adopts single-ended communication (unbalanced transmission mode); Data signal from receiving and dispatching end of RS-232 serial communication interface has a bigger difference from ten-signal earth level. When RS-232 serial communication interface sends and receives serial port data, driven positive level of its sending and dispatching end ranges from +5 V to + 15 V and its negative level ranges from –5 V to –15 V. When the data of discus accelerated velocity and angular velocity is transmitted by adopting RS-232 serial communication interface, on-line voltage of systematic signal is converted TTL level by transforming chip to RS-232 level, and then connected to RS-232 communication interface of the computer [12]. Voltage multiplying circuit and special circuit are included in MAX232AESE chip, without control signal. It only needs +5 V power source to make a double-four-directional transmission between RS232 level and TTL level; it should be noted that when used, it needs several external capacitance 0.1 uF. C8051F320 machine is connected with MAX232AESE through TX and RX pins; and then it connected with 9-core RS-232 serial communication interface of computer [13].

There are two purposes for baseplate system expanding serial interface: one is served as serial communication; another is for tool of computer debugging embedded system. As long as there are three pins—RXD, TXD and GND, serial communication can be achieved.

3.2.7. Anti-interference design of hardware system. (1) A large capacitor used to ensure the minimum distance between VDD pin and direct-current main in chip. For instance, 4.7 uF/16 V tantalum capacitor has a parallel connection with a little common capacitor. The power source must have a filtering processing that can supplies power for system. And the simulation is bound to be separated from data.

(2) When wired at PCB board, long power line should be avoided. Crystal oscillator and power line should keep far away from digital signal and control signal line.

(3) Ground electrode and power line of all integrated devices is respectively joined into decoupling capacitor. Because of on the printed-circuit board, all devices have large power consumption and potential difference is generated on the ground electrode; a solution to this problem is narrowing the linear length of switched current; so, PCB power line and the entrance of ground electrode have a parallel connection with decoupling capacitor. And then every ground electrode port and power port of integrated chip on the PCB is all joined into a decoupling capacitor with 0.01–0.1 uF capacitance.

(4) When wired at PCB of hardware structure, power line of circuit board and width of ground electrode are needed to be widened so that larger current can convey the circuit board; in addition, the whole PCB is pavaged and the circuit components and parts have a close ground connection, which avoided a long ground lead.

(5) In the hardware structure design, printed-circuit board is not divided into digital block and model area. Most chips on the printed-circuit board are digital chips. The sensor should keep away from strong interference source as much as possible (e.g. power switch); USB cable and clock line adopt parallel lines, and the distance between centers of tracks is possibly wide; under quartz oscillator and wireless radio frequency module, GND area is possibly large, without through signal line. When software draws printed-circuit board, it is noted that power line of the

whole circuit board and ground electrode direction should keep a same direction with USB as much as possible. The line is possibly short as well as semiconductor device, capacitance and resistance. And they needed to be avoided intersection with other guide lines. In the meanwhile, ground electrode is encrypted possibly, which can reduce impedance from ground electrode.

3.3. Software design of hardware system

Functional achievement of digitized discus hardware circuit system depends on systematical software design. Software writing is based on the deep understanding of systematical hardware.

3.3.1. Launching unit design. Program flow chart of launching unit system is shown in Fig. 2.

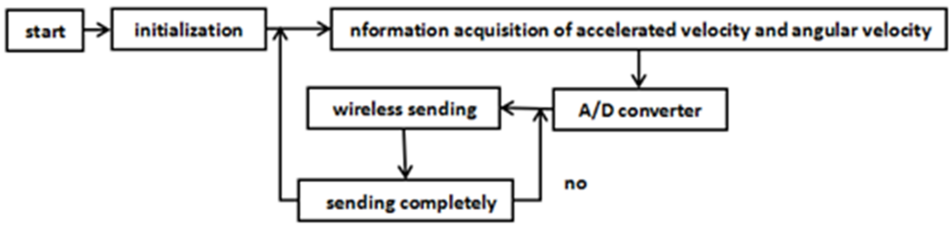

Fig. 2. Program flow chart of launching unit

3.3.2. Receiving unit design. System flow chart of receiving unit is shown in Fig. 3.

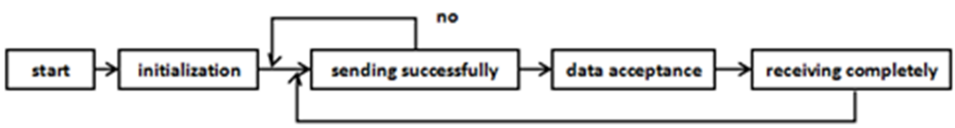

Fig. 3. Program flow chart of receiving unit

3.4. Throwing experiment

In Physical Education College of Zhengzhou University stadium, several throwing experiments are made. Transmitter module is wrapped in discus with foam, sponge, and foam is used to protect the exterior. In the experiment, accelerated velocity and angular velocity and other original parameters are gained.

Data in the Table 3 is a part of original data. In the Table 3, ACC_X, ACC_Y and ACC_Z respectively express the accelerated velocity component with front-and-back direction, up-and-down direction as well as right-and-left direction in coordinate system in the center of discus. And, GYRO_X, GYRO_Y and GYRO_Z respectively represent angular velocity with front-and-back direction, up-and-down direction as well as right-and-left direction in coordinate system in the center of discus.

Table 3. Original data

Sequence number	1	2	3	4	5	6	7	8	9	10
ACC_X	2032	2032	2030	2033	2032	2031	2037	2038	2031	2032
ACC_Y	2007	2000	2002	2001	1998	2000	1999	2002	1998	1999
ACC_Z	2021	2026	2021	2022	2022	2024	2018	2024	2022	2023
GYRO_X	2055	2055	2059	2065	2081	2094	2104	2115	2120	2128
GYRO_Y	1987	1971	1957	1944	1936	1927	1921	1913	1904	1900
GYRO_Z	2139	2149	2157	2165	2174	2181	2187	2194	2201	2215

According to collected original data, Beijing aerospace inertial navigation is applied to make a calculation to the coordinate transformation and differentiation as well as integral calculation. And then original data is processed, and accelerated velocity value of navigation system can be worked out by other parameters such as integrated pitch and roll compensated by algorithm and accelerated velocity.

Table 4. Navigation system data

Seq. numb.	1	2	3	4	5	6	7	8	9	10
A_x	-0.28	-0.29	-0.40	-0.65	-1.03	-1.48	-1.94	-2.32	-2.58	-2.70
A_y	-0.21	-0.20	-0.17	-0.09	0.02	0.14	0.26	0.35	0.37	0.31
A_z	9.21	9.20	9.31	9.51	9.82	10.20	10.58	10.92	11.21	11.46
V_x	2.12	2.11	2.11	2.10	2.09	2.08	2.06	2.03	2.01	1.99
V_x	-2.32	-2.31	-2.32	-2.32	-2.32	-2.32	-2.32	-2.31	-2.31	-2.31
V_z	-5.02	-5.03	-5.03	-5.03	-5.03	-5.03	-5.02	-5.01	-5.00	-4.98
Pitch.	-6.11	-5.64	-5.10	-4.47	-3.75	-2.98	-2.15	-1.31	-0.45	0.41
Roll.	-79.75	-79.90	-80.01	-80.08	-80.13	-80.15	-80.14	-80.10	-80.01	-79.89

The data in the Table 4 is a part of navigation system. In the table, A_x, A_y and A_z, respectively, express the accelerated velocity component with front-and-back direction, up-and-down direction as well as right-and-left direction in ground coordinate system in the center of discus. Symbols V_x, V_x and V_z respectively represent linear velocity with front-and-back direction, up-and-down direction as well as right-and-left direction in ground coordinate system in the center of discus; pitch angle is a included angle with front-and–back direction between discus surface and ground, roll angle is a included angle with right-and-left direction between discus and ground. As shown in Fig. 4, accelerated velocity is in the X direction. In Fig. 5, accelerated velocity is in the Y direction. In Fig. 6, accelerated velocity is in the Z direction. Figure 7 is the integrated pitch and Fig. 8 is the integrated roll.

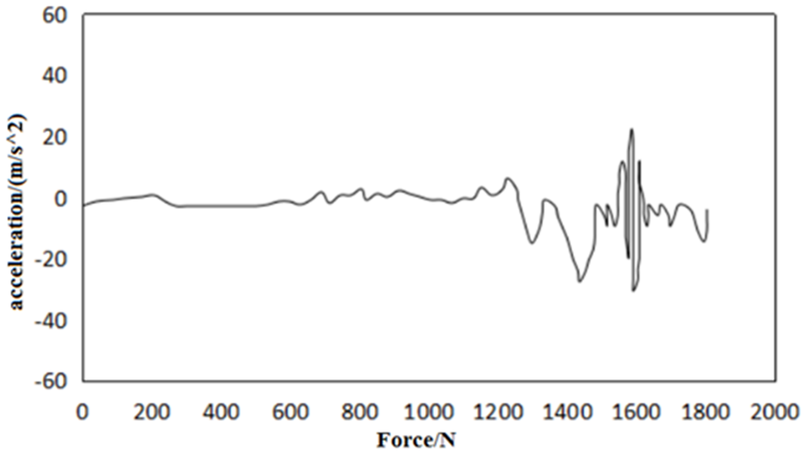

Fig. 4. X-directional accelerated velocity

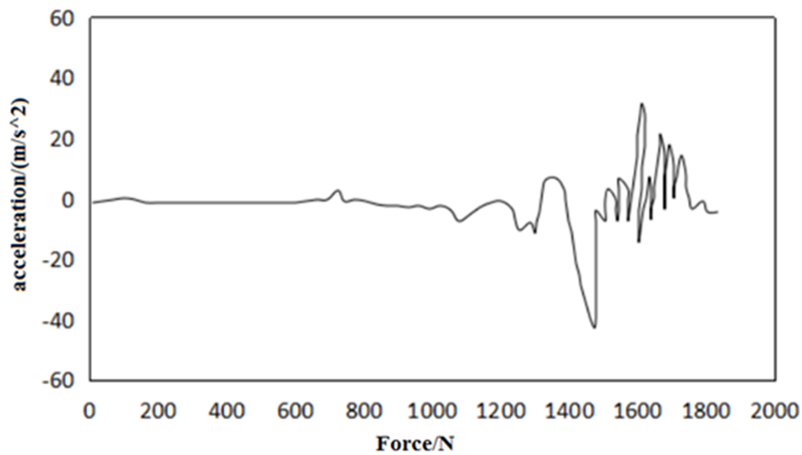

Fig. 5. Y-directional accelerated velocity

4. Conclusion

It is clear that, to some extent, data collected by digitized discus reflects motion law in the discus throwing process in terms of processed data. Therefore, this method is feasible and has a chance to find out new force application law of discus throwing. A large quantity of data is acquired for data mining with plenty of experiments. And combined with throwing experiments of discus athletes, laws are discovered to improve their score.

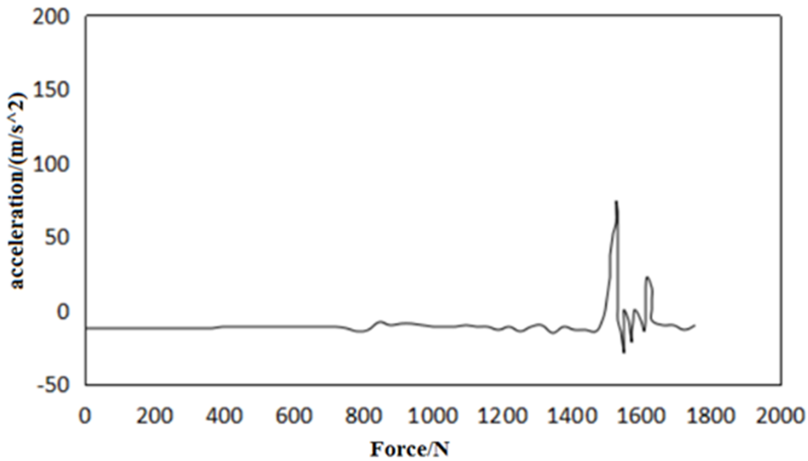

Fig. 6. Z-directional accelerated velocity

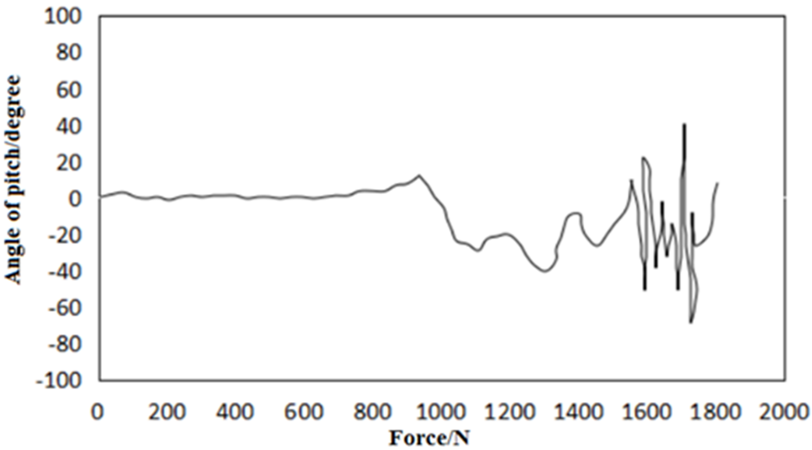

Fig. 7. Integrated pitching

Hardware circuit system of digitized discus achieves the function for acquiring 3-D accelerated velocity and angular velocity information with real time in the discus throwing process, which fulfills the transmission in hectometer. Sufficient experiments are made for real-time data acquisition and wireless transmission in long distance, to acquire sets of data and videos, which receives expectant results of force and postures.

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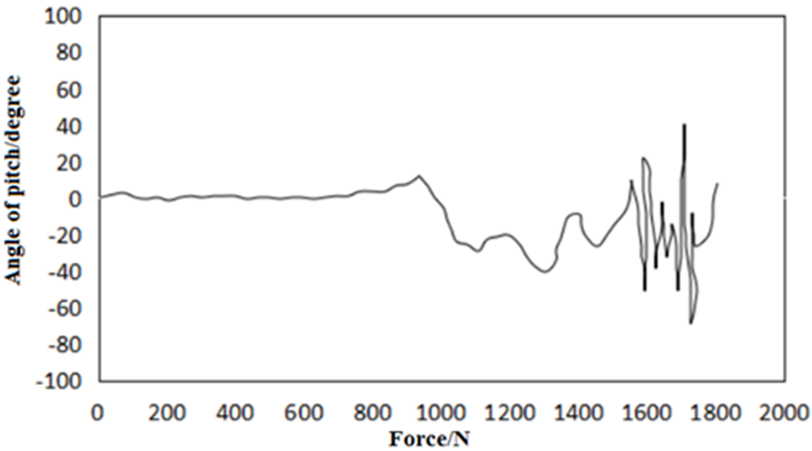

Fig. 8. Integrated rolling

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