



REVIEW ARTICLE

MOTION PARAMETER DETECTION BASED ON PROBABILISTIC MODEL

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ARTICLE DETAILS

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ABSTRACT

With the improvement of living standards, more and more people begin to realize the importance of good health. However, traditional physical exercise can only satisfy the needs of exercising and does little to do with improving health. Therefore, there is an increasing need for a piece of equipment which can detect the body motion parameter and reveal the physical state so as to develop a scientific and reasonable body-building plan, which is also reckoned as one of the trends of research in relevant realms. Probabilistic model is a powerful instrument to deal with nondeterminacy parameters. The establishment of probabilistic model can resolve such problems as the complexity and nondeterminacy of the motion process and the changing factors of the external environment, while traditional measuring method is hard to satisfy relevant requests. It is based on the previous reasons that this paper researches into motion parameter detection. During the research, relevant document literature is consulted and related research is conducted into the meaning and method of motion parameter detection and the theoretical basis and application method of probabilistic model and probabilistic reasoning. On the basis of the previous efforts, this paper researches into the composition principle and design method of the motion parameter detection system based on probabilistic model and accomplishes relevant design. The designed motion parameter detection system is tested for its reliability and accuracy through the comparison of measuring results of this system with those of the standardized testing equipment. The testing results demonstrate that the motion parameter detection system based on probabilistic model has relatively excellent performance and accuracy, can satisfy the detection demands in our daily life, and has the value to be further developed and promoted.

KEYWORDS

probabilistic model, motion parameter, detection system.

1. INTRODUCTION

Nowadays, with the increase of living tempo and working pressure, people have to allocate more time to work and to relax, leaving little time for exercise. On most occasions, they will sit or lie down. As a result, their physical function is declining. Fortunately, more and more people are beginning to realize the importance of exercise. With all types of information about body-building to choose from, many people choose to go to gymnasium to receive professional guidance on body-building. However, more people prefer convenient ways to exercise, such as morning exercise, jogging, swimming, and so on. Therefore, it is imperative to design a handy and portable equipment to help us know more about our own physical state and to choose the right type of exercise at the right time, especially when we do not have professional coach or equipment.

Scientific advancement has brought us with tremendous changes. More and more electronic devices are emerging in our daily lives, covering all the basic necessities of our lives. In recent years, many hi-tech products, such as smart phones, smart watches, smart bracelet and smart glasses, have come out in succession and their prices are declining, so that they are available to more and more people. Meanwhile, these smart devices are equipped with abundant sensors, which can satisfy the need of motion data detection. Therefore, the application of smart phones in motion

parameter detection has become a new research focus. This paper is also based on this in order to explore a more reliable motion parameter detection equipment which can provide more accurate detection data.

As for the questions raised in this paper, many relevant scholars have already done in-depth research into them and have already scored decent achievements. In 1887, the research of Animal Locomotion was the first involving motion capture with a purpose to capture the motion of animals, obtain their images, organize these images together, and to realize dynamic visual effect (Yi Mingyu, 2008). There are uncertainties in motion itself. The human body is very complex with its muscle and skin changing with the motion process and its temperature being inconstant. Therefore, the detection of human body motion cannot be simply interpreted as the detection of an ideal entity (Hung-sheng, 2008). The detection based on probabilistic model is a relatively ideal choice. The establishment of probabilistic model can detect the motion parameter in a more accurate way through the discretization of human body motion and the consideration of uncertainties (Xiao, 2005). An American company, ActiTrainer, promoted a professional detection recorder of kinetic energy consumption, which can calculate approximately the energy consumption in the process of motion through the motion parameter of the sporter (Gao, Zhang, 2006). There are many uncertainties in the process of detecting and modeling and turning the three-dimensional configuration

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into two-dimensional configuration in human body motion. The method of probabilistic model is quite ideal to describe such uncertainties (Li, 2005).

The second part of this paper makes an analysis of the relevant theories in motion evaluation, motion parameter detection and probabilistic model and introduces the relevant meaning, function and theoretical basis. On the foundation of theoretical research, the third part explores the construction manner of and way to realize the motion parameter detection system based on probabilistic model. The fourth part, through contrast experiment and analysis of results, demonstrates the designed system can provide accurate detection data of motion parameter, be user-friendly, and have the value of further research and promotion. The fifth part is the conclusion of the whole paper and also points out the deficiencies of this research and indicates the correct direction for future exploration.

2. STATE OF THE ART

2.1 Motion Evaluation

The major purpose of motion evaluation is to choose appropriate exercise program and exercise intensity in accordance with one’s own physical state and to reach the maximum exercise without harm to one’s own health so as to improve health and physical function (Jiao et al., 2009).

Exercise intensity is mainly determined by two indicators, namely heart rate and energy consumption. The measurement of heart rate at the current stage is relatively efficient and accurate. As revealed by research, while doing exercise, the maximum heart rate of an adult should be 125-145 times per minute if he wants to improve his cardio-pulmonary function (He, 1999). It is only natural that the ranges of maximum heart rate of people at different age group when they are doing exercise are different.

At the same time, the amount of energy consumed in the body while exercising can also be used as an indicator of exercise intensity. The higher the exercise intensity is, the more energy is consumed. Energy consumption cannot be directly measured. However, the metabolism of energy calls for the participation of oxygen. Therefore, the unit of exercise intensity is usually the ratio of oxygen consumption while exercising to that while relaxing and exercise is classified into the following intensity classes (Cheng et al., 2008).

Table 1: In the MET or classification of strength and strength parameters of inhaled oxygen

Oxygen consumption		Very light	Light	Medium	Heavy	Very heavy
Man	MET	1.6~3.9	4.0~5.9	6.0~7.9	8.0~9.9	1.0~
	L/min	0.4~0.9	1.0~1.5	1.6~1.9	2.0~2.5	2.6~
Woman	MET	1.2~2.7	2.8~3.7	4.4~5.9	6.0~7.5	7.6~
	L/min	0.3~1.1	0.7~1.1	1.2~1.5	1.6~1.9	2.0~

2.2 Method of Motion Parameter Detection

In the 1990s, authoritative scholars in human body energy research have indicated that the calculation of human body energy include two parts, namely energy consumption while exercising and energy consumption while relaxing. Part of the latter is relatively constant and do not change very much with a certain span of time and the latter one is easier to be calculated. The calculation of the former is much complicated. As for the detection of different motion parameters, the purpose is to calculate the exercise energy consumption so as to readjust one’s own exercise plan in accordance with this calculation result (Wu et al., 2011).

With scientific and technological advancement and the availability and application of many new technologies, there are more and more various detection sensing equipment. As the number of motion parameters which can be detected are increasing, there are more corresponding computing methods of exercise energy consumption (Hu, 2001).

Calorimetric method: while exercising, a large amount of heat will be generated in the body, which comes from the metabolic process of energy substance of the human body. Saccharides, protein and fat will release energy through oxidizing reaction to provide energy for the body and a large amount of heat will be released in the process. Therefore, the measurement of the caloric value released by the human body will help us to calculate the energy consumption while exercising (Lu, 2001).

DLW method: Double Labeling Water (DLW) method applied the means of

isotope labeling. Examinees have to take a type of water labeled by hydrogen atom and oxygen atom. After exercising, the remaining isotopic content in the body is tested. The measurement of the consumption of the two isotopes will help us calculate the amount of carbon dioxide released by the body so as to calculate the amount of energy consumed (Xiang et al., 2005).

Step-counting estimation method: this is a widely used method at the current stage. Its principle is to obtain the empirical formula of the quantity and frequency of steps and energy consumption through multiple experiments. Therefore, the measurement of the quantity and frequency of steps when people are walking or running will enable us to estimate the energy consumption. Currently most of the motion detection equipment, like smart bracelet, is designed by applying this method. The following is a figure of smart bracelet of a certain brand.



Figure 1: Some brand smart bracelet

Heart rate detection method: although heart rate cannot be used in the calculation of energy consumption, it can directly reflect the cardiopulmonary state of people when they are exercising. Therefore, heart rate detection is also frequently used in the motion detection. At the same time, heart rate is related to the amount of oxygen uptake. The measurement of the amount of oxygen uptake can help us estimate the amount of oxygen consumed in the process of metabolism and calculate the energy consumed. Therefore, it is a supplement to heart rate detection (Meijer et al., 1989).

2.3 Basic Concept of Probabilistic Model

In probability theory, for an event A, its occurrence probability is represented as $P(A)$. If this event shall not happen, then we have $P(A) = 0$. If this event is sure to happen, then we have $P(A) = 1$.

For two events A and B, the probability calculation of the occurrence of the two events is shown in formula 1 as follows:

$$P(AB) = P(A)P(B|A) \tag{1}$$

For two events A and B, the probability calculation of the occurrence of at least one event is shown in formula 2 as follows:

$$P(A + B) = P(A) + P(B) - P(AB) \tag{2}$$

As for a random variable X, if the probability density function of X is $P(X)$, then the calculation formula of the mathematical expectation of X is shown in formula 3 as follows:

$$E(X) = \int XP(X)dX \tag{3}$$

The mathematical expectation reflects the mean of the random variable X, which is a statistical magnitude of X.

The variance of the random variable X is represented by $D(X)$. Its calculation formula is shown in formula 4 as follows:

$$D(X) = E[X - E(X)]^2 \tag{4}$$

The variance reflects the fluctuation of the value of the random variable X with respect to its mathematical expectation. The square root of the variance is its standard deviation.

2.4 Probabilistic Reasoning—Maximum Likelihood Estimation

As for a group of measured values, we usually hope to find the internally related parameters and use these parameters to represent these

measured values (Matthews et al., 1995). For example, in the motion parameter detection, we measure the heart rate in the process of motion, and then calculate the desired parameters from these measured values according to the relation between heart rate and energy consumption and cardiopulmonary state. This process is probabilistic reasoning (Mathie et al., 2004).

The maximum likelihood estimation is a common method of probabilistic reasoning in the research. If the measured value is represented by X and the parameter is represented by i , then the calculation of the maximum likelihood estimation is shown in formula 5 as follows:

$$\arg(\max P(X | i)) \tag{5}$$

The meaning of the maximum likelihood estimation is to find a parameter within the defined interval and the probability P is the largest under this parameter. This is a simple yet direct parameter estimation method. With this method, the measured values are turned into variables and no parameters to be estimated will be involved.

3. METHODOLOGY

According to the previous theoretical study and the investigation of relevant devices on the market, we hold that the detection of heart rate among all the motion parameters by way of embedded system and based on the probabilistic model theory will realize more reliable and accurate estimation of energy consumption while exercising. Compared with simple step-counting devices, this system is more valuable for sporters.

The motion parameter detector designed by us includes both the hardware and software. We have the expectation of designing a small-volume, light-weight, and portable device with low power dissipation, stable function and accurate detection. This device is mainly used to detect the heart rate of human body, calculate the energy consumption while exercising, and provide data basis for people's body-building plan so as to better conduct sports activities.

3.1 Design of the Hardware in the System

The hardware in the system is mainly composed of the following parts:

1. Processor: we choose the mainstream low-power dissipation MCU MSP430 as the core processor responsible to read, calculate, process and display motion parameters. There are 8 roads 12 for A/D conversion module with no need for extra A/D chips. In doing so, the reliability and integration level of the system are enhanced.
2. Memorizer: this is mainly used to store the motion parameter detection values. We choose the M25P80-type ROM, which has a higher matching degree with MSP340. Its content is 8M and power supply is 3.6V. It is compatible with standard SPI port and supports rapid page editing operation with a maximum of 257 bytes.
3. Sensor: the measurement of heart rate is realized through the pulse sensor HKG-07A. Sensors can detect the changes of the blood volume at the tail end of the blood vessel and then calculate the number of heartbeat. After the treatment of amplifying and smoothing the measurement signal, it will be transferred to MCU for successive calculation.
4. Other parts: apart from the above important function modules, this motion parameter detector includes power module, in-out module and other supporting function modules. All of them make up a complete detection system.

3.2 Design of the Software in the System

The major functions of the software in the motion parameter detector are as follows: system initialization, display of the main interface; sensor initialization, renewal of the register; replacement of the data flag bit, interrupt counter initialization, waiting for measurement; to start measurement by pressing the "ON" button, to read the data of the sensor by MCU, to obtain real-time heart rate data; real-time calculation of motion energy consumption by way of probabilistic model algorithm based on heart rate value and then the storage of computer data in the external memory; to press the "OFF" button to end detection and data process after exercising and then to output and display the heart rate detection value and energy consumption value. The flowchart of the software system is shown in the following figure.

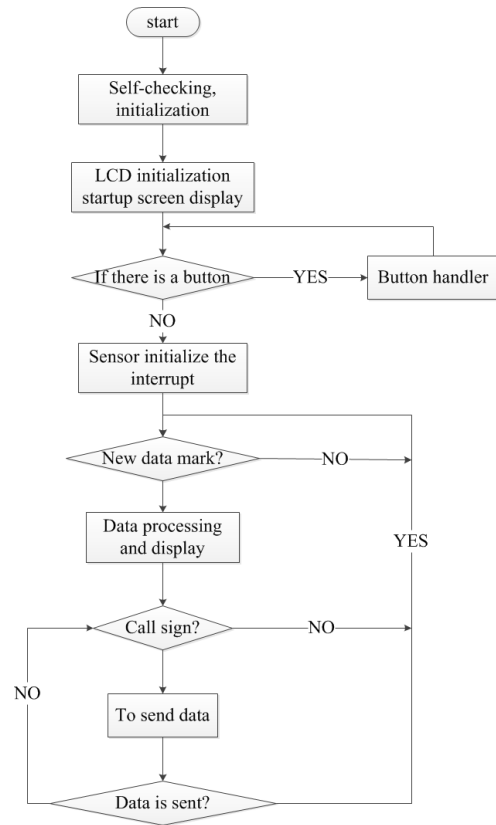


Figure 2: Motion parameters testing flow chart

4. RESULT ANALYSIS AND DISCUSSION

In part 3, we design a motion parameter detector to detect the heart rate value in the process of exercising and calculate the energy consumption while exercising. After hardware test, software simulation and hardware joint debugging, we randomly choose 60 subjects and ask them to wear the motion parameter detector designed by us and the standard heart rate detector. We randomly divide them into three groups and ask them to do sports activities with different sport intensity in thirty minutes and compare the disparity between the data of the motion parameter detector designed by us and the data of the standard heart rate detector so as to test whether our motion parameter detector is accurate or reliable. Relevant data drawing lists are as follows:

	The expect	The variance
Measured value	99	1.21
Standard values	93	1.01
Error	6.4%	0.2

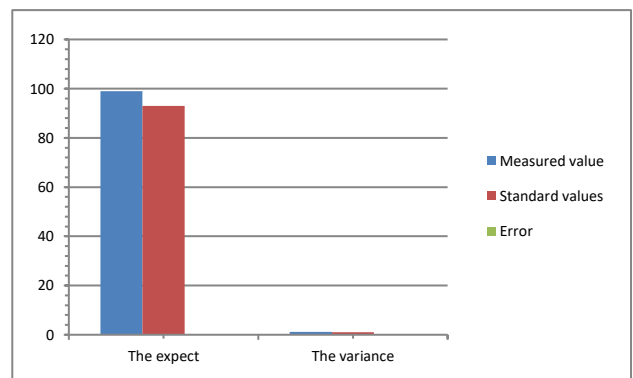


Figure 3: Testing data results of group A

	The expect	The variance
Measured value	135	1.16
Standard values	125	0.98
Error	7.8%	0.18

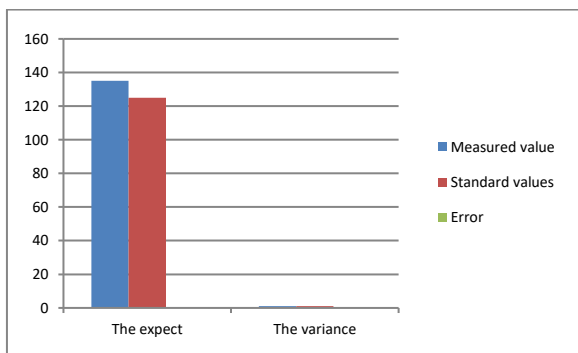


Figure 4: Testing data results of group B

Table 4: Testing data results of group C		
	The expect	The variance
Measured value	176	1.19
Standard values	164	1.05
Error	7.1%	0.14

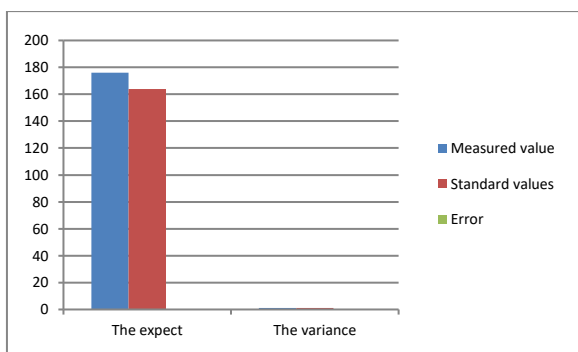


Figure 5: Testing data results of group C

Through the calculation of the expectation and variance of the three groups of heart rate values, we have found that the error range of the expectation and standard deviation of heart rate detection values under different levels of sport intensity is less than 10%, which demonstrates that this motion parameter detector can provide relatively accurate detection results. Meanwhile, the variances of the three groups of detection values under different levels of sport intensity do not change very much, which demonstrates that this motion parameter detector have reliable working performance under different working states.

Based on the comparison of experimental results, we can conclude that the motion parameter detection system based on probabilistic model has relatively good accuracy and reliability. In the meantime, as this device is low-cost, portable, and has relatively high commercial value, it deserves further research.

5. CONCLUSION

With the advancement of our society and the improvement of our living standards, people now pay more attention to their health. More and more people embark on a path to build up their body. However, it has become an issue attracting wide attention to know full well one's physical state and work out appropriate exercising plan accordingly. With scientific and technological advancement, many devices, like sensors and processors, are becoming more and more integrated and they have smaller size, lighter weight, and low power dissipation, which have provided opportunities for the development of portable detection system. In the meantime, the penetration of smart devices has also laid a solid foundation for the development of such devices. As there are many uncertainties in the process of motion and the state of human body will change at any time, simple detection cannot yield accurate data. Therefore, the introduction of probabilistic reasoning theory and the establishment of probabilistic model on consideration of these uncertainties will detect the motion parameter in a more accurate way.

Through the research of this paper, we can make the following conclusions. There are many detection methods of motion parameter and

all these methods have regarded the energy consumption in the process of motion as the ultimate detection value. The uncertainty of the motion process determines that the traditional detection and data processing method cannot get accurate data and that a new efficient data processing algorithm needs to be introduced to improve the accuracy of the detection. Probabilistic model is a data processing method based on empirical data and probabilistic reasoning and can resolve the influence of uncertainties on data in a better way so as to make the data received more accurate. The motion parameter detector based on probabilistic model has sound working performance and can yield accurate detection data. It can fully satisfy the demands in our daily life and deserves to be further developed and promoted.

Although some achievements have been reached in this paper, this paper still has some deficiencies, for example, the detection object of the motion parameter detector is rather simple. In successive researches, the detection of other parameters, such as the shell temperature and moving steps, should be included to complete this system and to satisfy the various demands of different people.

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