Design of Basketball Shot Track Recognition System Based on Machine Vision

Chonggao Chen(✉) and Wei Tang

Huali College Guangdong University of Technology, Guangzhou 511325, China

Abstract. Aiming at the positioning of the existing shooting track, which leads to the deviation of basketball shooting track, in order to maintain the basketball shooting track accurately, a basketball shooting track recognition system based on machine vision is designed. The ARM processor is used as the core application terminal of the identification component, and the high-precision orientation module and power supply conversion module are combined to build the hardware environment. Based on this, a machine vision technology model is established. Through defining the format of machine datagram, the subprogram of tilt angle sensor is optimized, and the software execution environment is realized. Experimental results show that, compared with the traditional recognition system, the physical distance between the starting position and the terminating position of the shot is greatly reduced, which can effectively solve the problem of basketball trajectory deviation caused by inaccurate shooting and meet the practical application requirements of precise maintenance of basketball trajectory.

Keywords: Machine vision · Shot trajectory · Recognition system · End user · Peripheral structure · Power supply transformation · Machine data · Tilt sensor

1 Introduction

Machine vision is a branch of artificial intelligence that is developing rapidly. Simply put, machine vision is the use of machines instead of the human eye to do measurement and judgment. Tools Options Options Page. Machine vision system converts the captured object into image signal by machine vision product (namely image acquisition device, divided into CMOS and CCD), transmits it to the special image processing system, obtains the shape information of the captured object, and transforms it into digital signal according to the information of pixel distribution, brightness and color, et al. [1]. The image system carries out various operations to extract the feature of the object, and then controls the equipment action on the spot according to the result of discrimination. Machine vision is a comprehensive technology, including image processing, mechanical engineering, control, electrical lighting, optical imaging, sensors, analog and digital video technology, computer software and hardware (image enhancement and analysis algorithms, image cards, I/O cards, et al.). The typical machine vision application system includes image capture, light source system, image digitization module, digital image

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processing module, intelligent decision module and mechanical control module. The most basic characteristic of machine vision system is to improve the flexibility and automation of production. Machine vision is often used to replace artificial vision in some dangerous working environment which is not suitable for manual work or where artificial vision is difficult to meet the requirements [2]. At the same time, the machine vision inspection method can greatly improve the production efficiency and automation degree in the large batch and repetitive industrial production process.

At present, machine vision technology has become mature, and the cost of using machine language to locate has gradually become suitable for general application equipment. At the same time, a large number of new technologies have emerged, making the accuracy of localization more and more high, which has been able to fully meet the needs of basketball shot trajectory recognition and achieve the goal of path automation supervision [3]. This paper introduces the research status of machine vision at home and abroad, demonstrates the feasibility of using this method for high precision positioning, and introduces the development history, composition range, positioning accuracy, main functions and influence significance of machine vision. While studying the development environment of the identification system and the application conditions of the simulation software, the experience and skills related to the practical engineering are analyzed, including the isometric cabling, the impedance cabling, the coordinate measurement method of the center point, the calibration method of the reference azimuth, etc., and the feasibility of the algorithm for track recognition is verified by the actual data [4].

2 Hardware Design of Basketball Shot Track Recognition System

2.1 ARM Processor

The core of end-user device is ARM processor. If it is only used for arithmetic processing and signal control, FPGA can be used to get higher processing speed. But it is more suitable to use S3C2440 ARM processor for cost consideration. The S3C2440 processor is an ARM processor produced by Samsung [5]. The processor is a 32-bit low-power processor based on ARM920T. Different from the traditional MCU, S3C2440 adopts the Harvard architecture which is separated by data bus and address bus. It has powerful computing ability, up to 400 MHz main frequency speed, and has a memory management unit. It can carry many operating systems and has rich on-chip peripheral resources, as shown in Fig. 1.

Selecting this SCM as the hardware core of a terminal device has the following advantages:

(1) The S3C2440, as an ARM processor that has been available for several years, its price has become reasonable [6], and it still has strong computing power and high performance-to-price ratio. It is widely used, and has a large number of development materials and secondary development kits, which can greatly shorten the time needed for product development.
(2) S3C2440 has the function of 1VIIVIU, and can be equipped with LINUX, WINCE and other operating systems [7]. Especially in the application of LINUX, S3C2440 has rich and extensive application. Many development kits are written under the

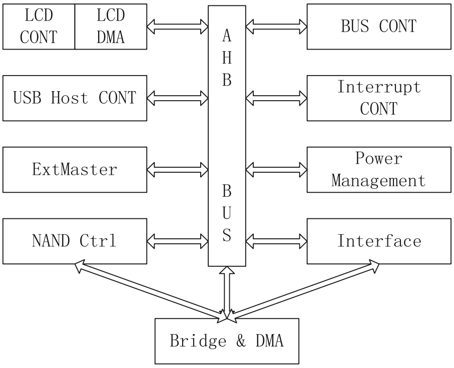

Fig. 1. S3C2440 peripherals for an ARM processor

platform of LINUX. Many difference algorithms of satellite positioning, path recognition algorithms and so on can find reference code in its application and shorten the development cycle of software.

(3) The S3C2440 has a large number of on-chip peripherals, such as analog-to-digital conversion, real-time clock, LCD control, various communication interfaces, and a large number of input-output interfaces, further reducing the cost, hardware volume and complexity of the equipment [8].

2.2 High-Precision Orientation Module

The high precision positioning and orientation module is the most important part of the hardware for basketball shot trajectory recognition. The performance of the module is directly related to the quality of the application equipment. This module selects the GT-1612-MTBD module of Gotop (as shown in Fig. 2), which is based on the MT3333 positioning chip of Media Tek and can be switched to GPS single mode, GPS double mode and Beidou single mode positioning mode [9].

The module has the following advantages:

(1) It is small in size and only 16 mm × 12 mm × 2.6 mm in size;
(2) Low power consumption, less than 160 mW;
(3) High reception sensitivity as low as 165 dBm;
(4) The positioning accuracy is high, which can reach 5 m even in the absence of a ground enhancement station.

According to the chip information of the chip, the wiring of the printed circuit board from the antenna port to the pin needs to use 50 Ω impedance line. The module communicates with ARM chip through serial port, and the 3 pin also outputs millimeter pulse, which can be used in other modules.

Hidden Markov model is the main method of dynamic trajectory recognition. Hidden Markov Model is very successful in node recognition, and there are many similarities between dynamic trajectory and node signal in space-time. So Hidden Markov Model is

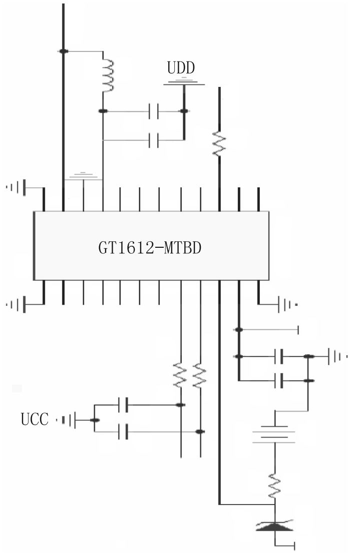

Fig. 2. High-precision orientation module

introduced into dynamic trajectory recognition. Hidden Markov model is a dual Markov stochastic process, which is developed on the basis of Markov chain. The hidden Markov model consists of two stochastic processes, one is the basic stochastic process, that is, the Markov chain describing the state transition, and the other is the general stochastic process describing the statistical relationship between the state and the observed value [10].

2.3 Power Conversion Module

Power supply conversion module is mainly composed of main power supply circuit and secondary power supply circuit. First of all, we must determine the coverage of the basketball shooting trajectory, that is, the implementation center and its boundary of each action, and define the range of shooting action approximately as a circle. Secondly, the position of the basketball can be obtained by satellite positioning, and the movement of the ball can be used to judge the direction of the shooting. Then the angle of the shot to the track center can be calculated by the movement of the ball to determine which basket the basketball is moving. According to the track of the basketball, judge the stage of the ball: the basketball is approaching to a certain area of the basket, the ball is moving in the basket, the basketball is gradually away from a free basket, the basketball is entering the preset frame. Finally, through the analysis of the stage characteristics of basketball, the recognition of the trajectory of shooting is realized.

Usually, only some parts of each image are interested in the captured trajectory sequence image, so we must segment it from the image in order to study it. Dynamic segmentation is the basis of the whole dynamic trajectory recognition system, and its segmentation effect directly affects the tracking of shooting behavior, feature extraction

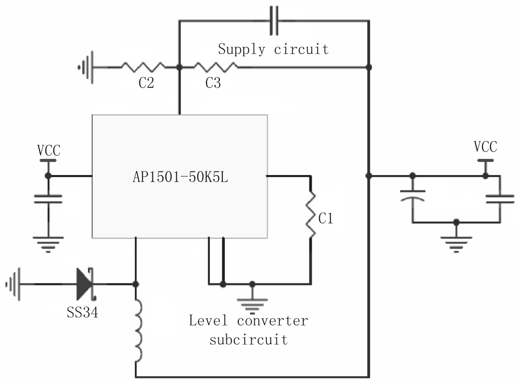

Fig. 3. Power supply switching circuit

and system recognition rate. Combining the advantages and disadvantages of the existing mature segmentation methods, a combined trajectory segmentation method is proposed. Firstly, the candidate regions are segmented from the trajectory images by motion detection method. In order to reduce the interference of shooting behavior near a given node in the candidate region, texture detection is introduced to remove the interference in the original shooting environment.

3 Software Design of Basketball Shot Track Recognition System

3.1 Machine Vision Technology

Using machine vision technology alone, the accuracy can only reach the meter level, and basketball shooting trajectory positioning is affected by many factors, which will cause errors, in addition to known satellite clock difference and receiver clock difference, there are satellite orbit errors, ionospheric effects, tropospheric effects, multi-path effects, changes in the antenna phase center and the combined errors of the receiver [11], the orbit error of satellite and the influence of troposphere and troposphere have the greatest impact on the accuracy of shooting trajectory. So the accuracy of shooting trajectory identification cannot be satisfied by machine vision alone.

Although the mathematical model of machine vision is simple, the amount of data is small, and the concept of innumerable datum ages, but the recognition base station and the end user must observe the same basketball shooting behavior. Although distance difference pairs do not need to observe exactly the same basketball shooting trajectory, the data age is only 30 s, and the data model is complex and the data is large [12]. The local difference model of single trajectory recognition base station is simple in structure, but the coverage is small, the difference precision will decrease with the increase of base station distance. The local difference of multiple base stations improves the reliability, improves the influence of distance on the accuracy, and enlarges the coverage, but the coverage is still limited and the model is not perfect. Wide-area difference can almost cover the whole system, and it has high precision, good reliability, precision is not affected by base station distance, but the system structure is complex and expensive.

In many machine vision technology, there is a called RTK positioning technology has been widely used, this system is also using this differential positioning technology for high-precision positioning. RTK is a real-time dynamic differential measurement technique, which uses the real-time dynamic positioning technique based on the carrier phase observation [13]. It can measure the 3D positioning results of the observation station in the specified coordinate system quickly, and the accuracy can reach centimeter level. RTK technology is also used in the GPS high-precision positioning at the earliest. Because the high-precision positioning technology must observe the carrier phase, RTK technology is also widely used in the BD high-precision positioning.

Suppose β represents the angle between the original position of the basketball and the position where the basketball terminates, $\bar{p}$ represents the mean value of the shooting behavior in the track to be identified, and λ represents the given identification coefficient, and the above physical quantities are combined. The application expression of machine vision technology may be defined as follows:

$$\varphi = \frac{\tan \beta^{-1} \frac{|Y_b - Y_a|}{|X_b - X_a|}}{\lambda \cdot \bar{p}} \tag{1}$$

Among them, $\tan \beta$ represents the tangent value of angle β, X_a, Y_a represents the transverse and longitudinal coordinate value of shot node a, X_b, Y_b represents the transverse and longitudinal coordinate value of shot node b.

3.2 Machine Datagram Format

With the further development of machine vision technology, and the coverage of ground base station and mobile base station is more and more wide, the technology of ground base station and mobile base station have appeared [14]. When the precision of ground reference station is high enough and the coverage is wide enough, sometimes it is not necessary to receive the satellite signal. Only by the identification signal of the reference station and the position information of some reference points, there is enough data information to ensure the accuracy of basketball shooting location. When the positioning requirements are not so high, even mobile base stations can be used to carry out rough positioning, the same can meet certain positioning needs [15–18]. The machine datagram is encoded in RTCM 3.1 frame structure, and the definition is shown in Table 1.

The RTCM3.1 frame structure includes 8-bit boot word, 6-bit reserved word, 0–1023 byte message data and 24-bit CRC check. The 8-bit guide is a fixed value, that is, 11010011;The reserved word is usually all 0 because it is undefined; The 10-bit message length represents the byte length of the datagram; Variable length message data is some defined message, such as RTCM1004 number, 1005 message; The 24-bit CRC check code is generated by the CRC algorithm through the data in front of it, which is used for verify the transmission [19].

In the research of trajectory processing theory, there are two kinds of motion detection methods: one is the calculation of motion vector field based on block matching or optical flow method, and the other is the detection of change between frames of sequential images. But it is not suitable to deal with fast moving objects because of its

Table 1. RTCM 3.1 frame structure encoding contents

Item	Head knot	Tail node
Guide word	8-digit number 11010011	10-digit number 1101001100
Preserve words	6-digit number all are 0	8-digit number all are 1
Message length	10-digit number message length in bytes	10-digit number message length in nodes
Variable length message data	0–1023 byte specific content of the message	0–511 byte specific contents of identification documents
CRC Checksum …	24-digit number based on previous data generation	12-digit number based on previous data generation

complexity and time consuming [20–22]. The second kind of inter-frame change detection method is simple and fast, which is more suitable for the applications with high real-time requirements. According to the actual situation of this subject, it is decided to use the second type of inter-frame change detection method to detect motion. Inter-frame change detection can be divided into frame difference method and background subtraction method.

Frame difference method is the simplest and most rapid motion detection method in video image sequence processing. The basic principle of the algorithm is that two consecutive adjacent frames in the trajectory image sequence are differentiated and denoised to segment moving objects. When moving objects appear in video image sequence, there will be a big difference between two adjacent frames [23]. Two frames of difference can remove the unchanged pixels, and then the moving objects can be obtained. The advantages of frame difference method are simple implementation, low program complexity, fast calculation speed, strong adaptability to dynamic environment and strong stability. Of course, the frame difference method also has some shortcomings: for example, when the gray value of some areas inside the moving object changes flat, the moving target extracted by the frame difference method is not complete, which will affect the following feature extraction and recognition.

Background subtraction is essentially a special frame-difference method. The biggest difference between the frame difference method and the frame difference method is the different reference background image [24, 25]. The frame difference method uses the previous frame of the current frame as the reference background image, while the background subtraction method uses the fixed or real-time updated image as the reference background image. The principle and algorithm design of background subtraction method are simple, and the information of moving target can be obtained more accurately than frame difference method [26]. But at the same time, the background subtraction method is also sensitive to the background environment, and it is easy to be affected by the changes of weather, light and other conditions. But at the same time, the background subtraction method is also sensitive to the background environment, and it is easy to be affected by the changes of weather, light and other conditions.

3.3 Dip Sensor Subroutine

Software Adopts Structured Design, Divides Software into Modules by Realization Functions, and Handles Various Processes in a Timely Manner by Interrupts and Inquiries. Using Mature Instance Programs, Library Functions, and Development Kits for Secondary Development reduces the difficulty in program development, makes code easier to understand and transplant, facilitates debugging, shortens the software development cycle, and improves efficiency [27–29]. The specific functions of the software include real-time acquisition of high-precision positioning and orientation information, reading of data from external tilt sensors, acquisition of application information of identification components; and receiving differential data and alarm information through wireless networks, sending high-precision position and azimuth data, shot trajectory information and configuration terminal parameters to the monitoring center; Display and play the alarm information, the basketball shot track recognition and processing [30]. Field configuration parameters and online upgrade system. The inclination sensor subroutine mainly collects the angle data of basketball shot track recognition sensor in real time, and saves the angle data to internal memory. Its application flow is shown in Fig. 3.

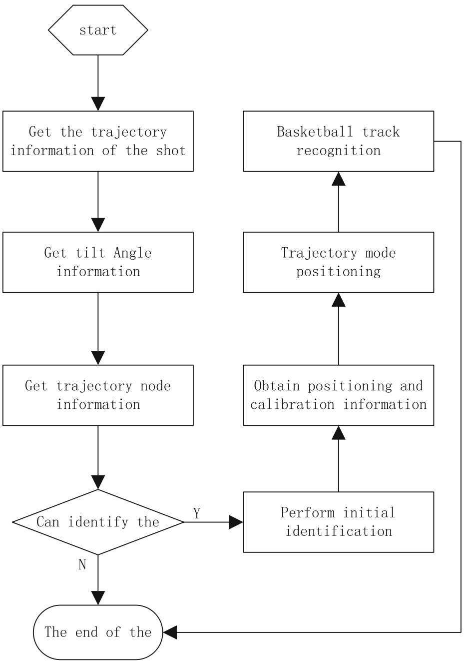

Fig. 4. Flow of the dip sensor subroutine

At this point, the software and hardware execution environment is built, and the smooth application of basketball shooting track recognition system is realized with the support of machine vision principle.

4 Data Comparison and Analysis

In order to verify the practical application value of basketball shot track recognition system based on machine vision, the following comparative experiments are designed. All participants were asked to make the standard shooting action shown in Fig. 4, fixed the position of the basket, so that all participants in turn to shoot into it, recording in the process, the specific changes in the experimental indicators.

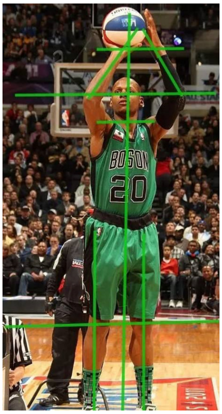

Fig. 5. Standard shooting

DUI can be used to describe the actual deformation of human joints. In general, the larger the value of DUI is, the larger the deformation of human joints is, and vice versa. The following table records the specific changes of DUI in experimental group and control group (Fig. 5).

Table 2 shows that with the extension of the experimental time, the DUI index of the experimental group appears the trend of rising first and then stabilizing, and the global maximum value reaches 29.4%, and the limit value level can maintain a stable state of 40 min. After the small stable state, the DUI index of the control group began to rise continuously, and the global maximum value reached 52.7, which increased 22.7% compared with the extreme value of the experimental group. Based on the application of machine vision basketball shooting track recognition system, the rising trend of DUI index value has been suppressed to a certain extent, which can effectively control the point shape variables of human joints.

Show Starting Shot Position in v_0, Ending Shot Position in v_n, and Physical Distance Between v_0 and v_n in v, and recorded the specific changes of each index in the experimental group and the control group during the experimental time of 120 min respectively. The experimental details are shown in Table 3.

Table 2. DUI comparison of indicators

Experimental time/(min)	DUI indicators/(%)	
	Experimental group	Control group
10	30.6	51.2
20	30.5	51.2
30	30.3	51.2
40	30.2	51.3
50	30.1	51.4
60	29.8	51.5
70	29.7	51.8
80	29.5	52.0
90	29.4	52.1
100	29.4	52.3
110	29.4	52.5
120	29.4	52.7

Table 3 shows that with the prolongation of the experiment time, the initial shooting position and the stop shooting position of the experimental group changed obviously, and the real value of the physical difference between them was relatively low, and the maximum value of the whole experiment was only 1.3 m. Although there was no obvious change in the starting position and the ending position of shooting in the control group, the actual value of the physical difference between the two was relatively high. The maximum value of the whole experiment was 2.8 m, which was 1.5 m higher than the extreme value of the experimental group.

On this basis, taking the recognition accuracy as the test index, a comparative experiment is carried out by manual and the proposed method, and the experimental results are shown in Fig. 6.

According to the analysis of Fig. 6, when the recognition time is 20 min, the accuracy rate of the manual method reaches 90%, and the accuracy rate of the proposed system is about 95%; with the increase of recognition time, the accuracy rate of the manual method continues to decline; when the recognition time is 110 min, the accuracy rate of the proposed system is about 95% The accuracy of the proposed method is still as high as 90%, which is significantly higher than that of the manual method, indicating that the proposed system has high accuracy.

Table 3. Comparison of Physical Spacing of Shooting Position

Experimental time/(min)	Physical spacing of shooting position in experimental group/(m)		
	v_0	v_n	v
10	0	1.2	1.2
20	0.2	1.1	0.9
30	0	1.0	1.0
40	0	1.2	1.2
50	0.1	1.1	1.0
60	0	1.3	1.3
70	0.2	1.3	1.1
80	0.1	1.3	1.2
90	0.3	1.2	0.9
100	0	1.1	1.1
110	0.3	1.2	0.9
120	0.1	1.3	1.2
Experimental time/(min)	Physical spacing of shooting positions in control group/(m)		
	v_0	v_n	v
10	0.3	2.8	2.5
20	0.1	2.9	2.8
30	0	2.5	2.5
40	0	2.8	2.8
50	0.1	2.8	2.7
60	0.2	2.6	2.4
70	0.1	2.7	2.6
80	0	2.8	2.8
90	0.2	2.5	2.3
100	0.1	2.7	2.6
110	0.1	2.6	2.5
120	0	2.7	2.7

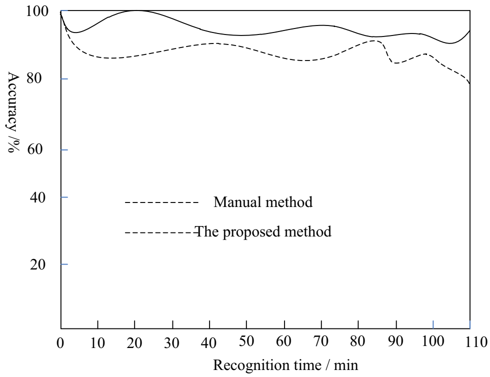

Fig. 6. Comparison of Identification Accuracy of Different Methods

5 Conclusion

To sum up, with the application of basketball shooting trajectory recognition system based on machine vision, the physical distance between the starting shooting position and the ending shooting position does show an obvious downward trend, which can meet the practical application needs of reducing the basketball trajectory offset, but there is still room for prompt. The future research direction is to shorten the basketball trajectory offset and reduce the basketball trajectory offset Less basketball shooting deviation times.

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