Functional framework construction of DSP sports application system based on improved genetic algorithm and AI

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ABSTRACT

Moving target detection and tracking is the core of computer vision system research, and it has always been a hot topic for scientists and engineers. Many remarkable achievements have been made in this field, and many preliminary applications have been made. With the introduction and development of the concept of open architecture CNC system, when designing a new generation CNC system, we should not only consider the standard questions of system real-time, machining accuracy, simplicity of user operation, fault diagnosis and system security protection, but also consider the new problems brought about by the new requirements of system software upgrade and maintenance, cross-platform transplantation and user's secondary application development on the system platform. Based on the self-developed DSP type motion controller, this paper designs and develops a special motion control software for single-needle computerized quilting. The system creates an application environment with genetic algorithm(GA) to deal with complex problems on the TMS320C6201 hardware platform, and performs functional verification on image matching problems with large data volume and complex fitness function calculation in the system environment. The experimental results show that the overall scheme of the system is feasible.

Keywords: Improved genetic algorithm; AI; DSP motion system; System functional architecture

1. INTRODUCTION

In recent years, the research focus of computer vision has gradually shifted from the study of static images to the study of dynamic image sequences. Multimedia technology and communication technology have always considered moving objects, such as people, as an important factor [1]. In industrial process control, video database, aircraft navigation, virtual reality, intelligent room, intelligent table and chair, and security monitoring and other technical fields, the detection and tracking of moving objects have a broad application prospect. With the rapid development of electromechanical integration technology, motion control technology, as its key component, has also achieved unprecedented development. Various manufacturers have launched new technologies and new products for motion control [2]. The open multi-axis motion controller has begun to be applied in emerging industries such as robot control, semiconductor processing, electronic assembly system, flight simulator, etc., and its market share in the traditional machine tool control field has also continued to expand [3]. Numerical control (CNC) technology refers to the digital control technology with digital computer as the core control equipment. CNC technology is the key technology applied in modern automatic production, manufacturing and processing. CNC machine tools with CNC technology have a series of advantages such as good processing flexibility, high processing accuracy and high production efficiency, and are convenient for modern management, which can meet the requirements of mass production of workpieces [4].

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The motion controller based on computer standard bus and the general motion controller with embedded structure have gradually become one of the leading products in the field of automation control. As the core control components of modern equipment, openness and reliability are the key to measure whether it can stand in the industry. High speed, high precision, high efficiency and high reliability are always the goals pursued by motion control technology. To achieve high performance control of motion control system, the design of servo motion controller is one of the basic and key technologies [5]. Therefore, make full use of the computing power of DSP to carry out complex motion planning, high-speed real-time multi-axis interpolation, error compensation and more complex kinematics and dynamics calculations, so as to make the motion control more accurate, faster and more stable. Making full use of network technology, CPLD and FPGA technology to make the structure of the system more reasonable and open and improve the practicability and reliability of the system has become the basic development direction of motion controller products in the future [6]. Genetic algorithm is a global search algorithm, but it requires a large amount of computation to obtain the optimal solution. At present, the processing speed of DSP is comparable to that of CPU. TMS320C6201 is a high-performance fixed-point digital signal processor with a working frequency of 200MHz and a computing speed of 1600MIPS. In addition to the pipeline technology of DSP, as long as the hardware structure of the program is optimized, image matching can be used to put forward higher requirements for the real-time motion control software due to the particularity of the real-time motion control system. The characteristics of real-time motion control software are in addition to the characteristics of general software systems, Real-time software also generally has real-time, multi-task, parallel and distributed characteristics [7].

In real-time systems, external events are usually carried out at the same time, which involves the problems of multitasking, concurrency and synchronization. Parallelism and distribution are two essential characteristics in real-time systems, which are determined by the real-time nature of real-time systems, that is, real-time response to external events and transactions that complete internal processing. Experimental simulation, and then through the use of DSP simulation platform for functional verification, and analysis of the results, draw a conclusion. Although the research on moving target detection and tracking has a history of more than 50 years, there are still many imperfections in the existing theories. Moreover, the continuous emergence of high-speed and high-performance processing chips also provides a better choice for its implementation means. Based on the above analysis, this paper puts forward a moving target tracking algorithm based on chaotic GA, and uses a hardware system composed of high-performance DSP chips to realize the algorithm.

2. CONSTRUCTION OF FUNCTIONAL ARCHITECTURE OF DSP SPORTS APPLICATION SYSTEM

2.1 Design scheme and system structure of motion control system

With the progress of microelectronics technology, power electronics technology, sensor technology, permanent magnet material technology, automatic control technology, and computer application technology, great changes have taken place in the motion control system in the past 20 years. The motion control system has developed from simple and extensive open-loop control to complex and high-precision closed-loop control [8]. At present, the open motion control system based on PC platform and motion controller is widely used. Generally, the motion controller and the PC unit form a master-slave control structure: the PC is responsible for the human-computer interface management and real-time monitoring of the control system, such as the management of the keyboard and mouse, the display of the system status, the motion path planning, the transmission of control instructions, and the monitoring of external signals; The controller completes all details of motion control, including the output of pulse and direction signals, the processing of automatic speed rise and fall, and the detection of signals such as origin and limit [9].

As the core of motion controller, DSP has flexible programming function and high-speed data processing and logic control ability. Complex motion planning algorithm and position control algorithm can be realized conveniently in real time; Improve the overall control performance of the motion controller; At the same time, the communication and interaction task between the motion controller and the PC host is completed [10]. With the continuous development of microelectronics technology, the reliability and stability of CPLD devices are constantly improved, and the circuit formed by this is obviously more reliable than the circuit composed of discrete components, which reduces the risk of system interference and the difficulty of debugging. Therefore, the programmable device CPLD is widely used in the circuit design of the whole system, and the logic control functions such as position feedback module, I/O interface, decoding and coding are integrated in it. In this way, the number of peripheral devices can be greatly reduced, the reliability and stability of the motion controller are improved, and the speed bottleneck of the discrete component system is broken. In the circuit design

of the whole system, a large number of programmable devices CPLD are used. A total of three EPM7128, one EPM7032 and one EPM7064 are selected. One piece of EPM7064 completes the decoding circuit of the whole system, the other piece of EPM7032 completes the timing conversion circuit between PCI9030 and dual-port RAM, the other piece of EPM7128 completes the design of the quadruple frequency phase detection circuit of all position feedback modules, the other piece of EPM7128 completes the design of the counting circuit and the Z phase point interrupt circuit of the encoder, and the last piece of EPM7128 completes the connection circuit between the switching value and DSP and other interrupt circuits. As shown in Figure 1.

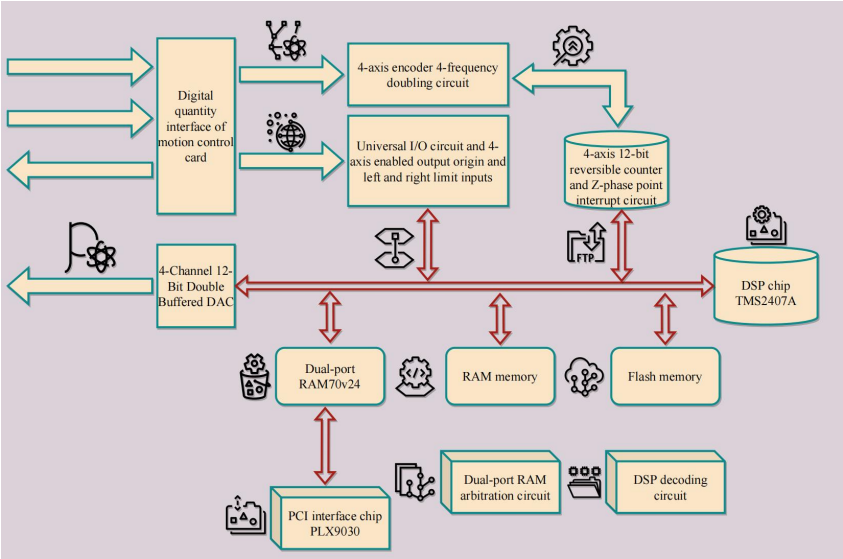

Figure 1. Overall structure of motion controller based on PCI bus

This system is a closed-loop multi-axis motion control hardware system, which has fast and accurate calculation ability and strong data communication ability, and is a good complex CNC system platform.

2.2 System hardware platform selection

With the development of large-scale integrated circuits, real-time digital signal processing technology based on digital signal processor (DSP) is developing rapidly, and has been widely used in image processing, voice processing, intelligent instruments, communication, automatic control and other fields. C6201 is a high-performance fixed-point digital signal processor. When the working frequency is 200MHz, the operation speed can reach 1600MIPS; With VLIW (Very Long Instruction Set) architecture, eight 32-bit instructions are executed in parallel every cycle; Eight independent functional units, including two 16-bit multipliers and six arithmetic logic units; The load storage architecture is adopted, and the data transmission between multiple processing units depends on 32 32-bit general registers. The memory addressing space of C6201 is 32bit, and the on-chip data storage area and program storage area are 64KB each. On-chip RAM is divided into two blocks: internal program cache memory and internal data memory. Compared with the motor phase current signal, the difference between this signal and the motor phase current signal is adjusted by the speed PI controller optimized by the improved niche GA (INGA) program written in C language, and an appropriate PWM signal is applied to the power electronic main circuit of the motor. By controlling the turn-on and turn-off sequence and time of the power transistor, the current magnitude and turn-on sequence in the stator winding are changed, so as to control the motor speed and output torque.

It provides users with the greatest flexibility. Its motion control software is all installed in the computer, while the hardware part is only the standardized universal interface between the computer and servo drive and external I/O. This structure is flexible, but the development cycle is long, and it is not very suitable for embedded applications with strict cost and development cycle control. This kind of motion controller is mostly based on high-speed single-chip microcomputer or DSP, and uses computer bus to communicate between motion controller and computer, which is more suitable for industrial applications. In use, field network communication interfaces such as Ethernet, RS232/485, SERCOS and Profibus are used to connect the superior computer or control panel. The expansion of program memory and data memory

shall meet the system requirements; In order to add human-computer interface functions, such as setting personal password, the keyboard and display hardware modules are shown in Figure 2.

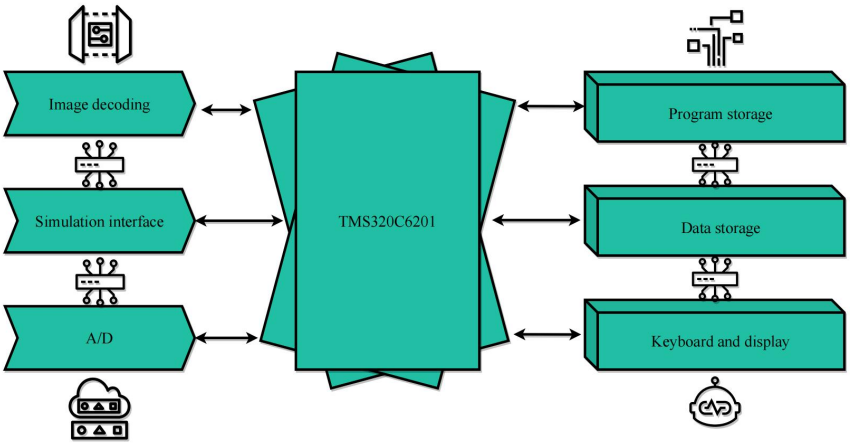

Figure 2. System hardware structure block diagram

After the hardware design is completed, connect with the computer, and use the development software CCS for program development. The advantage of the design method of finite state machine is that the design method based on finite state machine makes the designer think about all possible states in the system, as well as all possible inputs and state transitions in each state. It is suitable for describing the system dominated by control, easy to grasp, and the relationship between states is clear and intuitive. Detailed state analysis can be directly used for software development. This method integrates many new ideas and concepts in the object-oriented field, and uses UML to formalize modeling, which can make the developed real-time system have better understanding, reliability, maintainability and reusability. However, the modeling of concurrent and real-time systems still needs special extensions.

3. RESEARCH ON THE FUNCTION OF DSP MOTION APPLICATION SYSTEM BASED ON IMPROVED GA AND AI

3.1 Improved GA model

Genetic algorithm is a direct search optimization algorithm derived from evolution theory and genetic mechanism. It draws lessons from the competition mechanism of survival of the fittest in natural biological evolution, regards the optimization problem as a living environment and the solution of the problem as an individual in the living environment, evaluates the individual's survival ability with the objective function or its variation form, simulates the population selection process, and finally obtains the optimal solution of the problem, that is, the best individual. In order to test the adaptability of individuals, chromosome can be evaluated by evaluation function or mathematical formula of objective function. The description of GA is as follows: (1) Randomly select n initial points to form a group, and each point in the group is called chromosome. Usually chromosomes represent the optimized parameters, and each initial individual represents the initial solution of the problem. (2) Randomly select two individuals from the selected m individuals to perform hybridization operation or recombination operation according to the given hybridization probability p to generate two new individuals, and repeat this process until all individuals requiring hybridization are hybridized.

The design of GA mainly focuses on chromosome coding and population initialization. Because the system research is implemented on DSP hardware, binary coding is adopted. The operators of GA mainly include selection, crossover and mutation. The combination of these three operators determines the search performance of the whole GA. Some studies have shown that crossover has little effect on the performance of GAs, while the study of Walsh polynomial constructors shows that mutation operation is the main reason for the difficulty in determining the problem. The on-chip data storage area and the program storage area are 64KB each. For storing programs and data (such as the code DSP code compiled directly by the C compiler), it will generate a lot of redundancy, which is not conducive to the system implementation, especially the global optimization algorithm such as GA, which will waste a lot of operation time. According to the

hardware logic, software technology and assembly instruction set of DSP, through the allocation of memory and the compilation of GA using assembly language, the running time is greatly reduced, and the GA can be realized on DSP hardware to meet the requirements of real-time processing.

In this paper, the non-uniform arithmetic crossover operator is used to perform the corresponding crossover operation, and two new individuals are generated by a linear combination of two individuals encoded by decimal floating-point numbers. The specific operation process is as follows: Let $p_i=(u_1,u_2,...,u_k,...)$ and $p'_i=(u'_1,u'_2,...,u'_k,...)$ be two individuals in the t generation population, and v_k be the intersection point, then the new individuals after crossing v_k are: $p_t=(u_1,u_2,...,v_k,...)$ and $p'_t=(u'_1,u'_2,...,v'_k,...)$, in which:

$$v_k=a\cdot u_k+(1-a)\cdot u'_k \tag{1}$$

$$v'_k=(1-a)\cdot u'_k+a\cdot u_k \tag{2}$$

Where a is a random number with uniform probability $P'(t)$ distribution in the [0,1] interval. The population $P'(t)$ is obtained by cross calculation.

The function to measure individual fitness is called fitness function. Genetic algorithm basically does not need external information in evolutionary search. In image correlation matching search, normalized cross-correlation function (2) or minimum absolute error (3) can be used as the objective function. The design of the two GAs is different because the normalized cross-correlation function is to determine the maximum value (1) and the minimum absolute error function is to determine the minimum value (0). Because the calculation of minimum absolute error is small, this paper adopts it. Genetic algorithm is used to find the maximum value, so when the minimum absolute error is used as the fitness function, fitness calibration technology should be used. Let the minimum absolute error function be $f(x,y)$ and the fitness function be $F(x,y)$, then the transformation method of fitness calibration is as follows:

$$F(x,y)=\begin{cases}C_{\max}-f(x,y), if & f(x,y)<C_{\max}\\ 0. & if \quad f(x,y)\geq C_{\max}\end{cases} \tag{3}$$

In the formula, $f(x,y)=\sum_{w=1}^{N}\sum_{w=1}^{W}\left|S(m+x,n+y)-T(m,n)\right|,C_{\max}$ is a relatively large number, which is the maximum estimated value of $f(x,y)$ and can be an appropriate input value. This article takes.

3.2 Analysis of experimental results

In the subprogram call of motion controller, because each subprogram is called and executed in the timing interrupt cycle, for many types of tasks, a total task cannot be completed in one interpolation cycle or timing interrupt cycle. They need to call the same subprogram repeatedly in many interpolation cycles or timing interrupt cycles to complete. Because only one small step can be completed in one cycle, Therefore, in the case of multi-cycle switching, the subroutine variable block executed in the previous cycle must be retained. When the same subroutine is called again after the cycle switching, the subroutine can access the subroutine variable block executed in the previous cycle. In each position control cycle, DSP must complete encoder real-time sampling subroutine, speed averaging subroutine, position servo control subroutine and position error safety monitoring subroutine. In each interpolation cycle, namely, four timed interrupt cycles, the subprogram tasks that DSP needs to execute include: command decoding program, communication and program management subprogram, (vector) acceleration and deceleration subprogram, vector interpolation calculation subprogram, (interpolation) end-point location determination subprogram, general I/O PLC program, etc.

In the past, the rough interpolation in data sampling interpolation method was completed by the upper computer software, which required high real-time communication between the upper computer and the lower computer. When using Windows operating system, the problem of real-time lag often appeared, resulting in system instability. Moreover, interpolation calculation is a real-time work in computer motion control system, and the calculation task must be completed in a limited time. Therefore, we choose to use high-performance digital signal processor DSP to complete a large number of

interpolation calculations, which reduces the requirements of real-time communication and improves the stability of the system, and is suitable for the application of Windows operating system. Friction in servo system is a complex phenomenon, which greatly limits the improvement of system performance. Friction is not only difficult to accurately model, but also changes with unknown or incomplete laws when the system is running, so effective friction compensation becomes very difficult. Because the traditional compensation methods based on high gain PD controller, such as fixed compensation and pulse compensation, have their own limitations and defects.

In this paper, a unit step signal is applied to the speed reference value, and the speed step response curve is drawn. The results are shown in Figure 3 and Figure 4, and the overshoot and adjustment time are calculated. The results are shown in Table 1.

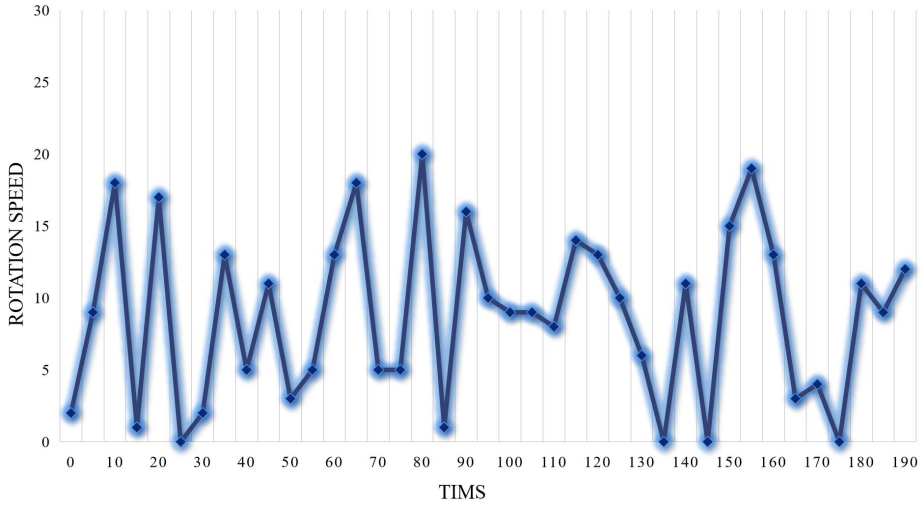

Figure 3. Using conventional GA

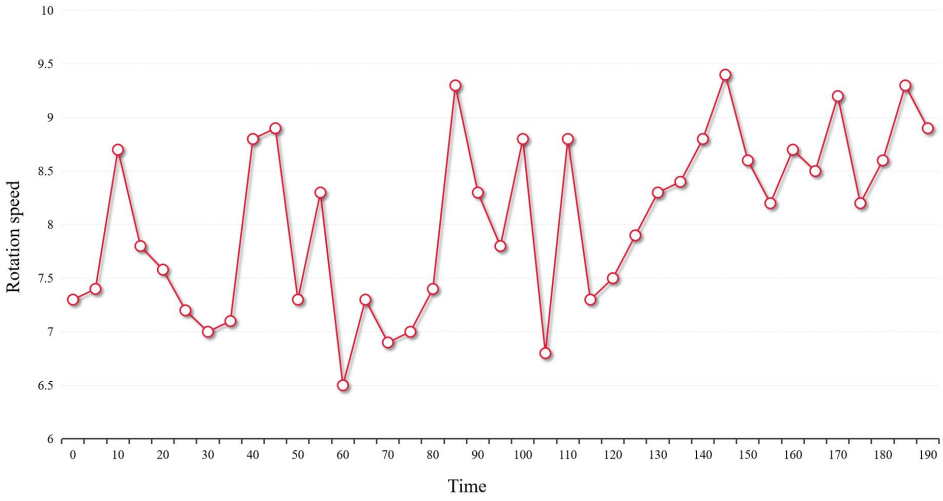

Figure 4. Using INGA design method

Due to the limitation of conventional GA (NGA) in design rules, it is difficult to find the optimal solution for the proportional coefficient. Its existence determines that the peak value is greater than the steady-state value, that is, there is overshoot, and it is difficult to determine the optimal combination of parameters, so it is impossible to avoid the existence of overshoot. For this reason, INGA uses MPPGA for optimization. In order to avoid overshoot, the penalty function is adopted in the program. Once overshoot occurs, the overshoot amount is regarded as an optimal index, and no overshoot is realized.

Table 1. Follow-up performance index corresponding to optimal design of speed controller

Optimal design method	σ / %	t / s
NGA	22.26	1.25
INGA	0	0.25

The test process of the motion controller is mainly completed through the test interface of the upper computer and the cooperation of the motion controller. The specific process is: the DSP and the upper PC carry out real-time data exchange, the DSP reads the digital input status in each interpolation cycle, obtains the actual position and rotation speed of the servo motor through the orthogonal coded pulse fed back by the servo motor, calculates the error with the set position, and sends it to the corresponding address space of the dual-port RAM. PC obtains various motion parameters and feedback states of motion controller through timing scanning of dual-port RAM. Then, it is displayed through the test interface of the upper computer. Test of position feedback circuit: use the pulse generator (handwheel) to simulate the encoder of the motor to participate in the test system. When the pulse generator rotates at a certain angle, the DSP reads the position feedback value in the counter, calculates the number of pulses (ps) generated by the change of the handwheel, and finds that the calculated value is correct. It shows that the position feedback circuit is designed correctly and works normally. However, the unit step disturbance response obtained by using conventional GA is shown in Figure 3: the stability of the speed regulation process is poor (showing attenuation oscillation), and its anti-interference process is long (about 0.7s). It can be seen that it is feasible to optimize the speed controller of brushless DC motor by using the INGA design method to improve the anti-interference performance, and it can really achieve the purpose of optimizing the anti-interference performance of the speed control system.

4. CONCLUSION

Transplanting GA on the hardware platform of DSP can solve many data optimization problems. The system conducts experiments on image matching algorithms with relatively complex fitness functions. From the experimental results, it can basically meet the real-time requirements of single image matching in time, provide effective solutions for engineering application problems, simplify engineering application problems (such as modifying specific parameters for fitness functions), and open a path for optimization problems in engineering applications. At present, the theory of GA and its application as an efficient search algorithm have become a hot research topic, and the application of high-speed processor DSP is becoming more and more extensive. In this paper, chaos theory is introduced into GA to search for moving targets, and the algorithm is implemented on DSP system. The timer interrupt processing mechanism based on real-time position is established, and the real-time synchronous position control of motion control is realized by using DSP timer interrupt. The four-axis synchronous control model is constructed, and the four-axis position synchronization in the quilting process is realized by using DSP position-based synchronous control.

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