A Design of Magic Cube Robot Based on STM32

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Abstract: This paper proposed a new project plan to build a magic cube robot. Under the precondition of ensuring to convenient to move and carry, we use external HD camera to collect magic cube’s surface color information and then sent it to a PC equipped with MATLAB to handle. So that we can get the optimal path to restore magic cube. As for image processing, we chose K-means to gain the magic cube’s original statue, in terms of path planning, we selected dimensionality reduction method, in general, the number of steps were about 20. According to the final result, the time of restoring process will be about 1 minute and which proved the project plan to be viable.

1. Introduction
Robot is an intelligent product with high technology content and energy. It arouses people's great interest and enthusiasm for research. Magic cube robot is such a mechanical design which combines system control and machine vision. The basic calculation of the solution of the magic cube is given in literature [1], but there were too many steps of the algorithm which will make the process of turning the manipulator to be long. According to literature [2], the design of the manipulator is low cost and small, but the magic cube turns slowly, and the stability is not strong. This paper proposes a design of a low grade, small size, stable performance and strong popularity which can Restore the magic cube fast. According to [3], based on layer-by layer algorithm and OpenGL 3D technology, a demo system is realized, which application platform the users to resolve the magic cube problem cube problem manully. And [4] embedded image processing system based on ARM integrates all the functions of image capturing, processing and dis-playing takes on the character of small size and low power consumption. The system designed in this paper is based on the processor of S3C2410 with the ARM9 core, which has the operation system modified from the ARM-Linux and the software based of the V4L library. In [5] this paper presents a novel reconfigurable modular robots(changeful magic cube robots) that also shares characteristics with self-reconfigurable and self-assembly and swarm robots. each module of changeful magic cube robots can be free to move and can be self-assembled to form a magic cube structure with the other modules. According to [6] aiming at the problem of Rubik's cube recovered by dual-arm robot, this paper designed a system of novel fast solving Rubik's cube. The system consists of image acquisition, image processing and mechanical arm control. First of all, Droid Cam which is an android mobile phone software is used to acquire Rubik's cube image, then the image information is transmitted to PC. Secondly, the library function provided by LabVIEW software is utilized to analyze and recognize the image, then the result is sent to the STM32 processor. In paper [7], Aim at the process detecting system in nowadays of real-time need, designing a low cost and moderate function image processing system. The system use ARM7(S3C44B0X) as core with circuit
realize image processing function, multi-communication interface constitute image transmission channels, SD card interface acquire image data. For [8], this paper presents a novel reconfigurable modular robots(Changeful Magic Cube Robots) that also shares characteristics with self-reconfigurable and self-assembly and swarm robots based on the Infineon XC886 microcontroller. Each module of Changeful Magic Cube Robots can be free to move and can be self-assembled to form a magic cube's structure with the other modules. According to [9], The architecture and simulation technology of RACS are also discussed. OpenGL and Visual C++ based modelling method has been used to establish the platform after considering the function of RACS. And for [10], a control system based on a 2-DOF manipulator and the image obtained through a camera, the coordinates of the manipulator's end executor are resolved by analyzing the image of motion area. This coordinates are subtracted with the anticipant coordinates to get an error as a compensation of the manipulator control system, then the full close-loop control of the system is realized and the problem of low control precision brought by half close-loop control is resolved.

2. General scheme design of the magic cube robot
The one based STM32 with two self is such a robot which can let any a three order magic cube to be reductive. It involves the visual tracking, the data collection, magic cube decoupling algorithm, manipulator control system. The feature of the robot is that it is fully controlled by STM32, small in size, simple in structure and cost low. Figure 1 is the robot control system, including control system, vision system, manipulator system.

3. Hardware Design
It is very important for the magic cube robot to design hardware, which would decide whether the robot run fluently.

3.1. Mechanical structure design
Mechanical structure is the most basic part of the magic cube robot. The main task of mechanical structure is to achieve the magic cube clip, holding, single side rotation and the whole rotation of it. In this paper, the design of magic cube robot with two degrees of freedom mechanism, which can not only cost less but also let the structure to be most brief. As the following Figure 2, the two arms are parallel to each other and have arms in the same plane. Such structure of the machine claw the magic cube up and down to reduce the influence of gravity on the process of solving the magic cube.

3.2. Electrical system design
The electric control system of the magic cube robot mainly includes control system system, communication system. Figure 3 gives a detailed description of the controller connection which include a camera, steering gear, and serial communication, mechanical arm and so on.

![Figure 3. control system function](image)

(1)control system: Choosing STM32F407ZG with main frequency 168Mhz and enough pins to meet the needs, which was made by ST semiconductor company.

(2)sensor: We mainly use camera to collect the color information, the process requires higher anti-interference capability for data transmission so that the capacitor filter circuit is designed in this circuit. By the design data transmission and the power supply lines do not interfere with each other, which makes the collected RGB data to be reliable.

(3)communication system: Communication system adopts a serial communication, which is used to do communications between the STM32 main control center and motor controller so that we can sure that the operator group we made advanced can be operated fluently.

4. Algorithm design
The software design part of magic cube robot mainly includes vision subsystem design, manipulator action group controsedx l and path optimization algorithm.

4.1. Vision processing algorithm
In this design we use a computer outside the camera to get the color information of the floor of the magic cube. Once get it, those information will be sent to PC to analysis, then the results will be be sent to control center so that STM32 will know how to operate the mechanical arm. The diagram is shown in Figure 4.

![Figure 4. the diagram of processing image](image)

As the result of the fact that the common type cameras we can buy on the market(such as OV7670, OV2460) are poor with pixel of the equivalent and too sensitive with light, in order to finish
restoration in shortest time and reduce the time of image analysis as soon as possible so we choose the high performance and high definition camera to connect to computer.

This design not any has optimized the use of hardware, but also the algorithm of image analysis. Once PC get the information from camera, their RGB value will be checked. Base it, we define such law:1 for white, 2 for yellow, 3 for red, 4 for orange, 5 for blue, 6 for green. Then for the color collected by camera, checking it from the center of the color block to outside by K-means. So that we can classify the color block to one of a number from 1 to 6. The reason why we sue K-means instead of classification is that the latter need to define category advance, which are too sensitive with outer factor such as light so it will be difficult to analysis its data. K-mean can select several data object as the center of clustering from various of data object. As for the rest of the data object could be adjusted to the most similar group.

4.2. Manipulator control algorithm

The every step used to describe mechanical arm take is called action group. There are 18 groups of action group are set in total, and they are named R, U, F, D, B, L, E, S, M, Ri, Ui, Fi, Di, Bi, Li, Ei, Si, Mi, as Figure 5 and Figure 6 showed.

4.3. Path optimization algorithm

In fact, in the magic cube rotation algorithm, there are whole magic cube rotation and a part of magic cube rotation. In consideration of its complexity, we need to simplify it to avoid too many unnecessary steps.

Step1: First, make the magic cube algorithm to be restored by the conventional magic cube algorithm, and record the instruction queue.

Step2: X, Y, Xi, Yi are used as transformation operators, transform the instruction sequence through string operation and record the instruction length n.

Step3: Check whether two adjacent characters are dual instructions, or can three adjacent instructions be turned into a reverse instruction, at the same time, simplify the instruction queue and
update the instruction length n by operating character string.
Step4: repeat Step3, if the instruction length n is a static value, output the current instruction set.

5. Software design
As for robot system, the hardware circuit to robot is equivalent to a body to a human, it is the same that software to robot is equipment to a head to a human, because all the function of information processing and controlling depends on software. On this text, software is mainly designed to communicate with PC by Bluetooth and control mechanical arm to execute steps we wanted. The software process is designed as following Figure 7 showed.

![Software design process](image)

**Figure 7.** software design process

6. Concluding remarks
Based on the embedded processor, the whole magic cube robot is designed and completed. According test, the magic cube robot could restore magic cube by average 2 minutes. The robot has the advantages of low cost, small volume, stable performance, strong popularity and strong adaptability to the environment.

7. Direction of improvement
According to existing schemes, the text designed a two degree of freedom intelligent robot which can restore a disordered magic cube automatically in 30 steps and in 3 minutes. Because of limited time and energy and so on, the robot remains many things could be do better, such as the following aspects:
(1) Image information processing program runs on a PC, which made the whole system to be clumsy and inconvenient. It will be better to remove it to MCU for better flexibility and adaptability.
(2) The algorithm of restoring a magic cube could be more efficient and so robot could restore a magic cube in shorter time.
(3) Replace the motor the text used with such the motor which has feedback angle information, and the motor will run more accurately.

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