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Highly accurate vision system of mobile robot*

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Abstract: A highly accurate vision system of mobile robot is presented. With its double-instruction confirmation function, safety and reliability of robot operation can be improved and control precision be assured as well. Furthermore, robot can automatically search its goals in three dimensional space (axis x, y, and z) and accurately operate by using the system.

Key words: rotot; vision system; double-instruction confirmation; image recognition

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1 Background of development

Nowadays, fields such as space industry, nuclear energy industry, highly-classified unmanned control centre and biological germless laboratory, operation accuracy of auto-navigating mobile robot is highly demanded[1~3]. In order to better robot's operation accuracy, location and identification ability of vision system of mobile robot must be enhanced. However, it's important to replace human being with robot to operate in the fields rather than simply imitate human's action. Based on such principle, this vision system is developed.

2 Robot and its identifying and operating goals

The robot proposed is four-wheel driven and self-navigated by using guideline navigation installation. The operating goals are various switches on different panels. Robot equipped with the vision system and articulated manipulators can move among control cabinets. Information flowchart of the robot control system is demonstrated as Fig. 1 and operation control process is shown as Fig. 2. Switches operated by robot and operating modes are shown as Fig. 3, Fig. 4 and Fig. 5 respectively.

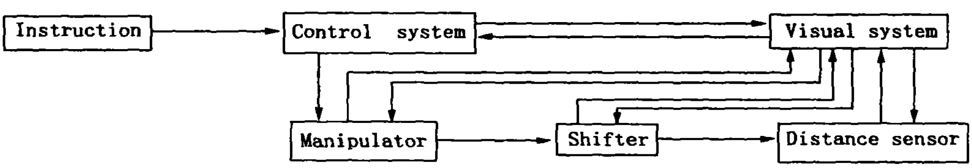

Fig. 1 Information flowchart

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To effectively and correctly operate switches on different panels under unmanned situation, the robot proposed should have higher manipulating capability, be more accurate as well as more reliable than the ordinary one does[4, 5]. In order to allow the vision system to identify and locate the centrals of switches quickly and precisely, as well as assure that the robot can operate effectively and correctly, the differences between panels and switches and switch properties, its safety and reliability are take into account[6]. Based on experiments of its shape, size and material of coat, switch is modeled as a cube (30 mm × 30 mm ×30 mm) with curved surface, on which reflection material is coated and identification mark is stamped. During the early stage of the developing course, positioning system consisted of two laser floodlight projectors (LFP), one charge coupled device (CCD) sensor and one charge coupled device (CCD) black-and-white camera. Results of experiments on it, no matter how it installed, horizontally or vertically, both were not stable. Their extreme cases are showed as Fig. 6, Fig. 7, Fig. 8 and Fig. 9. Under such cases, light spots may be only concentrated on upper, lower, left or right verge of the switch and that could lead to mispointing of the switch's center. Consequently, the robot will operate wrongly.

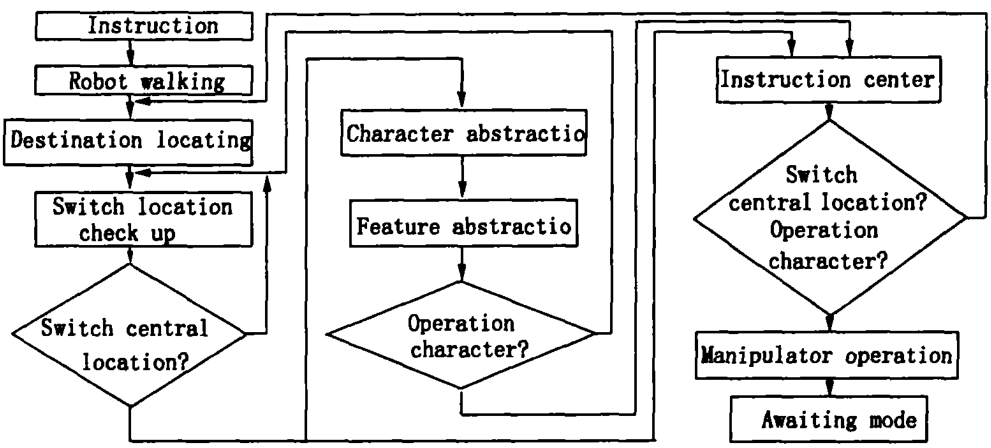

Fig. 2 Operation control process

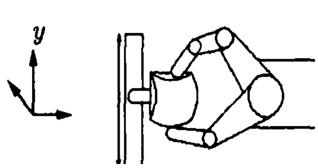

Fig. 3 Vertical operation vision system

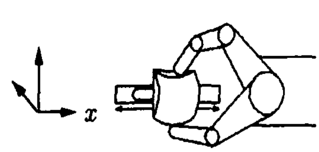

Fig. 4 Horizontal operation

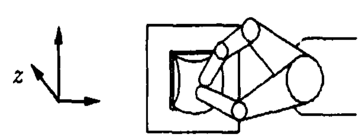

Fig. 5 Key in operation

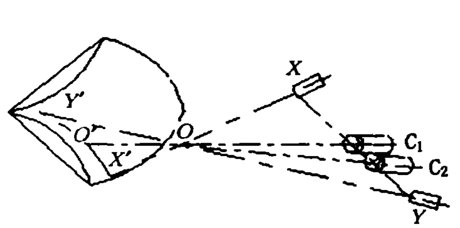

Fig. 6 Left horizontal deviation

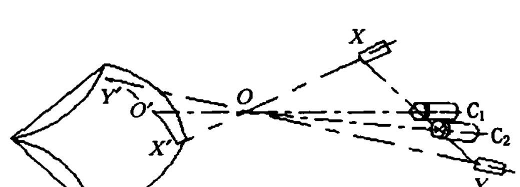

Fig. 7 Right horizontal deviation

Repeating researches and contrasts witness confirmation of a highly-accurate positioning system showed as Fig. 10. The vision system proposed consists of four LFP, one CCD sensor and one CCD camera. Four LFP are installed orthogonally. At the center of orthogonality is one CCD sensor and under it is one CCD camera. Principle of distance measuring and center positioning is also showed as Fig. 10.

Positioning and identifying principle: Central lines of coplanar-installed LFP (A, B, X and Y), CCD sensors (C_1) and CCD camera (C_2) converge at a certain point O. Rays of LFP (A, B, X and Y) go through the point O and intersect with switch′s surface at point A', B', X' and Y' respectively. Information of the four points (A', B', X' and Y') is sampled by one CCD sensor and then transmitted to information processing system to process. Value of DX will be adjusted till the CCD sensor detects that points A', B', X', Y' and O have been converged at one point which is the very center of the switch, that is, the center of the manipulator with position error less than + 0.1mm. After the information processing system confirmed the center location of the switch, robot′s control system will compare the confirmed switch′s coordinates with those given by instruction.

After positioning, the information procession system acquire and process characteristics of the images (characters) taken by the CCD camera (showed as Fig. 11) and then compares them with those given by instruction. If they can be totally matched, robot will operate the switch. Fig. 13 shows the process of characteristics acquiring[5].

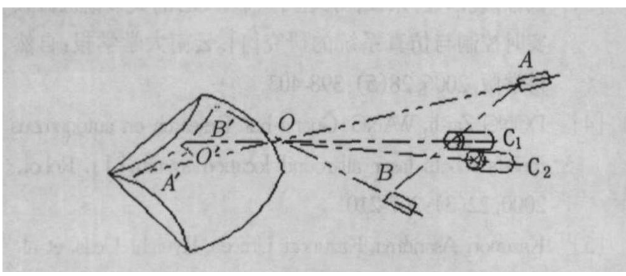

Fig. 8 Top vertical deviation

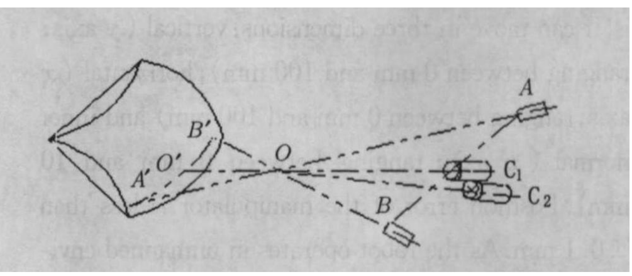

Fig. 9 Bottom vertical deviation

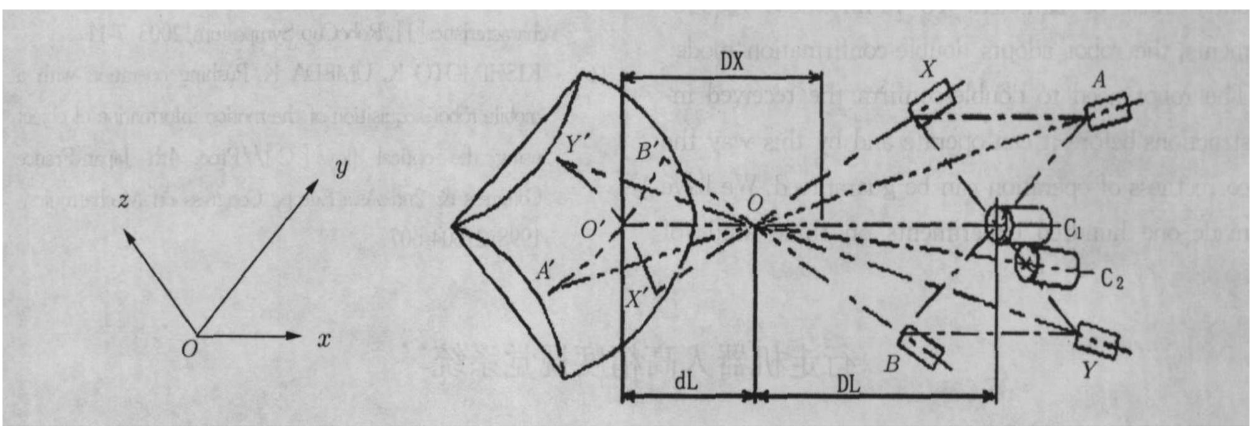

Fig. 10 Principle of distance measuring and center positioning

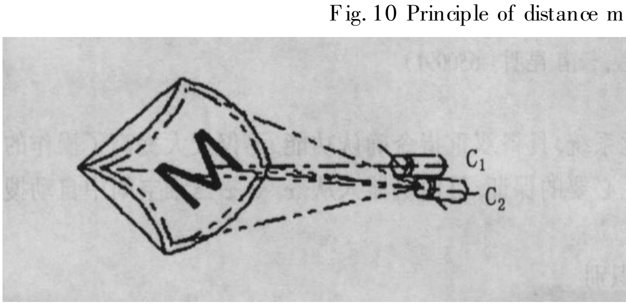

Fig. 11 Image acquisition

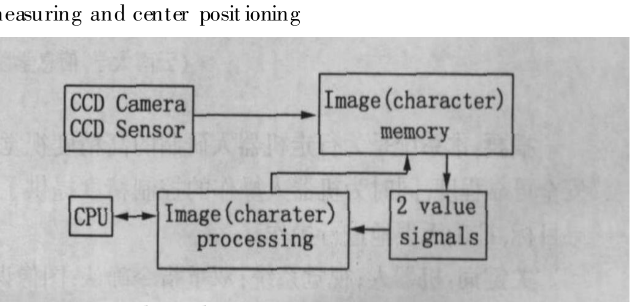

Fig. 12 Principle of characteristica acquiring

It is of great importance for a robot to operate correctly in an unmanned environment to have highly accurate identification ability. In the development of the system presented in this paper, adjustment and test have been made repeatedly on those operating modes showed by Fig. 6—9 and Fig. 10 to acquire highly accurate identification ability. However, one hundred operation experiments on a circle with diameter 5 on those modes respectively shows that mode showed by figure 10′s has 100% success rate of identification, while others are 83%, 87%, 82%, and 78%. The result shows the last mode is more reliable.

3 Conclusion

Robot with the vision system can carry out such operations showed as Fig. 3, Fig. 4 and Fig. 5. That is, it can move in three dimensions: vertical (y axis; ranging between 0 mm and 100 mm); horizontal (x axis; ranging between 0 mm and 100 mm) and inner normal (z axis; ranging between 0 mm and 10 mm). Position error of the manipulator is less than ±0.1 mm. As the robot operates in unmanned environment, special requirements on security and reliability must be satisfied. To fulfill those requirements, the robot adopts double-confirmation mode. The robot need to double-confirm the received instructions before it can operate and by this way the correctness of operation can be guaranteed. We have made one hundred experiments on three kinds of switches respectively and the rate of success of operations on each switch is 100%.

With the particularity of the object the vision system can position and identify, there are some limitations with the vision system which make it impossible to transplant on large scale. Improving and strengthening the control system and the information processing system of robot to make the vision system highly transplantable and applicable to automatic mobile robot is the object of further study.

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行走机器人高精度视觉系统*

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摘要: 本系统是为行走机器人研制的高精度视觉系统, 具备双重指令确认功能, 不仅大大提高了操作的安全可靠程度, 同时为机器人操作的控制精度提供了必要的保证, 可使机器人从 x, y, z 三维空间中自动搜寻目标, 准确无误地进行操作.

关键词: 机器人; 视觉系统; 双重指令确认; 图像识别

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