

## Research on Smart Handling Robot for Nuclear Reactor

Li-min WANG<sup>1</sup>, Xiang FANG<sup>1,2,\*</sup> and Qing-wei JIA<sup>1</sup>

<sup>1</sup>WILD SC (Ningbo) Intelligent Technology Co., Ltd, Ningbo, China

<sup>2</sup>Qinghu Rising Sunshine Data Technology (Beijing) Co. Ltd, Beijing, China

\*Corresponding author

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**Abstract.** Smart handling is more and more important to the core of nuclear power plant (NPP)-nuclear reactor. Refueling of nuclear fuel was mainly relied on NPP operators in the past. The potential risk always exists. The smart handling robot is developed so as to reduce the related risk. The research method of the robot development and key point is introduced in the paper. The smart handling robot for nuclear reactor will have broad prospects in China.

### Introduction

Smart handling robot for nuclear reactor is a project with more and more needs of nuclear power plant in China. Currently nuclear business in China is growing steadily. In future nuclear energy will occupy 10% roughly in China power industry. Nuclear power is a kind of clean and high effective energy. The core of NPP is nuclear reactor. The fuel of nuclear reactor is replaced periodically. In the past the task is done by NPP operator. However, the relevant potential risk including reliability, consistency and recognition always exists. The research objective of the paper is to reduce the risks.

### Requirement to Radiation Source Intelligent Handling System

There are nearly 10 NPPs now in China. The number of undergoing and planning plants is over 10 [1]. The smart handling robot will have broad application prospects.

### Detail Requirement to Radiation Source Intelligent Handling System

Considering the situation of NPP and reactor in China, the smart handling robot will meet main technical indicators as below.

- (1) The system is divided into two parts including actuator and control terminal. The system can be controlled to move and accomplish appointed process remotely.
- (2) Radiation source code can be recognized accurately.
- (3) Sole neutron source or  $\gamma$  source can be got from radiation source distributor and assembled to appointed box. Then the combined radiation source can be transferred to intermediate transfer container.
- (4) The combined radiation source can be taken out from intermediate transfer container. Then it is disassembled sole radiation source and transferred to radiation source distributor.
- (5) The radiation source box can be rotated tightening and disassembling. Grasping smooth surface, tightening, disassembling and grasping should have certain flexibility. The relevant data should be online displayed on terminal.
- (6) The volume limit is 2000mm×2000mm×2000mm control terminal.
- (7) The system should have emergency handling function.

### Key Technology to Smart Handling Robot

The smart handling robot has some key technology steps including lightweight structure design of mechanical arm, fast positioning and teaching, workpiece recognition and visual servoing and autonomous location and grasping of moving targets etc. The detail is as below.

- (1) Capturing target information based on sensors such as vision and laser range finder, rapid programming and teaching of mobile manipulator can be realized by graphic teaching of human-computer interaction.
- (2) Autonomous navigation and fast & precise positioning of robot arm mobile platform can be realized through the combined technologies of ultra wideband microwave positioning and inertial navigation.
- (3) Size measurement and pose recognition of 3D workpieces can be realized by visual image processing technology with gray level integral and stereo feature recognition.
- (4) Autonomous localization and grasping of moving targets can be realized by end effector with machine vision and force motion control strategy.
- (5) 7DOF mechanical arm can be designed by the structure of lightweight of high strength carbon fiber composite mechanical arm so as to improve positioning accuracy and operation flexibility.
- (6) High end embedded integrated controller can be developed so as to realize coordinated motion control of mobile platform and manipulator.

## **Solve the Key Technology of Smart Handling Robot**

### **Fast Positioning of Omni-directional Mobile Platform**

Currently there are several kinds of Omni directional mechanisms. The method of mobile platform autonomous navigation can be solved through the related analysis. Now there are 3 of Omni directional mechanisms. They are all wheel steering omnidirectional mobile mechanism, orthogonal-wheels and Mecanum wheel. Mecanum wheel leads to the success of robot development.

Indoor positioning and autonomous navigation technology is an active research domain. The methods include magnetic navigation, inertial navigation, laser navigation and visual navigation etc. [2]. At present the R&D hot spot is concentrated on using integrated innovation and multi-sensor fusion technology to realize precise & reliable positioning and autonomous navigation [3].

In order to realize autonomous navigation of robot, the key system and technology needing to be developed include high precision and low drift gyroscope, indoor ultra wideband (UWB) microwave navigation system and autonomous navigation algorithm.

Rapid positioning and navigation of mobile platforms can be obtained through combination of UWB position & inertial navigation and embedded digital map [4].

### **Carbon Fiber Composite Manipulator**

Multi link modular light arm is ordinary now. The method is to use articulation module with rotation function to combine according to some structure so as to become mechanical arm configuration with corresponding functions.

However, current robot is made mainly from cast iron and aluminum because of industrial robot business being controlled by foreign enterprises and expensive carbon fiber composite material cost [5]. With carbon fiber raw material cost decreasing, fiber production increasing and the maturity of molding technology the robot shell weight can be deducted to its original 40% weight.

Based on current 7DOF industrial mechanical arm, brief arms and panels are selected. The structure which is suitable to forming process of carbon fiber composite is designed. The design of mechanical arm is started from end tasks. The design solution of mechanical arms and connection parts can be confirmed based on past experiences. The technical indicators can be satisfied gradually through CAE analysis, statics analysis and optimization design.

### **Force Motion Control End Effector**

The traditional end effector is usually a designed executive tool according to operation task and need. These effectors include various dexterous hands, grippers and multi free micromanipulation devices so as to realize macro-micro operation and precision compensation [6, 7]. In this project

force motion control end effector will work according to the material characteristics and expected action.

The clamping method will be chosen between multifunctional flexible clamping mechanism and tool quick change clamping mechanism. When the clamping mechanism ready, the precise clamping of target workpiece will be obtained based on workpieces database and feedback information of force sensor [8, 9].

### **Machine Vision Technology**

In the past a few years, with maturing of vision sensor, digital image processing technology and the rapid development of DSP & FPGA chip of picture & image processing, automatic target recognition(ATR) is possible and becomes an important direction of high technology [10].

Image shape feature has no distortion advantages to space, rotation, retracting and motion. It can meet the requirement of computer vision technology to things recognition. The method is widely used in robot workpiece recognition domain. At present shape testing algorithm is mainly advanced Hough transform class method. The method has high reliability. Besides the method, other methods like structural pattern recognition method and pattern recognition method based on artificial neural network etc. are widely used. However, these methods have shortcomings like large amount of computation, large storage capacity and poor real-time performance [11, 12].

The digital database of target workpiece and working environment is set up by the fusion of visual sensor, image feedback and laser ranging information. The processes including auto-measuring and recognition, auto-guide of initial working area, workpiece tracking and positioning, mechanical arm motion and auto-control etc. to the motion target of mobile operation mechanical arm can be realized through creating robot virtual working environment and programming interface based on computer 3D technology.

### **Motion Control System**

Currently robot control structure mainly utilizes split driving control structure. The structure consists of upper controller and lower controller. The upper controller is usually used industrial personal computer (IPC) or PLC. The upper controller is responsible for path planning, mobile platform navigation and task assignment etc. The lower controller is responsible for IO information collecting and control, sensor information collecting, and control motor driver etc. The structure will lead to cost growing and system complexity. The robot function will be influenced greatly [13, 14].

The integrated driver will be used in the project. The integrated driver can collect and get feedback of information of motor through multi control interface controlling mobile platform driver motor. The structure can shorten communication time of all drivers and machine control period, decrease system cost and realize industrialization of R&D products to the maximum extent.

The integrated driver has characteristics of high efficiency including high precision, high speed, high reliability, low power consumption and low cost etc.

### **Key Technology of the Project**

The robot manufacturing has relationship with some key technologies including controller, reducer and servo-mechanism.

Currently WILD SC (Ningbo) Intelligent Technology Co., Ltd has its own technology & intellectual property right controller of robot. The controller is designed through embedded structure. The controller also has some characteristics including high precision, high speed, high reliability, low power consumption and low cost etc. The design of controller can be described as Fig. 1.

## Conclusion

The smart handling robot will have broad prospects in China. The main reason is that China will develop nuclear power industry greatly.

Now there are total nearly 20 NPPs need including in operation and planning to build. The relevant reactors will touch nearly 300. Considering each reactor needs nuclear fuel periodic handling, there will be over 500 robots to meet the need in the industry. The robotics will develop rapidly in nuclear power industry in China in near future.

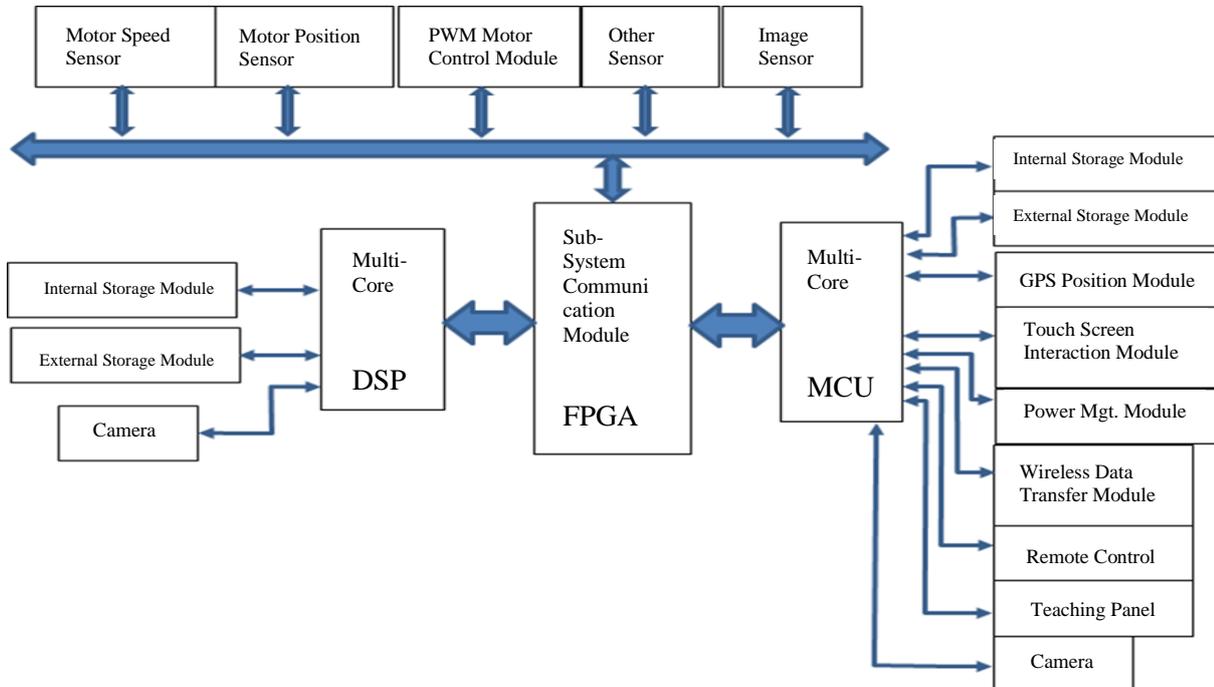


Figure 1. The embedded integrated controller.

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