Research on Self-Reconfigurable Ability of Remote Control System

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Abstract: Setting in the mobile robots in the damageable unknown environment, the paper is to do research on the self-repair design for recombining the internal control system by the self-reconfigurable-robots' reconfigurable control algorithms in remote control application. This paper discussed the reconfigurable design preventing being damaged later from the aspects of the reconfigurable and self-repairable subassembly design of the remote control system, the embedded operating system design of the self-reconfigurable robots, operating system scheduling for the hardware mission, operating system scheduling for the software system, multiprocessing embedded supported cooperative system and Multi-Agent System principle etc.

Key Words: remote control system; self-reconfigurable; self-repair; Multi-Agent System

1 INTRODUCTION

Contemporary robots' research field had already walked out from the structure environment fixed-point operation. It is developing to aspect of unstructured environment independent operation including aerospace, interplanetary exploration, military reconnaissance attack, underwater underground piping, disease examination and treatment, emergency rescue and disaster relief etc. The development of robotics improves the robots' ability continuously. And robots' applied realm and scopes are expanding continuously. The people hope that the robot can complete the more complicated mission. Future robots will work in the known or unknown environment that mankind can't or hard to attain. More and more, the remote control becomes main control mode and we desire that robots could survive and complete a variety of tasks in the bad and damageable environment (such as: battle-field, outer space etc.).

The traditional autonomous concept basing on sensor has expanded to that basing on structure self-recombining. Although the traditional robot has various kinds of sensing and planning information, it will hard to complete the given-task when the given-tasks go beyond the organization physics characteristic of its own. Self-reconfigurable robot is one form of the remote control robot based on configuration of autonomy. Also known as metamorphic robot, self-reconfigurable robots are organic joined by the modular robots which have simple function but certain perception ability. The difference between the self-reconfigurable robots and the general reconfigurable robots is the former emphasizes self-adaptation, that is to say the robots' system can adjust and change the shape according to environment and need of executive tasks, and it can optimize the shape automatically according to environment and repair itself.

This work is supported by Fujian Province university service channel West bank economic zone construction key project (Grant No. B054), the Quanzhou Technology development and research projects of China (Grant No. 2010Z59),the Quanzhou Science Foundation for the Excellent Talents of China (Grant No. 10A24) and the Science Program Foundation of Fujian Educational Committee (Grant No. JA10245S).

2 RECONFIGURABLE AND SELF-REPAIRABLE SUBASSEMBLY DESIGN FOR REMOTE CONTROL SYSTEM

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In the damageable unknown environment that people can't reach, for example, a dangerous battlefield environment, robots are often susceptible to external damage, so the Self-reconfigurable robots' control system should have the Characteristic of reconfiguration, namely the Characteristic of self-repair. The control system of remote robot need to be able to send the test information or the picture data of the robots' internal structure or external body back to the control centre, in order to estimate the damage, determine the feasible scheme, remotely modify the control system model, recombine the damaged circuit, download again the control software through remote communication, even modify the circuit structure basing on Field Programmable Gate Array so that it could coordinate afresh the functional components ,make it recovery partial function and continue to carry out the tasks.

The remote control robots according to the task, the external environment condition and the differences of fault types, judge in connection with the tasks, environment and fault types through robots' autonomous Intelligent, choose independently or change the job structure model of the control system, determine the best configuration of the control system, adapt to the tasks or the external environment or repair faults independently, in order to ensure that they could successfully achieve the predetermined locations and finish the task. For example: In a modular distributed control state or the damaged condition of the main control module, they could take over control through the free detection system, choose the module of the lowest importance in the task, and reconstruct the distributed control systems by reloading the

978-1-4577-2074-1/12/$26.00 ©2012 IEEE

FPGA chip, upgrade it to main control module, restart the main control system (As shown in Figure 1).

In addition, this system's each function circuit module should have the ability of segregating automatically the error signal which comes from the damaged circuit module through the remote control, namely amputating it automatically when part of the module is damaged. Simultaneity, this system's each function circuit module should also have the characteristic of additive, when the reconfigurable robots do the reconstruction or absorb the external homogeneous structure, the main control system should be able to redistribute the function. For example: on the battlefield environment people can not reach, two damaged robots recombine into a new robot through reconfiguration of the remote control, then robot's control system should have the ability of addible function circuit module and control well the newly added function module, compose extended control system.

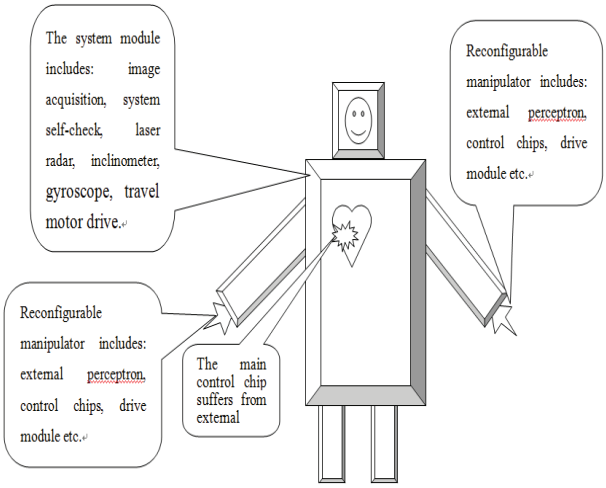

Figure 1. The Reconfigurable Robot's Main Structure and External Reconfigurable Module（Note: The control system will also apply to other types of reconfigurable robot, for example: CEBOT etc.）

In order to implement the control system's reconfiguration, namely design the reconfigurable robot's control system to explore bus topology that makes it has reconfiguration, implement the feasibility and reliability of reconfigurable function as follows:

1) the replacement each other of the main and sub control system function circuit; 2) the replacement one another of sub control system function circuits; 3) the automatic take-over control function of the low-lever system (such as: detection system) ,when the high-lever control system is damaged; 4) the amputation function of the system when module is damaged; 5) the expansibility of the system module and automatic change or upgrade online function of the operating system module in the extended state when robots add new module.

3 THE RECONFIGURABLE ROBOT'S EMBEDDED OPERATING SYSTEM DESIGN

Along with the increase of the self-reconfigurable robots' functions and modules' number, the concentrative control's computation increases quickly, it will reduce the computational efficiency and the reliability of operation, so distributed control is the only solution. The self-reconfigurable robots need to disperse lots of work to the body's each chip, that improves system's reliability and capability of resisting the stroke outside.

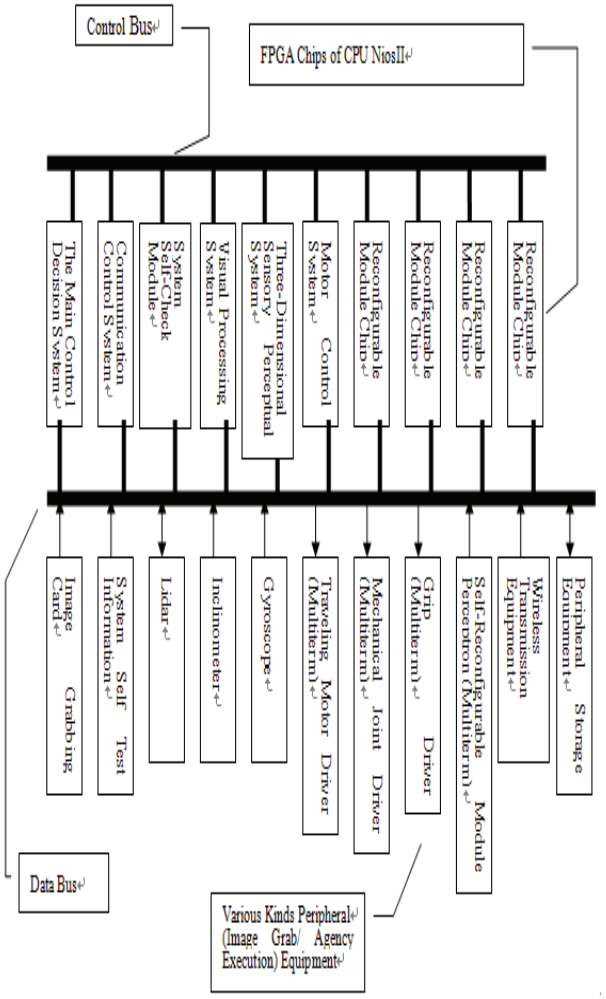

Figure 2. The Reconfigurable Control System's Structural Representation

Whether more complex functions or higher performance requirement, both make the self-reconfigurable robot and reconfigurable module's embedded system have great software complexity, so it becomes extremely important that introduces the operating system. Actually ,it becomes core in the process of system design that the embedded system use the Real Time Operating System. So, multiple embedded systems' scheduling of resources and management in the self-reconfigurable robot will be one of the unavoidable problems in the control system research.

4 SCHEDULING HARDWARE TASKS BY THE OPERATING SYSTEM

Real time operating system can supply many valued function to application system, but the most important is supplying schedule. Schedule is a science that allocates limited resources for competing task on the time axis, including CPU, bus, memory and other shared resources.

Reconfigurable resources of reconfigurable system are also scheduling resources.

Reconfigurable hardware such as Field Programmable Gate Array and Complex Programmable Logic Device can make special calculation achieve high performance in the different application, the system's responsible function can mapped to hardware, thereby it can reduce the bottleneck that influence the system's function. The hardware of the reconfigurable calculation can already do partial reconfiguration at run time, thus it improves flexibility without impacting performance. Because of reconfiguration, applied fine-grained and coarse-grained concurrent behavior can both get support; as a result, the embedded system's function can be improved remarkably.

It can upgrade hardware and correct error by reconfiguration and it can reconfig the robot control system's hardware in a similar way to remote upgrade software and correct error. The configuration process of dynamic logical device can make the configuration of resources in good graces and it can reconfig hardware after a calculation, so the logical device's configuration and internet can adjust on line during the period of execution, and the runtime configuration can based on the intermediate results of calculations to generate, as a result, the dynamic configuration method can make the hardware cooperate with robots in reconfiguration, and make the control system more close to ideal reconfigurable goal of self-reconfigurable robots.

Self-reconfigurable robots' main control operating system needs to consider the reconfigurable resource of robots' all sub system chip (including all the reconfigurable modules) as a whole and unify scheduling. But traditional operating system's scheduling algorithm doesn't support hardware scheduler task of reconfigurable device, hardware scheduler in the process of reconfiguration has particularity, it needs to research special scheduling algorithm to optimize the utilization of resources, centralize the reconfigurable resource and give full play to advantage in reconfigurable hardware.

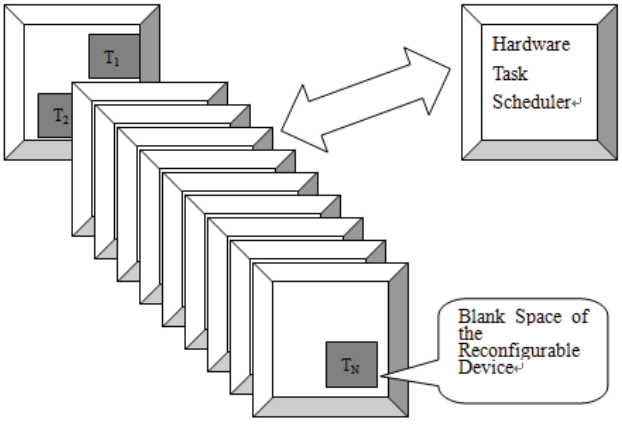

Figure 3. The System Hardware Task Scheduler For Reconfigurable Resource Management

5 OPERATING SYSTEM FOR THE SOFTWARE TASK SCHEDULING

Along with the expansion of the scope of application and the increasing complexity, heterogeneous distributed system has been widely used in real-time embedded system, the analysis for time performance requirements is getting more difficult, and it is difficult to determine scheduling even if using the static scheduling analysis method. At present, the research for the multiprocessor system's task scheduling problem most concentrated in the homogeneous systems, but the simplified homogeneous system scheduling problem is NP - complete problem the same as the single processor, so it is often using heuristic algorithm to solve the scheduling problem in the practical application. The main heuristic algorithms are list-scheduling algorithm and genetic algorithm. The existing homogeneous multiprocessor system's list-scheduling are Modified Critical Path (MCP), Dynamic Critical Path (DCP) etc. The research of task scheduling is relatively few in the heterogeneous system. The existing algorithms are Dynamic-level Scheduling (DLS)、MH algorithm、HEFT algorithm and CPOP algorithm. These all belong to the list-scheduling algorithm.

The existing scheduling algorithm doesn't consider the multiprocessor system's interconnection or considers only communication equipment's competitive access. In fact, schedule needs to consider both processor scheduling order and system's communication behavior for the real-time embedded system of composition self-reconfigurable robots' control system.

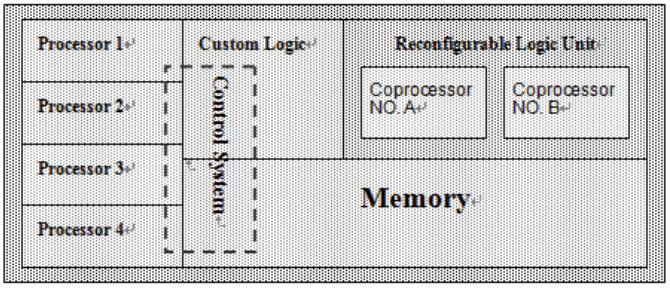

Figure 4. The Schematic Diagram of Programmable System Structure on Chip and Coprocessor to Generate

In addition, the existing chip operating system scheduling algorithm doesn't direct at the reconfigurable chip design, the number and type of Algorithm Hypothesis coprocessor is definite. But the coprocessor increasing and decreasing online becomes possible because of the introduction of partial reconfigurable function, the operating system of the future can decide the coprocessor's increasing and decreasing according to the task's urgent degree, the length of the queue and current tasks for reconfigurable resource usage.

So, the research of the operating system's scheduling problem contains the following aspects:

- Assign tasks to appropriate hardware or software processing unit and consider the communication resource availability at the same time;

- Because of the processor's order execution characteristics, it needs to decide appropriate execution sequence for each processing unit task.
- Because of the introduction of partial reconfigurable function, it can increase or decrease the number of coprocessor according to reconfigurable resource status.

6 MULTI-EMBEDDED SYSTEMS COORDINATION SYSTEM AND MULTI-AGENT ROBOTIC SYSTEM CONCEPT DESIGN

Many years ago, inspired by the Multi-Agent system research in the Distributed artificial intelligence, researchers apply the concept of agent in the research of multi-robot system; it is called Multi-agent Robotic System. The so-called Multi-Agent System is the set which is made up by multiple calculable Agents. And each Agent is a physical or abstract entity that acts on itself and environment, and communicates with other agent. When the single Agent can not complete or effective complete the task, it needs to assign the task to a group of Agent, and Agent complete the task through the alliance form.

In most cases, the self-reconfigurable robots constitute a distributed multi-agent robotic system in essence. Control structure's main research question is to design correct and reasonable local control scheme, that is to enable the Multi-Agent System can efficiently solve the problem of contract. It is already a large number of research about the design of control structure. As Cai Zixing et al. they apply the mixed type three layer intelligent architecture which combine the deliberative way and behavior control method based on heterogeneous Agent Technology.

6.1 Robot self-reconfiguration behavior design

The three layer intelligent architecture based on Homogeneous / heterogeneous Agent Technology includes: Deliberative layer, Coordination layer and Control layer. The three layer intelligent architecture admits each Agent equal competitive position in the system, Agent which implements the deliberative layer is often artificially designated, such as decision making Agent, once it is determined that will be difficult to change. But Agent of self-reconfigurable robots can dynamic change through reconfigurable components, such as: two or more robot reconfig for a machine.

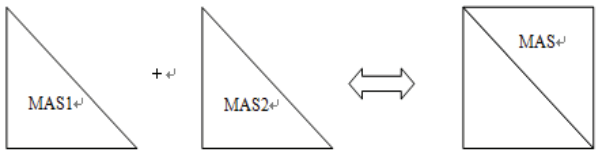

Figure 5. System consolidation (split) of self-reconfigurable robots in the reconfigurable process

Embedded system which compose the self-reconfigurable robot control system can be viewed as a heterogeneous /isomorphism / mixed MAS system apparently, but the FPGA chip embedded system in the open layout is a perfect equality relation. In the self-reconfigurable process of reconfigurable robots, it is possible to introduce the reconfigurable components which have higher performance processors system or even the whole running another self reconfigurable robot control system.

Therefore the self-reconfigurable robots face with the problem of control system during the reconfiguration process, so the three layer intelligent architecture based on Homogeneous / heterogeneous Agent needs to redesignate during the reconfiguration process. Some Agent needs to transfer decision right, and transfer high level control (careful reflection) to high performance Agent through Agent competition.

6.2 reconfiguration analysis of control system hardware

In addition, multi Agent system's collaborative alliance problem, namely set partitioning and set covering problem in the same system, is always one of the important directions of MAS research. In the traditional Agent alliance problem, the total available Agent quantity is determined, in the case of hardware scale determination.

However, in the case of introduction FPGA system on chip that has partial reset function, the deliberative layer has been able to combine the task status to create and delete Agent independently because the operating system can manage effectively the reset resource. Then a limited number of Agent alliance problems will turn into Agent create and collaborate (Alliance) problem in the limited reconfigurable resource. So the original union is no longer Agent set partitioning and set covering problem, but the reconfigurable set partitioning and set covering problem.

7 CONCLUSION

In this paper, it puts forwards the reconfiguration facing to self repair function. Taking the case of the robots in the dangerous environment, it discusses the robots' self-reconfigurable structure whose core is controlling the system reconfiguration. This paper researches the reconfigurable control system which suits for self-reconfigurable robots. From the angle of structure design of control systems, it researches the control system bus layout which makes the control system still work normally when the self reconfigurable robot control system has suffered localized damage. From the angle of the control law, it makes the control system still can rely on the redundancy function of other functional components to continue to complete the task on the basis of reconfigurable control law when the self-reconfigurable robot's external functional components suffer damage, thus it improves the survival ability of remote control robot in the complex, dangerous, easy to damage environment. From the angle of embedded operating system design, it researches the scheduling hardware resource and software resource on chip. From the angle of intelligent structure, it researches multi embedded system's collaborative problems in the self-reconfigurable robots.

Intelligent reconfigurable control of complex nonlinear dynamic system has become an important direction of self-repairing control field. The author's design research in this aspect has obtained the preliminary progress. Self -repairing design will greatly provide survival ability of

remote control robot: After the failure of the remote robot's communication module, the robot will automatically repair getting help from other module chip, when the robot's main control chip damage by the external force hit, it will automatic lift the chip of some other subsystems as main control chip in a short time, and quickly restart the main control system. So, the reconfigurable design of self-reconfigurable robots' remote control system has the broad application prospect.

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