The MDARS Multiple Robot Host Architecture

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ABSTRACT

An architecture for distributing and allocating robotic planning resources has been developed for the MDARS robotic security system. This Multiple Robot Host Architecture can be applied to other systems with certain features and application requirements similar to those of MDARS.

INTRODUCTION

The Mobile Detection Assessment Response System (MDARS) is a joint Army-Navy development effort to provide an automated intrusion detection and inventory assessment capability for use in DoD warehouses and storage sites. The program is managed by the Physical Security Equipment and Management Office at Ft. Belvoir, VA. Overall technical direction for the program is provided by the Naval Command Control and Ocean Surveillance Center Research Development Test and Evaluation Division (NCCOSC RDTE DIV, or NRaD).

The MDARS goal is to provide multiple mobile platforms that perform random patrols within assigned areas of warehouses and storage sites. The patrolling platforms:

- detect anomalous conditions such as flooding or fires;

- detect intruders; and

- determine the status of inventoried items through the use of specialized RF transponder tags.

Separate development efforts target warehouse interiors and outdoor storage areas. The MDARS Interior Program development utilizes the Cybermotion K2A Navmaster mobility base, equipped with additional collision avoidance, intruder assessment, and product inventory subsystems, and has successfully demonstrated the simultaneous control of two robots patrolling within an interior warehouse environment. The Exterior Program, initiated in February 1993, has recently awarded a contract for the development of the mobility platform to Robotic Systems Technology (RST) of Westminster MD. Testing of the first prototype is expected to begin in October 1994.

SYSTEM DESIGN DRIVERS

The design of the MDARS system is driven by a number of characteristics of the application domain:

- MDARS must function as a key component of a complete security system that also includes fixed detection capabilities and human security guards;

- the patrol coverage of a large number (expandable up to 32) of mobile robotic platforms must be controlled and coordinated to minimize opportunities for undetected intrusion, even by insiders; and

- both the interior warehouse and exterior storage site environments require navigational capabilities intermediate between those of an unknown and dynamic environment (e.g., battlefield) on the one hand and a completely structured and static environment (e.g., hospital corridors) on the other.

What is important about the "semi-structured" nature of the MDARS operating areas in terms of implications for the system design are the following:

- the robot operating area is mappable because the positions of the principal features of navigational interest (e.g., roads, bunkers, walls, corridors, and storage bins) are known in advance and change relatively infrequently;

- the major sensory characteristics of these features can be characterized and in some cases be tuned to facilitate detection and classification by the robot's sensors (e.g., by installation of reflective position markers);

- many variable features of the environment represent either features of interest to the mission (e.g., intruder, missing storage container, flooded floor) or "friendlies" whose cooperative behavior can be relied on (e.g., to stay on the right hand side of the road, to get out of the way eventually).

The significance of novel features ("exceptional events") sensed by the robots must be assessed by the MDARS system, relying strictly on robotic sensors when possible and invoking the assistance of the human operator when necessary. When automated assessment indicates that a valid threat condition exists, the appropriate response must be invoked. Noncritical events must also be handled, with minimal involvement of the human operator (e.g., autonomously navigate around a parked vehicle or other obstacle).

THE MDARS ARCHITECTURE FOR PLANNING AND COORDINATION

One area of the high level system design which particularly reflects the requirements of the MDARS application is the distribution of processing functionality within the system, especially for navigational planning. The mappable nature of the environment, the relatively low frequency of exceptional conditions, the need to achieve coordinated coverage of multiple platforms, and the requirement to support up to 32 platforms simultaneously all suggest a navigation approach based on centrally planned routine patrol routes, with any deviations handled on an exception basis.

Moreover, the fact that each MDARS robot spends most of its time autonomously executing a downloaded set of navigational commands suggests that a relatively small number of planning resources should be dynamically allocated to the different robots as needed, instead of being dedicated on a one-to-one basis.

These ideas are implemented in MDARS via the Multiple Robot Host Architecture (MRHA), which is depicted in figure 1. A LAN interconnects a Supervisor computer, a pool of centrally located Planner/Dispatcher computers, one or more (human guard) Operator Stations, and a Link Server (to route messages to and from the robots via RF modems). When a robot becomes idle, the Supervisor assigns a Planner/Dispatcher from the pool to plan a new path and download it. The robot then autonomously executes the set of commands until it is completed or until an exception condition is encountered, and the process repeats. Meanwhile, the Planner/Dispatcher is released back to the pool for allocation to another platform, so that a small number of Planner/Dispatchers can handle a large number of robots. When an event is deemed to require the attention of a human operator, the Supervisor assigns an Operator Station, which displays the appropriate information to the guard and provides an interface for command entry. The MDARS Interior Program has successfully demonstrated the simultaneous control of two robots and four simulated robots operating in an interior warehouse environment. MDARS Exterior will capitalize on this work, adapting it as required for the needs of the exterior application.

A series of MDARS technical papers provides documentation of additional details of MRHA ([1], [2], [3]) and other technical aspects of the MDARS system ([4], [5], [6]).

MRHA AS AN "ARCHITECTURE"

The word "architecture" is used in the robotics community in several different senses. The most common use is probably in the sense of "intelligent control architecture"; i.e., as a mechanism for implementing desired behaviors of effectors based on inputs from sensors. Examples are Brooks's subsumption architecture [7] and Albus's Real-time Control System, (RCS) [8]. An "integration architecture", on the other hand, is a mechanism for gluing predefined subsystems together into a coherently functioning whole [9], [10]. A third use of the word is in the sense of "implementation architecture", as a style of designing a system and building it -- for example, using one large central processor as opposed to a number of smaller ones. Of course, a specific integration architecture may support a specific control architecture and in turn assume a specific implementation style or architecture, and the developers of the system may refer to all three architectural aspects of the system by one name.

With this as preface, then, the MDARS Mobile Robotic Host Architecture (MRHA) is an effective approach to allocating a relatively small pool of centrally located processing resources to handle the navigational (and other, mission specific) planning requirements of a potentially much larger number of autonomous robots. MRHA does not support the integration or intelligent control of a single robot, nor does it require that any particular command language be used in the interaction between the planners and the robots. MRHA can be easily applied to other systems comprised of multiple robots requiring only intermittent planner (or "supervisory") attention.

REFERENCES

1. Everett, H.R., Gilbreath, G.A., Heath-Pastore, T.A., Laird, R.T., "Controlling Multiple Security Robots in a Warehouse Environment," Proceedings of AIAA-NASA Conference on Intelligent Robots, Houston TX, March 1994.

2. Everett, H.R., Heath-Pastore, T.A., Hower, S.P., "Host Architecture for Coordinated Control of Multiple Autonomous Platforms," Proceedings of ISRAM 94, Maui HI, August 1994.

3. Everett, H.R., Gilbreath, G.A., Heath-Pastore, T.A., Laird, R.T., "Coordinated Control of Multiple Security Robots," Proceedings of SPIE Mobile Robots VIII, Cambridge MA, September 1993.

4. Smurlo, R.P, Everett, H.R., "Intelligent Sensor Fusion for a Mobile Security Robot," SENSORS, May 1994.

5. Everett, H.R., Laird, R.T., "Reflexive Teleoperated Control", Proceedings of Association For Unmanned Vehicles Symposium, AUVS-90, Dayton OH, July-August 1990.

6. Everett, H.R., Gilbreath, G.A., Tran, T.T., "Modeling the Environment of a Mobile Security Robot", NOSC Technical Document 1835, Naval Oceans Systems Center, August, 1990. NTIS/DTIC AD Number A233074.

7. Brooks, R.A. "A Robust Layered Control System for a Mobile Robot", IEEE Journal of Robotics and Automation, RA-2, April 1986, pp 14-23.

8. Albus, J.S. "System Description and Design Architecture for Multiple Autonomous Undersea Vehicles", NIST Technical Note 1251, September 1988.

9. Gage, D.W., Harmon, S.Y., Aviles, W.A., Bianchini, G.L., "Subsystem Interfaces for Complex Robots", Workshop on Robot Standards, Detroit MI, 6-7 June 1985, Proceedings pp 119-124.

10. Aviles, W.A., Gage, D.W., Harmon, S.Y., Bianchini, G.L., "An Architecture for the Coordination and Control of Complex Robotic Subsystems", 1985 Conference on Intelligent Systems and Machines, Rochester MI, 23-24 April 1985, Proceedings pp 40-46.