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Integration of Task Level Planning and Diagnosis for an Intelligent Robot

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Abstract

This paper describes an AI and robotics research project being conducted for NASA. The applications of our findings are for robots performing tasks in space.

The use of robots in the future must go beyond present applications and will depend on the ability of a robot to adapt to a changing environment and to deal with unexpected scenarios (i.e., picking up parts that are not exactly where they were expected to be). The objective of this research project was to demonstrate the feasibility of incorporating high level planning into a robot enabling it to deal with anomalous situations in order to minimize the need for constant human instruction.

Our heuristics can be used by a robot to apply information about previous actions towards accomplishing future objectives more efficiently. Our system uses a decision network that represents the plan for accomplishing a task. This enables the robot to modify its plan based on results of previous actions. Our system serves as a method for minimizing the need for constant human instruction in telerobotics.

This paper describes the integration of expert systems and simulation as a valuable tool that goes far beyond this project. Simulation can be expected to be used increasingly as both hardware and software improve. Similarly, the ability to merge an expert system with simulation means that we can add intelligence to the system.

This paper describes a satellite in space that has a malfunction. The expert system uses a series of heuristics in order to guide the robot to the proper location. This is part of task level planning.

The final part of the paper suggests directions for future research. Having shown the feasibility of an expert system embedded in a simulation, the paper then discusses how the system can be integrated with the MSFC graphics system.

Integration of Task Level Planning and Diagnosis for an Intelligent Robot

Arthur Gerstenfeld*

Introduction

It has been recognized for some time that intelligent telerobot architecture will become an increasingly important force in space activities [Reference 1]. There has been a great amount of previous research which has focussed on these issues [References 2-27]. At this point we are focussing on one part of the architecture, namely task level planning. The balance of this paper will describe our research in that area and some thoughts for future directions.

Project Objectives

1. The first objective was to show the feasibility of having a robot in space exhibit some autonomous behavior.

2. The second objective was to demonstrate the ability for the robot to use intelligent planning and replanning.

3. The third objective was to show how the system can be adaptable to different satellites or space station configurations.

4. The fourth objective was keep the "man-in-the-loop" so that when the search did not yield the expected results, then ground control can redirect the search.

5. The fifth objective was to develop a feasibility model and demonstrate it at MSFC.

The objectives are shown graphically in Figure 1.

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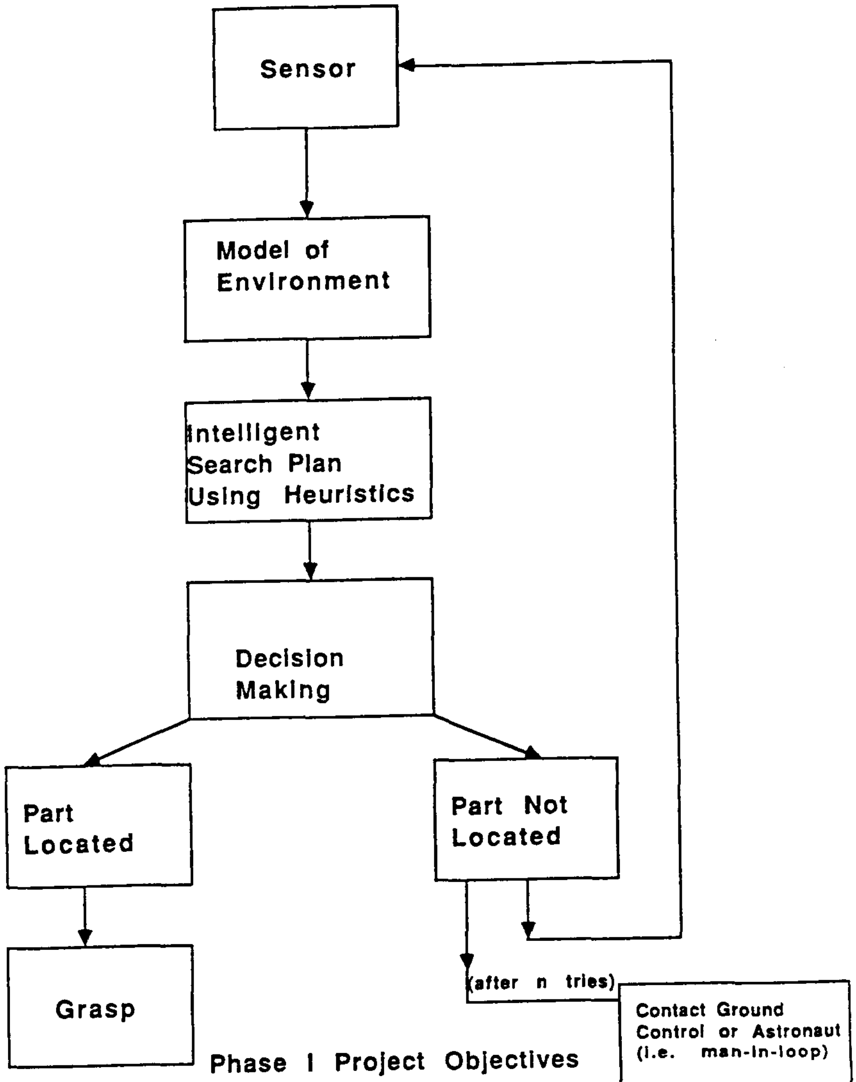


Phase I Project Objectives
Figure 1

Work Carried Out

The work carried out can best be understood by referring to Figure 2. The robot is instructed to replace module A. The robot, however, is located at module H. Therefore, it must plan how to get from where it is located to the required location.

In order to do that planning we showed how it was necessary for the robot sensor to obtain two orientations:

1. Present location (i.e. "H")

2. Module directly above (i.e. "D")

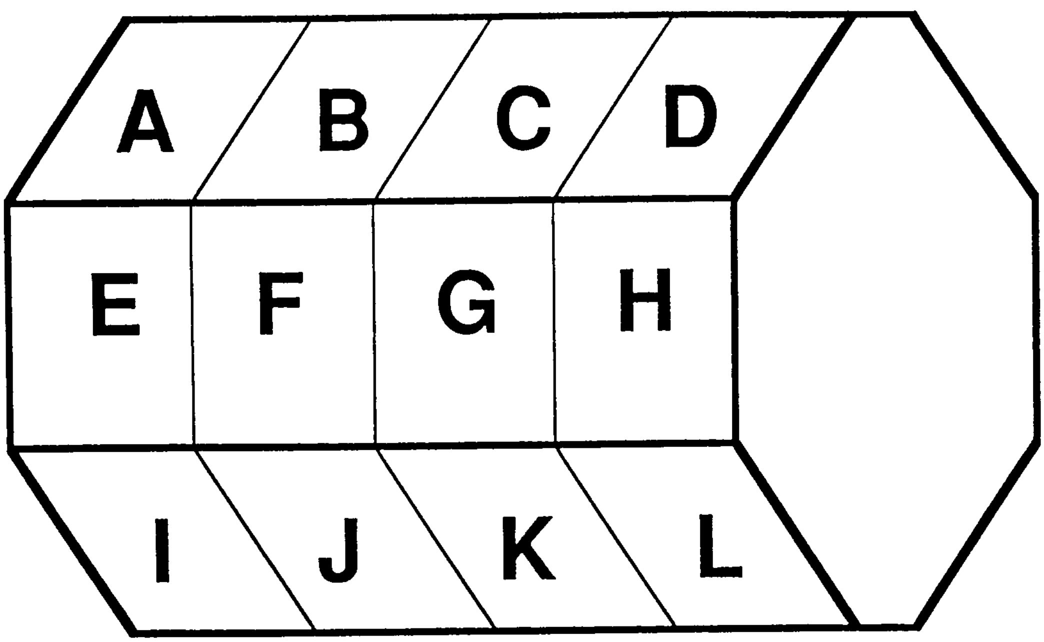
It is necessary for the robot to know the module above in order to gain orientation. This can be thought of as a person who is lost and he locates the street he is on but that is not enough. He must also know one other point (another street or landmark) in order to determine his orientation.

Having determined that the robot is at H and oriented so that D is directly above it - the decision can then be made that the robot must:

Move UP "1"
Move 4 to LEFT

After moving up 1 and 4 to left the robot may still not locate module A due to other discrepancies. In that case the robot will use further heuristic search using the same principle as described above. This can be done recursively until a solution is found or instructed otherwise by a human in the loop.

A second example is that the robot is at "G" and must move to "L". His orientation shows that "K" is above the robot and the robot then reasons that it must move 1 down and 1 to the right.



A Simulated Satellite with Different Modules

Figure 2

We, therefore, observe that each movement for the robot does not have to be given to it. Rather the robot can reason and perform intelligent search. During Phase I we designed the computer code necessary to accomplish independent search.

The work carried out included the building of a simulation on a COMPAQ 386. We designed the computer code to integrate the graphics and artificial intelligence.

Results Obtained

The results obtained can best be understood by referring to Figure 3 in terms of goals and subgoals. For example, in Figure 3 let us assume the goal is to locate a particular part of a satellite. This could also be a part on space station exterior or interior.

Figure 3 shows that:

- Subgoal 1 is "Recognize current location"
  In order for the robot to regognize its present location it is necessary to have two further subgoals as follows:

- Subgoal 1.1 is "Identify the place where the robot is currently located"

This is achieved by an action as follows:
"Use vision system to locate a point straight ahead".

This can best be thought of by thinking of a person lost in an area he does not know. The person must first look for a street sign to identify the street where he is standing. Having achieved the above it is necessary for the robot to find one other point. For the example we used, the other point was the module directly above the current module.

By using the analogy again of the lost person, once he found out what street he was located on he then had to locate one other marker. Let us assume that his eyes moved up and he located a cross street to the one on which he was standing. Referring to Figure 3 that is the following action:

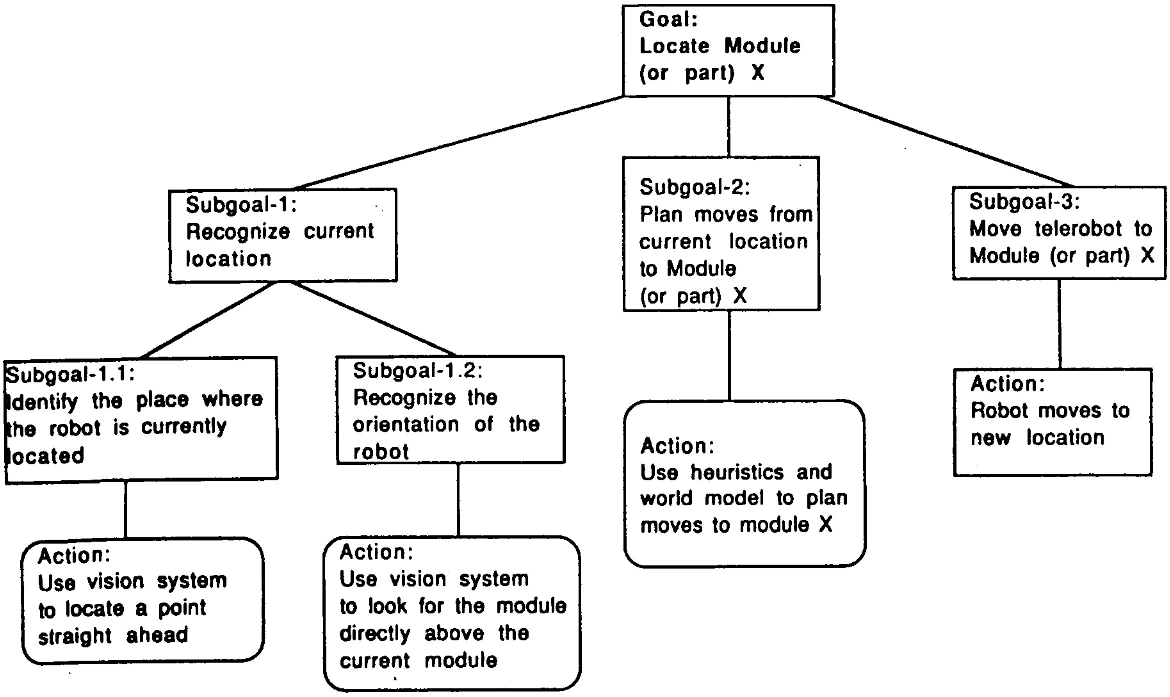
Use vision system to look for the module that is directly above the current module.

Having now established the locations of the robot (and its orientation) the subgoal 2 is as follows:

- Plan moves from current location to module (or part) X.

The action in that case is to:
Use heuristics and world model to plan moves to module X.

This can be thought of again as the lost person who has now sufficiently identified his location and orientation then planning his move to his destination.



Different levels of decision-making in the system

Figure 3

The final subgoal is:

- Move telerobot to a particular location or part

The action associated with that goal is as follows:
Robot moves to new location

We showed this process of goals, subgoals, and actions using a model of a satellite. In this case we limited our investigation so that the input from the sensors were given by the user of the simulation. This can be visualized in Figure 4.

Future Directions

1. Development of an AI planner to generate task level path commands to a satellite servicer robot.

2. To integrate our system with the graphical simulation model at MSFC.

3. To include a model of a generic satellite with subsystems, e.g. power, altitude control, communications, etc.

4. To develop a diagnosis system that will be used to identify a list of possible failed subsystems.

5. To demonstrate higher level task planning by performing diagnosis and robot path planning in order to replace (or repair) a subsystem.

Our approach can best be understood by considering Figure 5. We shall be focussing on the task decomposition modules and show how they can perform real-time planning. The task decomposition modules plan and execute the decomposition of high level goals into low level actions.

Figure 4 shows on the right, the operator interface. On the left the global memory. The task (which might be "locate tool A" or "replace module B" is shown in H4 of Figure 1. Having received the task requirement the system would then check the world model by moving one square to the left in Figure 1 to M4. This is integrated with the sensory information shown in G4 for Figure 1.

The control system architecture is shown in Figure 5. The level we are focussing on is Level 4, which decomposes the object task commands specified in terms of actions performed on objects.

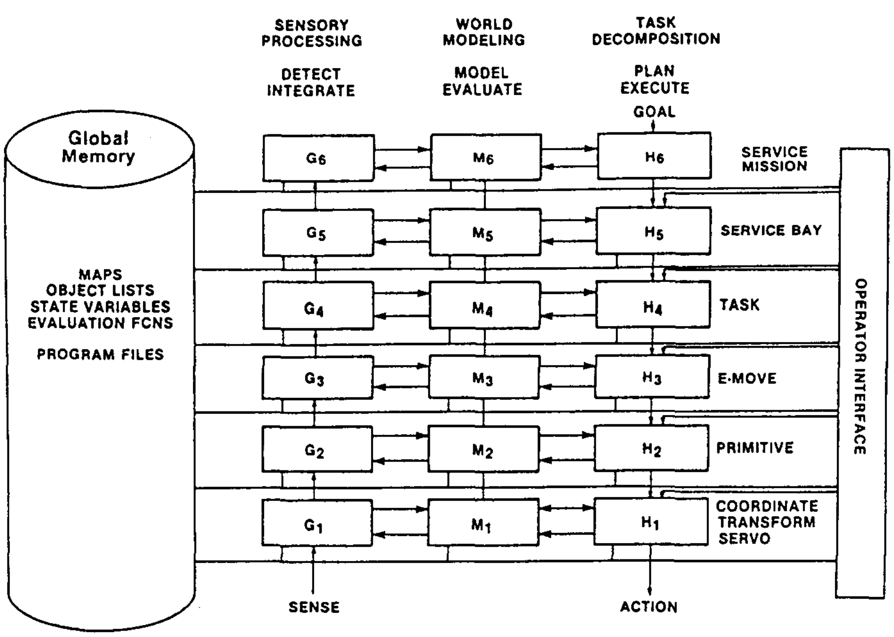


Fig.4 A hierarchical control system architecture for intelligent vehicles.

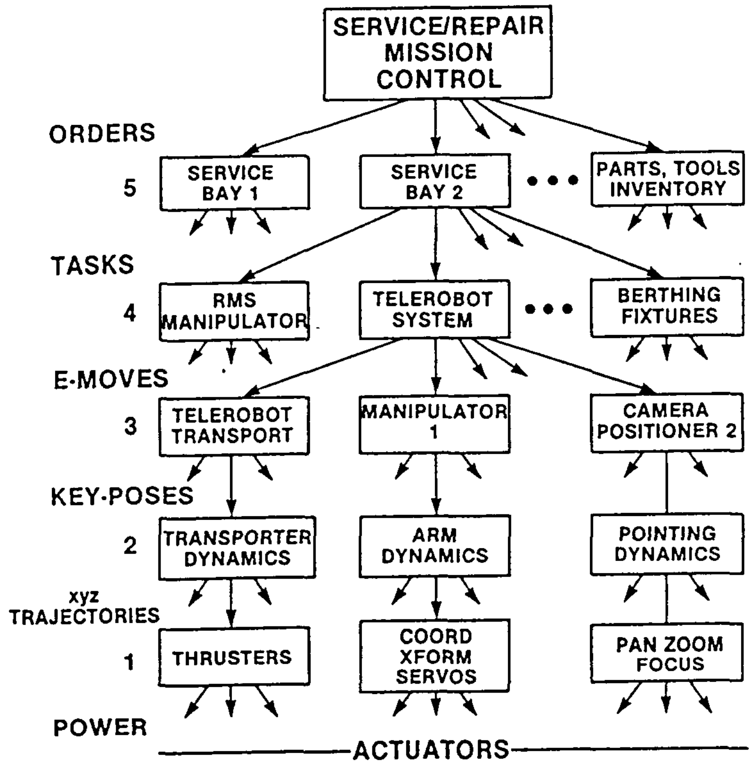


Figure 5

A six level hirearchical control system proposed for multiple autonomous vehicles.

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