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An update on "Lab Rover": A Hospital Material Transporter

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ABSTRACT: An update on "Lab Rover", a hospital material transporter current health care costs in the USA, are 1% of the G.N.P. This translates to 750 billion dollars/year. By the year 2000, health care costs are projected to reach one trillion dollars/year or 20% of the G.N.P. Health care costs are skyrocketing and the Government has made cost containment its number one priority for health care. Cyberotics' approach to cost containment has been to automate material transport within medical institutions. Conventional material transport now utilizes people power, push carts, pneumatic tubes and tracked vehicles. Hospitals are faced with enormous pressure to reduce operating costs. Cyberotics, Inc. developed an Autonomous Intelligent Vehicle (AIV). This battery operated service robot was designed specifically for health care institutions. Applications for the AIV include distribution of clinical lab samples, pharmacy drugs, administrative records, x-ray distribution, meal tray delivery, and certain emergency room applications. The first AIV was installed at Lahey Clinic in Burlington, Mass. Lab Rover was beta tested for one year and has been "on line" for an additional 2 years.

INTRODUCTION:

During the past 18 months, Cyberotics embarked upon a program that allows for manufacturing cost reduction, expanded intelligence, navigation enhancement, and improved appearance. This resulted in Cyber V, the latest achievement in a technology which represents over 10 years of research and development.

OPERATION:

The vehicle's motion and steering is provided by a velocity controlled, differential wheel drive. Main power for all systems is supplied by a pair of high capacity batteries. The vehicle operates for a minimum of an eight (8) hour period. The power package is designed for easy replacement .

The "on board" computer works in conjunction with ultra-sonic and infrared sub-system, to navigate freely throughout the work environment. The AIV does this without the use of wires, or floor tapes. It is completely flexible and can be programmed to navigate a defined delivery route. It is capable of accepting instructions, manually through the control panel keyboard, or through a digital radio communications link. Additionally, a complete operational status can be acquired through the RF link.

Infrared beacons at key locations communicate to the vehicle, instructing it to stop, turn, or sound an audible arrival signal to area personnel. If there is no one to unload the vehicle, it "times out" and, again continues with its assigned tasks.

MATERIAL HANDLING:

The work surface of the vehicle may be optionally divided into spaces for trays, racks, or boxes. With the addition of the radio frequency (RF) communications option, the vehicle may be used in a "dispatch mode". This allows for continuous scheduling from a central base station, which may also be connected to the hospital's Local Area Network (LAN). This option also allows for instant vehicle location information, at any time, from any work station. This dispatch system handles multiple vehicles.

SALIENT FEATURES:

The AIV's intelligent software and its ultra-sound navigational system combine to allow safe mobility through corridors, avoiding people and other unforeseen objects in its path. Top speed is approximately 2.5 mph, with automatic slow-down while avoiding obstacles. A tactile bumper is an added safety feature, which allows for an instant stop and automatic assessment of unusual circumstances.

A brief review of Cyberotics' sensor and navigation development.

Cyber I Feasibility Model

The original design consisted of a circular array of ranging transducers comprised of two inch speakers, a separate transmitter and receiver, having four speakers each. The Polaroid transducer was not available yet.

The speakers have a natural resonance of 5 KHZ and when set in an array of four speakers with a backing plate, it provided a beam width of 36 degrees. An eight bit 16K OSI computer provides all the computing power. While crude by today's standard, it indicated that the approach had promise.

One particular problem to overcome is in the acoustic vision. Elimination of false echoes, mirror effects and cross talk were of particular concern. An open loop wheel drive, a natural language processor, and a video screen was used. The control software was based on behavior reaction. It was functional, but hard to add new behaviors, because the control parameter was embedded in the main body of the software. A combination of Assembly Code and Basic was used.

Cyber II

This design was to be the answer to the personal robot craze of the 1980s, but was too late and too expensive for the hobbyist and experimenter. The circular transducer array proved to be a viable concept.[1] It provided a geometry that all but eliminates the specular effects, by insuring that a transducer was always perpendicular to a vertical surface.

The Polaroid transducers were now available. This provided a more efficient way of collecting range information. Running at 50 KHZ with a 22 degree beam width, it allowed for a higher resolution sensing of the environment. A pulsing pattern was devised to help eliminate false echoes. The transducer density, however, was not sufficient enough to eliminate blind spots in its vision. It operated quite well for the experimental use, but was not reliable for practical applications. A new programming concept was developed - behavioral induction.

In behavioral induction, a model of behavior is provided. The model consists of a set of co-efficient in a data base, that are selected to set the parameters of a fixed function. The model is compared with real world data. A difference or error representation is derived. A set of heuristic rules evaluates the error and specifies appropriate wheel responses. Different functions, coefficients, rules, and responses are capable of producing a wide range of behavior types. Automatic and fixed selection of behavior types, allow the vehicle to move freely through the environment.

The ability to behave and to react to the environment, does not necessarily give the vehicle a useful purpose. The ability to go from point A to point B, requires navigation and command input to give it direction.

A reference position system was added that provided information to the vehicle when it reached key locations. The system consisted of an ultra sonic ranging transducer which measured the height of an object overhead. Stations were built with dimensions of specific heights. When height was detected, that location was fixed, e.g.: ceiling heights, doorways, stations. A command at the keyboard would be mapped to a location having a specific height, thereby, fixing the robot at that location. This system was convenient to implement, but not meant to be practical. It's use was to assist in developing the navigational software.

Cyber III

A closed loop velocity controlled servo drive was added. This provided a selection of 255 speeds. The motion of the vehicle could now be contoured for a smooth response.

The acoustic overhead detector was replaced by an infrared beacon system. The basic navigation concept remains the same. The infrared beacons provide a positive method of location without ambiguity. It also provides directional information.

The navigation algorithm is goal seeking. At each beacon, the vehicle path is compared with its intended destination. If a correction in path is required, the navigation algorithm reevaluates and chooses a new path. Cyber III contained a total of 60 Polaroid transducers. This provided for higher resolution for the vision system, but introduces acoustic problems. Transducers are now closer together and isolation becomes a problem. A baffle was added to serve several purposes. It isolates the output of one transducer from the input of another. It reduces the problem of false echo arrivals by limiting angular reception. It also eliminates side lobes produced by the transducers.[2]

Cyber IV

Product Enhancement:

This model was intended to be product ready, requiring all of the mundane, but necessary, features to make it practical. As an addition to the goal oriented navigation, an error correction system was found to be necessary. Occasionally, the vehicle would be diverted from its defined operating area and wander down the hallway where no navigation beacon exists. To alleviate this problem, an error correction system was devised by utilizing peripheral beacons specifically for recovery purposes. These beacons are placed at edges of the defined work environment, in areas where the vehicle is not allowed to go. They provide explicit instructions on how to get back to the defined area.

Additional features that were added are:

1) Smart bumpers
2) Emergency shut down switch
3) Go - No go button
4) Servo disable switch
5) Battery gage
6) Key lock on - off switch
7) Battery removal cart

Cyber IV was developed as an Autonomous Intelligent Vehicle (AIV), for the hospital market; and beta tested (1991) at the Lahey Clinic of Burlington, Mass., where it was promptly and affectionately named "Lab Rover." After beta testing was completed, Lab Rover has continued to remain "in service" for over two years, delivering biological samples to various labs, proving that a system based on this technology can be reliable and cost effective.

Cyber V

While Cyber V required no new major concepts, a range of enhancements, however, have been incorporated making the difference in terms of becoming product ready.

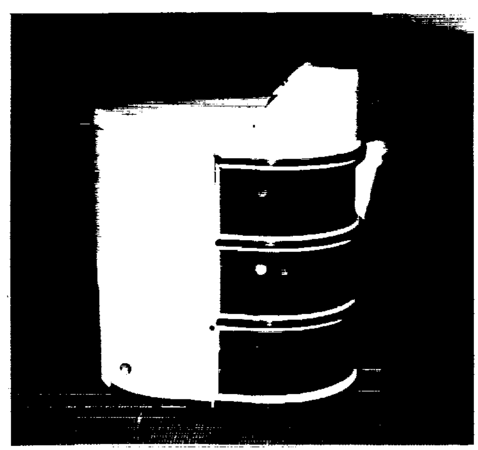
A major engineering effort was undertaken to reduce manufacturing and servicing costs, replacing expensive machined parts with one piece formed metal and molded plastic parts. An outer fiber glass shell allow for improved cosmetics and easy access to internal circuits. Pneumatic tires were replaced with solid tires, eliminating a nagging flat tire problem. Gel cells replaced liquid lead acid batteries. Gel cells, while more expensive initially, reduced battery service calls to zero. This eliminated the need to add water to the batteries on a monthly basis resulting in a net savings in service costs.

Particular attention has been placed on the human robot social interaction. The vehicle operates in the same space that people do. While people have developed a protocol for working in small spaces, they demand equal access and respect. Robot vehicles must do the same. They must be perceived as important contributors in the work environment. A timid robot vehicle will not gain respect. e.g.: When elevators were first introduced, people would hold the doors open, denying use to users on other floors. This presented an operational problem to elevator manufacturers.

A solution to the problem was to modify the elevator door controls so that they would automatically close after a prescribed amount of time. More aggressive doors would actually push people out of the way. The publics initial reaction to this modification was annoyance, but soon gained acceptance as a necessary behavior modification. We have found that adjusting the behavior of the robot vehicle to politely approach, but come very close to people blocking hallways, soon gained respect for the robot vehicle and people now, automatically, move out of its way.

Conclusion:

We believe that Cyber V is now ready for the market place and are now installing Cyber V systems in various applications. We expect that new problems may arise and solutions must be found. This technology is now ready for the commercial market place and are now shipping systems to customers and licensed OEM dealers.



LAB ROVER - CYBER V

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