PTS MONTHLY CHECKLIST

Submitted by: University of Michigan Report Month: DECEMBER 2000
Submitted to: U.S. Department of Engery/Albuquerque Office
TTP No.: ALO-7-C1-61 (UMichigan)

EARNED VALUE ANALYSIS DATA. *Check **one** box in Line A and **one** box in Line B.*

A. How is your project's schedule doing compared to your TTP baseline?

☒ 1X. As planned ☐ ☐

B. How is your project's total cost doing compared to your TTP baseline?

☒ 2.X As planned ☐ ☐

PTS NARRATIVE INPUT CHECKLIST. *Check that you have prepared the following narrative inputs:*

☐ 1. SIGNIFICANT ISSUES/PROBLEMS/CONCERNS:
Note if there are any problems; otherwise, state "None." Report only problems considered "showstoppers" or fatal flaws (i.e., a lack of funding will cause the project to be shut down).

None

☐ 2. CORRECTIVE ACTION:
If a significant issue/problem/concern in Section 1 above is described, this section is required; otherwise state "None needed."

None needed

☐ 3. SUMMARY ASSESSMENT:
This should be a BRIEF paragraph summarizing the overall status of the project. This section is a synopsis of the entire report.

During this reporting period, progress continued as expected on obstacle avoidance, position estimation, novel mobility concepts, as well as a vision for navigation and radiation imaging. Of particular note, we have experimented on one segment of the Omnipede platform, learning the importance of friction mitigation. The work in vision used a range sensor mounted on a mobile platform. Improvements in calibration procedures are described within. Fundamental research in understanding sonar reflections is described in this report, in binaural sonar and testbed studies. The results could yield significant improvement in obstacle avoidance. Finally, we are experimenting with a new obstacle avoidance technique that is less conservative for navigating through highly constrained openings.

☐ **4. COST VARIANCE:**
If you checked number 4 or 6 in the Earned Value Analysis section, *you must provide an explanation here.* Explain funding issues such as variances, carryover, commitments, incorrect FIS data. Avoid using only the words "Within budget." Some narrative is preferred.

Spending is balanced with funding.

☐ **5. SCHEDULE VARIANCE:**

If you checked number 3 or 5 in the Earned Value Analysis section, *you must provide an explanation here.* Note if the project is on schedule, ahead of schedule, or behind schedule. If behind, explain what is being done to bring the project back on schedule.

☐ 6. TECHNICAL STATUS:

This is likely to be the longest section of the narrative and describes the technical accomplishments during the reporting period. Provide enough detail to inform, yet avoid extensive details that can confuse the reader.

6.1 **Obstacle avoidance**

6.1.1 Binaural sonar techniques

This month's work dealt with improving the software for correlating the echoes from the transmitted signals. The scheme used by the software is based on the following procedures:

1. Each transmitted signal is categorized into one of eight categories according to the combination of short and long bursts (each signal consists of three bursts).
2. Each echo is divided into bursts, according to the procedure described in last month's report.
3. The time difference between the bursts is calculated. In addition, the relative size of the bursts is determined. This is done by comparing the number of cycles of each of three consecutive bursts. Based on the relative measurement, the type of the echo is determined.
4. The algorithm searches for a combination of signal type and time differences that match the perceived echoes. If it finds a series of three bursts that match a specific transmitted signal in terms of the signal's type and schedule it assumes that the echo is related to that signal and the algorithm calculates the range (based on three measurements of the three bursts).

Currently the system includes only two sonars (one transmitter and one receiver), therefore the current range of experiments is limited. In the experiments conducted so far the two sonars were located close to each other, similar to having a single sonar performing as a transmitter and receiver. The experiments included various types of reflectors (flat, cylindrical, smooth, rough etc.). Results with this setup show that the measurements were accurate regardless of the reflector's geometry and surface type. We are now in the process of adding additional transmitters and receivers to our system.

6.1.2 Obstacle Avoidance Testbed

UM has resumed its work with the Obstacle Avoidance Testbed. We recall that this testbed comprises a 4-meter (12 feet) linear motion table that allows us to move objects (i.e., obstacles) at controlled speeds toward stationary obstacle avoidance sensors, such as sonars. Work on the testbed was paused after the graduate student that had worked on the project left UM. We hired a new student, who has now learned enough about the project to continue.

In last month's work we investigated apparent inconsistencies in the linear motion table's response and found that that limited buffer length within the motion table's controller and a low baud rate of the serial communication were the problems. We have now worked around this problem by limiting the number of position inquiries to two per sonar firing: one after the sonar fires and one after an echo is received.

With this procedure in place we were able for the first time to fire the sonar and read echoes, concurrently with obtaining accurate distance and speed measurements from the motion table. This enabled us to compare the distance readings from the sonar with the readings from the motion table. We are now in the position to conduct formal experiments, measuring the exact relation between relative speed, distance, angle of incident, and sonar error.

6.1.3 New Indoor Obstacle Avoidance System

Over the past few month UM has made a new attempt at further improving its indoor obstacle avoidance system. In earlier years UM had developed the now widely used VFF and VFH algorithms. One known shortcoming of these methods is their "overcautious" behavior near very narrow openings. For example, an opening (like a door frame) that is only four inches wider than the robot is typically not recognized as a passable opening; rather, it is avoided like an obstacle.
To begin this new effort UM developed a simulator for testing new obstacle avoidance methods. During December the new approach developed in the simulator was tested for the first time on the real robot. The initial results are promising, indicating that the new approach has merit. However, it will likely take another few months of experimentation before we can decide whether the new approach is significantly better than the VFH method.

6.2 Position Estimation

UM is continuing its time-out with regard to the development of position estimation technologies in order to summarize and document our significant progress over the last two years.

6.3 Novel mobility concepts

6.3.1 OmniPede

We received back from the rapid prototyping shop our first OmniPede segment manufactured with a new laser technique. We have since machined this prototype segment and assembled the gears, shafts, and bearings. This working prototype has afforded us the opportunity to see where design modifications need to be made. Some of these modifications were performed this month, such as changing the dimensions of the body and the motion of the legs to insure the body does not interfere with the legs. Other changes will be made in the next prototype. Friction in the gears is a major issue with this first prototype and we are thinking of ways to reduce this friction. One of the options is to eliminate some of the gears by using belts or chains. Belts are particularly appealing because they can slip, thereby allowing a stuck leg to be uncoupled from the rest of the drive train. This should eliminate the possibility of one or two legs binding up the entire kinematic chain of the OmniPede.

We have attached a 24-volt motor to the segment to observe the motion of the legs and the required power. The motion of the legs matches the computer simulations. And we measured a current of around 80 mA to drive the four legs of the segment, resulting in a power requirement of 1.92W without external resistance.

6.4 Infrastructure

6.4.1 Multi-controller interface board

UM has completed the debugging effort for the last batch of ten MCIBs. These boards are now available for use in UM's growing fleet of mobile robots. Specifically, we are planning to install MCIBs on the OmniPede platform and on two ClodBuster platforms.

6.4.2 ClodBuster

UM is conducting a low profile effort aimed at converting commercially available radio-control model cars for use as mobile robots. The incentive for doing so lies in the relatively high price of commercially available small mobile robots like the Pioneer AT (~$4,000). Model cars of the same size cost under $400. UM has been experimenting for some time with one model car, called ClodBuster. This is a 4-wheel drive/4-wheel steer platform comparable in size to a Pioneer AT and designed to travel over rugged terrain. The foremost problem with such a conversion is the need to install optical wheel encoders for

odometric position feedback. Commercial model cars are designed for remote control, where no such position feedback is needed.
UM has now successfully installed sub-miniature optical encoders on its ClodBuster platform. We have also completed other conversion issues, such as the installation of our MCIB card which functions as the interface between the computer and the motor power amplifiers.

6.4.3 Conversion to Linux

We have successfully completed the conversion of all software on our Pioneer robots to Linux. We also implemented a remote control feature that makes it possible to log on to the robot's onboard computer from any other computer in the lab and run the onboard software remotely. This way we can either view only a text screen with real time updates of the onboard information or a graphics screen that shows the real time map building progress of the obstacle avoidance algorithm. The text version runs in a cycle time of 30ms. The graphics version is slow at the moment but it may be possible to improve that. However, for debugging (i.e., a non-runtime activity) we can use the graphics version.

6.5 Vision for Navigation and Mapping

December's progress has been directed toward improving the data acquisition accuracy of the structured light sensor:

- To improve calibration, we have built a 4x8 foot plywood calibration grid with painted markers at 4 inch intervals. The new calibration procedure consists of placing the grid at several known locations between 5 feet and 18 feet away from the sensor.

- Software has been written to take advantage of the new row and column striping system during the triangulation phase. Instead of computing 3D points as an intersection of a (camera) ray with a (projector) plane, the points are now computed as the halfway point between two (camera and projector) rays.

- Previous tests showed that specular reflections of the projected light off of the floor was causing false data. To reduce this effect, a polarizing filter was attached to the camera.

Using the above improvements, another trial run was performed. New calibration software was implemented to be used together with the new calibration grid, and calibration was performed. Within the expected range of viewing distances between 5 feet and 18 feet, accuracy was estimated to be within 1 cm. However, because we failed to increase the camera aperture to account for the reduced light levels due to the polarizing filter, a large amount of the data points had to be discarded.

After adjusting the aperture, the sensor was recalibrated, this time using a slightly larger number of calibration views (11 vs. 6). Then the calibration grid was removed and the Omnimate was manually positioned at 62 different positions and orientations within the laboratory. The encoder values for both front and rear truck were recorded at each location, and a total of 1 GB of data was captured. Total capture time, including manual positioning of the grid was 6 hours. Results are pending.

6.6 Radiation Detection and Imaging

To investigate "Industrial Gamma Ray Imaging," we are studying the necessity of redesigning the coded mask used in the existing hybrid camera to improve its angular resolution. The hybrid camera uses Electronic Collimation (EC) and Mechanical Collimation (MC) to cover a large gamma ray energy range. A coded mask is selected as a mechanical collimator since it can provide a large field of view and high efficiency for low energy gamma ray measurements, as well as at medium energies when combined with electronic collimation. However, the coded mask was initially designed for astronomy and space applications where only a far-field condition is encountered. Although coded mask has ideal imaging properties in the far-field case, this is not true for near-field cases. While the hybrid camera design is intended for far-field applications, the experimental setup in the lab may not satisfy this condition. Thus, it may be necessary to introduce an artifact-reducing technique.

☐ 7. MAJOR ACCOMPLISHMENTS:
Note MAJOR accomplishments during the reporting period; "None" is a valid, *occasional* entry.

Our paper (Shoval and Borenstein), "Measuring the Relative Position and Orientation Between Two Mobile Robot With Binaural Sonar," has been accepted for presentation at the ANS 9th International Topical Meeting on Robotics and Remote Systems," Seattle, Washington, March 4- 8, 2001.

MILESTONES. *Check that you have updated the status of your milestones.*

☐ 1. MILESTONE STATUS UPDATES:
Make sure you have provided a brief, one- or two-sentence comment on each active milestone and completion/new forecast date as appropriate.

No milestones were due this month.

DKW/pm/1-4-2001