PTS MONTHLY CHECKLIST

Submitted by: *University of Michigan* Report Month: *October 2000*
Submitted to *U. S. DoE*
TTP No.: *ALO-8-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?

☒ 1. As planned ☐ ☐

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

☒ 2. 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 "show-stoppers" 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.

Work is continuing according to schedule. As described below, we're looking at the details reflected sonar pulses for more information on the environment. Work on the obstacle avoidance test bed has resumed, and we are beginning work on the more difficult problem of perceptual obstacle negotiation. In the area of vision for navigation, a prototype sensor has been mounted on a mobile platform for data acquisition. For radiation imaging, Mich. has been working with Florida to execute joined imaging projects experiments here. Work is also continuing on improving and refining software for image reconstruction.

☐ **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.

Within Budget.

☐ **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

UM is continuing its investigation into a new method, in which ultrasonic sensors include a distinguishable “signature” within the burst of ultrasound they emit when “firing.” One of the problems we found is that when comparing the reflected signals to the original signals, the shape of the reflecting surface, as well as its texture and surface quality, affect the shape of the echo. After some experiments we concluded that it will be difficult to accurately relate each echo to its source, as real environments consists of various types of shapes, materials and textures. Furthermore, the angle of the reflector relative to the transmitter and the receiver further affects the shape of the echo. Typically the echo becomes wider as the reflecting angle increases.

To overcome this problem, we have begun the development of a method, in which a sonar transmits a coded signal that consists of several bursts, each consisting of various cycles. For example, if the code includes three bursts, and there are two types of bursts (short and long), there are eight combinations (e.g. short-long-short, long-short-short, short-long-long etc.). If there are three types of bursts (short, medium, long) there are 27 combinations. The advantage of this method is that the differences between the original signal and the reflected echo are similar to all bursts. If a short bursts consisting of six cycles becomes an echo of, say, 10 cycles, a longer burst of 12 cycles would become an echo consisting of 16 cycles. Another parameter that is not affected by the shape and type of the reflector is the time difference between the bursts. If, for example, the firing schedule is “short – 30μs pause – long – 40μs pause – short,” the echo is received with that same sequence, even if individual bursts are distorted. This method is similar to the Morse Code. The problem now is to compare the received bursts to each other in term of their length and sequence, and match it to the original signals.

During November we will develop algorithms to filter the echoes and sort them by bursts, measure the length and schedule of each burst, and then compare them to the original signals.

6.1.2 Obstacle avoidance testbed

UM is developing a tesbed for in-depth obstacle avoidance research. The testbed is based on a 4-meter long, computer controlled linear motion table. Different objects – representative for certain classes of obstacles – can be mounted on the moving part of the table. At one end of the motion table we have installed a pan/tilt table, onto which a variety of obstacle detection sensors can be mounted for testing. With this setup we can move “obstacles” toward the obstacle detection sensor at precisely controlled speeds, and at precisely controlled angles. More importantly, experiments are accurately repeatable, allowing for precise experiments and analysis of obstacle detection performance. Lack of such precise repeatability made it impossible in the past to analyze obstacle avoidance performance.

This project had been paused for several months to accommodate more pressing technical issues, but we are now in a position to continue this work. During the last month a new student familiarized himself with the software and hardware of the project, and we expect him to continue doing so during November.

6.1.3 Perceptual Obstacle Negotiation

UM is starting a new effort aimed at developing obstacle avoidance capabilities for mobile robot operation on rugged, outdoor terrain. This is a major new area of interest, and it deserves some explanation. Roboticists differentiate between different obstacle-related behaviors, but the terminology used to describe these behaviors is often confusing. To avoid this confusion we clarify the following terms:

- **Obstacle detection** (OD) – The ability of a mobile robot to detect the presence of an obstacle.
- **Obstacle avoidance** (OA) – The ability of a mobile robot to circumnavigate a detected obstacle. This behavior can range from *reflexive* (i.e., with minimal knowledge of the environment, no planning) to *planned* (i.e., knowledge of the environment is used to plan a path such as to avoid dead ends).
- **Obstacle negotiation, *Perceptual*** – The ability of a mobile robot to decide whether a detected obstacle can be traversed or whether it needs to be circumnavigated. This ability depends on the performance of the above OD/OA sensors and the data-processing algorithms associated with these sensors.
- **Obstacle negotiation, *Physical*** – The physical ability of a mobile robot to traverse obstacles. This ability depends on the kinematic attributes (such as wheeled, tracked, articulate, etc.), the dynamic attributes (such as velocity, acceleration, inclination, load distribution) and the control software.

The problem of perceptual obstacle negotiation can be broken down into the following sub-problems:

a. Raw performance of the sensors used for OD/OA.
b. Extraction of *relevant* sensory data and creation of maps based on the extracted data.
c. Planning, based on the sensory data map.

We believe that the bottleneck in perceptual obstacle negotiation performance is caused by sub-problems (a) and (b). Typical sensors for OD/OA are stereo vision, laser scanners, sonar, infrared, and radar. The shortcomings of each of these sensor modalities are widely known and we will not recount them here.

Problem b, however, is probably the more challenging of a and b. This is because on rugged terrain, *anything* other than smooth, flat, horizontal ground is – at least potentially – an obstacle. Therefore, detecting an obstacle is typically not something accomplished by a single sensor in a discrete sensing event, like, for example, detecting a vertical wall while performing indoor OD/OA. Rather, for perceptual obstacle negotiation a topological surface map *must* be generated and rules based on vehicle dynamics and kinematics must be applied to that map in order to decide whether a given surface feature can be traversed or not. Generation of such a map is a formidable difficulty, especially with sensors mounted on a low-profile, fast vehicle.

We are currently reviewing the literature for commercially available 2D or 3D laser range finders suitable for this purpose. We are also negotiating with a researcher, Dr. Cang Ye from the University of Hong Kong who has several years of experience with perceptual obstacle negotiation. We believe that he will significantly accelerate progress in this project.

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. We have now identified material within the newly written documentation that may be suitable for publication at a conference and possibly in a professional journal.

6.3 Novel mobility concepts

OmniPede

The OmniPede project is temporarily halted because the student that had worked on the project has graduated. UM has identified and hired a new student to continue this project. The new student has now had the opportunity to work with the graduating student, to assure a smooth transition.

The UM Technology Management Office (TMO), the UM-internal office that helps with the filing of patent applications, has indicated its intent to file a patent for the OmniPede invention, pending a thorough review of the prior art.

6.4 Vision for Navigation and Mapping

We have completed porting our calibration and triangulation code for the structured light 3D sensor to the PC/Windows platform. This port involved rewriting about 2000 lines of code from Matlab to C, and took about 4 weeks to accomplish. The code is integrated with framegrabber support code, installed, and tested on the final hardware platform. Our calibrated sensor can now capture a 3D view without human intervention in about 10 seconds.

Prototype testing indicates that the projector can maintain sufficient focus over a field of depth of about 5' to 25', with a field of view of approximately 15 degrees by 30 degrees. A 12mm lens with a baseline of about 1.5 feet was found to be an appropriate compromise. The camera has been securely mounted on the Omnimate robot, but we have not yet constructed a secure mount for the DLP projector. The first round of first tests will start in early November. These tests will be used to find out (1) how do vibrations from a moving robot affect the sensor calibration, (2) what is the best travel distance between views, and (3) how to tune the sensor parameters for mapping of an indoor environment. A second round, planned in late November will be used to acquire data that will actually be used to construct the map.

6.5 Radiation Detection and Imaging

University of Michigan and University of Florida researchers have met and planned joint radiation imaging activities. A Florida professor will be traveling to Michigan to perform an imaging experiment utilizing the facilities at the Ford nuclear reactor during November 2000. Michigan is working to provide a radiation imaging camera and radioactive sources to test the Florida imaging algorithms.

Work continues on isolating those factors which can enhance the performance of the new hybrid gamma camera. Utilizing improved system modeling, we have documented a significant improvement in the quality of reconstructed images from this device.

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

Professor Wehe attended the DOE Radiation Detection Technologies for the National Security Community Workshop in Las Vegas, NV to discuss mutually-interesting radiation imaging technologies. Professor Wehe also presented papers at the 2000 IEEE Nuclear Science Symposium this month.

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.