

MONTHLY REPORTING CHECKLIST

Submitted by: University of Michigan Report Month: March 2001  
At request of U. S. Department of Energy/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?

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 "showstoppers" or fatal flaws (i.e., a lack of funding will cause the project to be shut down).

No significant problems.

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 past month, work has continued in robust navigation, sensing, and radiation imaging. A new indoor obstacle avoidance algorithm is being implemented and tested. The novel OmniPede vehicle is continuing development, with construction of a prototype. A robust platform based on a commercial ATV has been acquired and work has begun in transforming it to drive under internal control. The vision work for navigation is continuing, with work on understanding previously acquired data. The work on the radiation imager continued with testing of the RMD ultracompact imager and repair of its predecessor, our PSD2 imager.

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.

## 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.

## OBSTACLE AVOIDANCE

### Binaural (coded) sonar techniques

We have now successfully installed three Pico dual-digital oscilloscopes in the control PC. After some problems running the three boards simultaneously, the system is now working properly using the Borland C compiler. While testing the system we noticed that the response time of the scopes to the commands from the computer is relatively long (for some commands it may take as long as 250  $\mu$ seconds to execute). In the earlier, single-scope system we used the trigger signal from the firing sonar to start sampling data with the scope. However, this approach can't be used with our new triple scope system since each scope may need to receive a different trigger. To overcome this problem we used a digital signal generated by a computer I/O line.

In order to fire the six sonars according to the precision timing sequence that is required for our new binaural technique, we will be using the Assembler code from the earlier developed EERUF code. Specifically, we will use the implementation of the so-called firing schedules from the ERRUF code. We are still working on the new sonar board and sonar design needed to implement the binaural sonar experiment. We expect to complete the hardware work shortly and begin with the actual experiment.

### Obstacle Avoidance Testbed

Last month we completed the implementation of our unique obstacle avoidance testbed and we began the first round of actual experiments. In this set of experiments we mounted an 8-foot wide piece of plywood on the motion table so that it faced the ultrasonic sensor while moving toward or away from the sensor. We then ran numerous sets of experiments, in which the plywood was moved toward the sonar, through the whole range of motion of the motion table, that is, from about 3.5 m distance to 50 cm distance between the plywood and the sonar. After each completed run the plywood returned to its starting position and the sonar was rotated 2 degrees away from its original direction perpendicular to the face of the plywood.

The result of this experiment is a rich data set that shows under which geometric conditions the plywood wall was detected by the sonar. We found an excellent match with the experimental baseline data available from Polaroid, and we believe that with the testbed we have an powerful tool available for in-depth experimentation that goes well beyond the type of experiments reported from other research facilities.

Based on the early results of our experiment we decided that a fundamental improvement in the utility of ultrasonic sensors could be achieved if it was possible to shape the sonar wavefront propagation cone so as to make it narrower than its formal specification of 15-80 degrees (corresponding to the published specifications of the primary through tertiary lobe).

We conducted a literature survey of techniques designed for reducing the beamwidth of the primary lobe and also eliminating/reducing the secondary/tertiary lobes. Some of the methods found included acoustic horns, waveguides, and phased arrays. We found a commercial product, the Dimension Master Plus, which consists of three modified Polaroid ultrasonic sensors in a 2-D array configuration. The

manufacturer claims that this device produces a very narrow beam width of 2 degrees. We ordered and received this product and we will test it on the testbed during the next month to verify its claims.

## **Position Estimation**

### **Coriolis Gyroscope**

We have begun analyzing the extensive data collected with the Coriolis gyroscope. However, our results so far are not encouraging: It appears that the static bias drift changes dramatically (compared to our reference fiber-optic gyro) with temperature. Furthermore the scale factor shows clear evidence of non-linearity, but from the collected data we haven't been able to find a good compensation model. We should emphasize, however, that the Coriolis Gyroscope is very inexpensive, and we are investigating its utility for precision navigation because it would be very desirable to have a low-cost, small, and light-weight gyro for installation on low-cost, small robots.

## **Novel mobility concepts**

### **OmniPede**

The three new segments, rapid-prototyped using Selective Laser Sintering (SLS), have arrived and we have been working on machining and assembling these new segments. After constructing the original first segment we found that the dimensional tolerances of the SLS process, +/- .015" are not sufficient for the proper meshing of the many gears and moving parts in the OmniPede. For this reason we adopted a new approach to constructing the three new segments. The critical features in the segments are no longer fabricated using SLS, as in the original segment assembled; instead we are now machining these features.

This method allows us to create these features with a tolerance of +/- .001". The improved precision will reduce the friction in the segments and it will insure uniformity between the motion of the 12 legs of the OmniPede first prototype (4 legs for each of the three segments in the first prototype). Uniform motion of the legs is not critical for the OmniPede to walk, but it will be important for the OmniPede to walk in a straight line. This new method of constructing the OmniPede offers many improvements in the quality of the segments, however it also requires more time to manufacture.

While most of our effort last month was devoted to the construction and assembly of these three segments, we have also worked on some other tasks. We completed a design for mounting the single motor that will be used to power all legs of the OmniPede. We also found a few papers on the control of snake-type robots, which may impact our current ideas of how the joints connecting the segments should be actuated. We will revisit these ideas after completing the next three segments and demonstrating the walking ability of the shoveling motion used by the OmniPede.

## **Infrastructure**

### **Gorilla Mobile Platform**

We have received the Gorilla electric utility vehicle that we ordered last month. We have since begun looking for sensors and actuators that will enable the Gorilla to be controlled by a computer. We have now identified a suitable motor and gear head that can handle the 25 ft-lbs torque required to steer the front wheels of the vehicle. Our design considerations apart from the torque were: source voltage 24 Vdc, speed 2 rpm, and maximum size 10" length x 4" diameter.

In order to implement the all-important odometry on this vehicle we intend to use an internal gear of matching diameter and mount it inside the rear wheel rims. The gear can then be meshed with a conventional incremental optical encoder. Alternatively we are considering the use of a miniature inductive proximity sensor that can detect the teeth of the internal gear and produce a binary pulse for each gear that passed by the sensor head. The advantage of the encoder approach is the higher pulse count per revolution. The advantage of the proximity sensor approach is its resilience to dirt that would likely be picked up during travel over rugged terrain.

## **Software development environment on mobile robots**

### *Installation of TCP/IP on DOS operating systems*

Last month we acquired wireless Ethernet cards in order to provide a faster and more reliable connection between on-board and off-board computers. The manufacturer of the wireless Ethernet cards claimed that they support the DOS operating system. We found, however, that this was true only to a very limited extent. As a result, the seemingly simple task of setting up a wireless network became a time consuming job and there were numerous problems that we had to solve before the DOS based wireless network worked to our satisfaction. There are several components that have to be installed in order to establish a TCP/IP network in DOS: 1. Socket services, 2. Card services, 3. Client or enabler, 4. Low level protocol (packet drivers), and 5. High-level protocol (TCP/IP libraries and applications). From this list, only components (3) and (4) were provided by the manufacturer, the remaining pieces of software were supplied by third parties and the main problem was to make all the components work together. After a considerable effort we were able to establish a TCP/IP wireless network under the DOS operating system.

### *Windows timing*

Because of the persistent difficulties of finding device drivers for computer peripherals that work under DOS, it would be highly desirable to work under Windows. This is because virtually any peripheral designed for IBM-PC type computers comes with Windows drivers. The well-known problem with software development under Windows, however, is that real-time control of mechatronic devices requires that the developers' program has complete control over the timing of all events. Under Windows this is not typically possible, because the Windows operating system controls the timing of events and may execute background tasks at any time that may interfere with the execution of the primary control task.

After researching this issue we found one company that has developed a Windows timer library (called "ExactTicks"). The company claims that this library provides microsecond resolution timing while running under Windows. In order to test this claim we developed a basic set of test functions using the ExactTicks library. Our results show that with these library routines it is indeed possible to *measure* the duration of any event with microsecond accuracy. One problem, however, is that tasks don't always perform at the exact specified time the programmer intended. This condition makes it questionable that all time-critical real-time control programs can be implemented this way. However, even though events can't be guaranteed to happen at the intended instant, a program can measure, at least, how long the event was delayed. While we intend to do more testing on this subject, we feel for now that it is feasible to use these Windows-based timing functions in non-critical applications, such as the development of basic calibration and test programs, for which timing is important but not critical.

## **ClodBuster**

We completed the installation of the optical incremental encoders on the ClodBuster wheel hubs. We also completed the installation of the MCIB on the ClodBuster. We successfully tested the wheel encoders using the MCIB software. Additional work included the installation of a HITEK 4-channel R/C receiver to control motors and steering manually and the installation of a single electronic speed control for both motors. We further added an emergency kill switch that operates independently of the HITEK R/C system.

## Vision for Navigation and Mapping

We have run experiments on the multiview registration algorithms using the synthetic cruiser data set, and fixed several software defects. Our software now works well for multiview registration about a single cycle. Next, the data that we captured in December '00 was recalibrated, examined, and run on the multiview registration. This experiment failed because the pairwise algorithms failed to find a good registration. We believe that this is probably due to the use of distance-based thresholding, instead of the view-based thresholding we used in the cruiser data set. To test the view-based thresholding, we will need to spend some additional effort to extract the center of projection and field-of-view parameters from our calibrated setup.

## Radiation Detection and Imaging

Work focused during this past month on upgrading the PSD2 gamma ray imager. The problem experienced was the failure of one electronic chip that is no longer manufactured. We're searching for equivalent replacements, but may need to redesign the electronic interface board entirely.

We also served as the testbed for the RMD ultra compact imager. We set up various environments in which our robotic platforms were used to carry their imager throughout radioactive environments within the Ford nuclear reactor and Phoenix Memorial laboratory high caves. Excellent images, both optical and radiation, were obtained. Their prototype imager is a spin off design from the PSD2 camera developed under this grant.

### MAJOR ACCOMPLISHMENTS:

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

We presented the paper: Shoal, S. and Borenstein, J., 2001, "Measuring the Relative Position and Orientation Between Two Mobile Robot With Binaural Sonar" at the ANS 9th International Topical Meeting on Robotics and Remote Systems," Seattle, Washington, March 4- 8.

**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 due this month. All milestones are on track for completion.