

MONTHLY REPORTING CHECKLIST

Submitted by: *University of Michigan*
Submitted to: *US DOE/Albuquerque Office*
TTP No.: *ALO-7-C1-61 (UMichigan)*

Report Month: *February 2001*

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).

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 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. The vision work for navigation is continuing, with a patent application recently submitted. The work on the radiation imager continued, with simulations identifying the critical limiting factors with the existing hardware.

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 ordered and received two additional Pico digital oscilloscopes for sampling another four channels of sonar data (for a total of 6 channels). We have been able to write code that reads high-speed data from these scopes but we have not yet been able to read all six channels concurrently, as will be required for our application. We are still trying to resolve this problem.

Obstacle Avoidance Testbed

We made some final improvements to our testbed software before beginning the actual experiments. The main improvement involved a modification to allow the target object to be in motion while the sonar was firing, whereas before the target object had to be stationary when the sonar fired. With this improvement in place a complete set of experiments (described below) can be completed in a fraction of the time it took before.

In order to implement this modification correctly it was necessary to estimate the object's momentary position during motion. The complication here is the slow serial communication between the control computer and the motion table controller, which causes uncertainty about the actual position of the moving object at the time the control computer issues a position data request to the motion table controller. We have determined that the bounds for this uncertainty is ± 4 ms, corresponding to a potential ± 4 mm position error when moving at 1 m/s. This potential error, however, is not significant for the purpose of our experiments.

In our finalized testbed program the motion table moves a target object linearly within a range of 0.5 – 3.5 m. Concurrently the program acquires one sonar reading for every 25 mm of object travel. At the end of each linear run the motion table returns the object to its starting position, the pan/tilt table increments the direction of the sonar (i.e., the panning angle) by 2 degrees, and the object is moved again through the whole range of 0.5 – 3.5 m. Using the testbed in this fully automated fashion allows us to characterize the object detection pattern of the sonar within just a few minutes, for any given obstacle.

After completing the software development for the fully automatic test procedure explained above, we are now beginning to produce the first full sets of experimental data. Our efforts at this time aim at developing data representations that can show the relevant information contained within the large amount of measurement data obtained in each experiment.

New Indoor Obstacle Avoidance System

In continuation of our experiments with the so-called Random Firing Algorithm (RFA) we fully integrated the algorithm with the obstacle avoidance software running on the Pioneer robot. However, results of actual obstacle avoidance performed with the robot while running the RFA algorithm did not show the expected improvements. This is so despite the fact that our earlier tests showed a 20%

improvement in the effective firing rate with the RFA algorithm. We are still investigating several theories explaining this behavior, but we are discouraged by this result and may choose not to use the “improved” method on our robots.

Position Estimation

Sensor Alignment

In earlier work UM developed a highly accurate yet low-cost dead-reckoning system. In its most basic configuration the system is designed for indoor use on flat, horizontal floors. In this configuration only a single-axis fiber-optic gyroscope for measuring the heading angle is used, along with wheel encoders for odometry. The only alignment issue for this configuration is the placement of the gyro so that it is perfectly parallel to the floor.

A more advanced version of our existing dead-reckoning system is designed to function on rugged terrain. For this application environment the system requires three gyroscopes, two accelerometers and two or more encoders. In our earlier work we found that the alignment of the sensors with respect to each other and with respect to the body of the robot is a formidable challenge. Even small inaccuracies in alignment can cause comparatively large errors, especially if the whole system is otherwise highly optimized for great accuracy. In the past we aligned sensors using a cumbersome and time-consuming procedure that involved the use of a rotary table and countless test runs with the sensors mounted on the robot, until a reasonable alignment could be achieved.

We have now researched the literature for algorithms and techniques that could be used for streamlining the sensor alignment problem. Our first approach was focused on finding mounting hardware that facilitates this task. We found commercial mounting plates that are used in the optics industry to align mirrors, and that are suitable for use as sensor alignment in our case. We also found an interesting alternative approach that does not require a very accurate physical sensor alignment. Instead, that method uses a sophisticated mathematical algorithm to compensate for any sensor misalignment. We have begun testing these different approaches and will evaluate the test data in the next few weeks.

Coriolis Gyroscope

In earlier work with our dead-reckoning system for rugged terrain we used an accurate but expensive fiber optic gyro for the critical heading information, but we used inexpensive Coriolis-type gyros for measuring tilt. This is because inaccuracies in tilt measurement affect the overall dead-reckoning accuracy one to two orders of magnitude less the inaccuracies in heading information. In our earlier experiments with the Coriolis gyros we determined that these devices are useful only for relatively short missions, because of their high drift rates.

We have now begun to re-evaluate the Coriolis gyros. Our first step in this direction was the use of a high-accuracy fiber-optic gyro as a reference for the exact calibration of the Coriolis gyro. After this precise calibration we found that the performance of the Coriolis gyro improved significantly, enough to warrant further efforts aimed at improving the utility of these low-cost devices. We will conduct these additional experiments in the next few weeks.

Novel mobility concepts

OmniPede

We have completed the revisions to the OmniPede drawings and ordered the three new segments to be manufactured by the same company that had built our previous prototype. Several aspects of the new design were improved over the previous version. Gear shafts that were supported by only one bearing are

now supported by two bearings; this will reduce some of the play in the legs. However, this play cannot be completely eliminated because of backlash in the gears. The frame was also modified for the use of belts or chains in place of gears and for a new air cylinder mount that will eliminate the lateral force on the piston that was present in the old design. Also, the frame was made lighter by removing excess material.

The majority of the parts that we ordered last month have arrived, including the belts and pulleys to replace the gears. We tested these belts and found that they reduced the friction in the segment and subsequently lowered the required power for driving the legs from 1.5 watts to 1.0 watts. The belt and pulley replacement did not, however, provide the benefit of slippage during overload, that we had hoped for.

The new student working on this project also completed a machine shop course that will help him with the assembly and the inevitable modifications to the three new segments, once they are made by the rapid prototyping company

Infrastructure

Gorilla Mobile Platform

UM has decided to purchase a new mobile platform for the upcoming work on indoor obstacle negotiation (ION). We recall that ION is aimed at avoiding obstacles on normally man-made, smooth indoor or outdoor ground, but with the ability to traverse debris or other relatively small irregularities on the ground. UM feels that these environmental conditions most closely match those found at many DOE remediation sites.

Because ION requires the ability to traverse debris and other irregularities, but on the other hand does not require full off-road motion capabilities, we decided that an electric utility vehicle would make an ideal development platform. We specifically identified a commercially available, one-person utility vehicle called "Gorilla" to meet our requirements. The Gorilla is slightly smaller than a conventional one-person all-terrain vehicle (ATV), but its handlebar-steering and driver position are identical to those of an ATV.

Conversion of the Gorilla to computer-controlled operation will require some work, notably in designing suitable steering servo drives to rotate the handlebar and controlling the breaks. On the other hand, control of the motor does not require extensive modifications, because of the already existing electric power control system on the vehicle. Nonetheless, the off-the-shelf vehicle costs only \$4,800 fully equipped, which is only a small fraction of the cost of an off-the-shelf mobile robot platform of similar size and power.

ClodBuster

We continued the conversion of our Clod Buster radio control 4-wheel drive/4-wheel steer truck to a fully autonomous mobile platform. We installed the MCIB motion control and sonar interface unit on the vehicle and we installed the appropriate software development environment on a Toshiba Libretto sub miniature notebook computer. Once the complete development environment software is installed, the Libretto will be permanently installed on the Clod Buster.

Vision for Navigation and Mapping

We have made additional progress in the theoretical analysis of multiview registration. When views are arranged in a graph, with edges in the graph corresponding to pairwise registration results, we are able to make the graph consistent by repeatedly applying a closed-form optimal solution to cycles within the graph. In order for all possible closed paths to be consistent, we must carefully choose these cycles. We have a method that chooses a set of cycles such that if rotations about the set of cycles are consistent, then the rotations about any closed path in the graph will be consistent. Further, we have shown that the repeated application of the closed-form solution converges, and therefore may be used in the design of a stable algorithm.

Our other progress has been to perform additional experiments on the feature-based registration algorithm to:

- (1) provide additional evidence of improved performance
- (2) provide better visualization of the size of the convergence region
- (3) provide a comparison of the three feature classes

The details of these experiments have been incorporated into a revised paper sent to IEEE transactions on pattern analysis and machine intelligence.

Radiation Detection and Imaging

To investigate “Industrial Gamma Ray Imaging”, we are studying the literature to look for candidate materials to replace detectors in the existing hybrid camera. The hybrid camera uses Electronic Collimation (EC) and Mechanical Collimation (MC) to cover a large gamma ray energy range.

The existing hybrid camera’s overall angular resolution is still not optimal although the existing camera proves that hybrid collimation outperforms either electronic collimation or mechanical collimation. The main reason of this poor angular resolution comes from the poor performance of the existing detectors --- poor intrinsic spatial resolution of both detectors and poor energy resolution of the second detector. The poor spatial resolution is directly translated to poor angular resolution. The poor energy resolution of second detector eventually prevents the use of energy information from the second detector in the image reconstruction. From results obtained this month, our simulation shows that including this information could dramatically improve the system angular resolution.

However, as the camera is for practical DOE use in situations with limited radioactivity, we also need high efficiency. We are looking for new materials and detectors that have both good spatial resolution and energy resolution without losing efficiency compared with the existing camera.

7. MAJOR ACCOMPLISHMENTS:

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

None.

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/3-5-01