PTS MONTHLY CHECKLIST

Submitted by: University of Michigan Report Month: November 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   [ ] 3. Slower than planned   [ ] 5. Faster than planned.

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

[2.X] if we As planned   [ ] 4. More costly than planned   [ ] 6. Less costly than 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, work continued on obstacle avoidance, position estimation, novel mobility concepts, as well as a vision for navigation and radiation imaging. Of particular note, we have received and assembled one segment of the Omnipede platform. The work in vision used a range sensor mounted on a mobile platform. Improvements in calibration procedures should improve these images further. Fundamental research in understanding sonar reflections is described in this report. The results could yield significant improvement in obstacle avoidance techniques.

[ ] **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

After developing a basic approach to coding sonar signals in a Morse Code-like fashion during October, we have now started working on developing an algorithm to analyze the coded echoes and try to relate them to the transmitted signal. In the first stage the system transmits three ultrasonic signals, each consisting of either a short burst (6 cycles) or a long burst (24 cycles). The sequence of the signals is selected randomly by the computer (e.g. short-short-long, long-short-long, short-long-short etc.). In total there are eight possible combination. The time delay between each signal can also be selected randomly, but for simplicity it is set to constant (0.4 msec). Next, the receiver digitizes the received echo into a sequential buffer. The buffered data stream is then analyzed by the computer according to the following procedure:

1. Detect all peaks of the echo signal.
2. Filter out peaks that are below a threshold value (currently a constant value set as the equivalent of 0.4V).
3. The peaks are divided into ultrasonic bursts and bursts are divided into signals based on the following criteria:
    i. The time difference between two consecutive peaks is verified to be between 17-23 μs, in accordance with the frequency at which the ultrasonic signal is being transmitted. Consecutive peaks not meeting this criterion are excluded from further consideration. The system also accepts two consecutive peaks if the time difference is 34-46 μs for the case where a peak had been lost either when transmitted, reflected, or detected.
    ii. The number of peaks in each burst is counted, and the time at which the first peak occurred is recorded.
    iii. If the time difference between bursts is within a range of 0.35-0.45 ms (bursts were fired 0.40 ms apart), then the system concludes that the bursts were fired from the same transmitter and therefore belong to the same signal.
4. The relative number of peaks in each burst of the same signal is counted to determine the sequence of the signal (in terms of short and long bursts).
5. Once the echo is related to the transmitted signal, the TOF is calculated. In fact, each calculation consists of three TOFs, one each for the respective burst. If no error occurred in the process, then the three ranges determined by each signal should be similar.

Based on our preliminary results with this method we believe that it is worthwhile extending this system to a more practical one that employs eight transducers.

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

The new graduate student that has taken over the OmniPede project has completed his transition time and is proceeding with the construction of one segment of the Omnipede. He has implemented several changes, including the decision to have the main body of the Omnipede rapid prototyped as one solid

segment, as opposed to splitting the segment in half for easier assembly. Consequently we revised the CAD drawing files and submitted them to rapid prototyping companies for quotes. The quotes ranged in prices from $1,200 to $3,000 for the body of the Omnipede and four legs. However, one of the companies offered to manufacture the parts as a donation. They fabricated the parts using SLS (Selective Laser Sintering). The material used by this is company is Duraform, which has similar mechanical properties to Nylon 6-6. Because of the warping and large tolerances associated with rapid prototyping the holes for bearings were undersized so that they could be drilled and reamed to the correct sizes. We have since done this, and we have inserted the 24 bearings that one segment of the Omnipede requires. We have also cut the shafts and inserted set screws in the gears. Throughout this process we took note of the various changes that will be implemented in the next segment. Most of the changes are related to easier assembly and reducing the weight of the segments.
We expect to obtain several results from assembling one segment of the Omnipede.

1. Verification on the spatial relationship between the gears, shafts and legs to insure that there is no interference and that friction is reduced to a minimum.
2. Verification on the proper motion of the legs.
3. Estimates on the power consumption of the segment.

Item 3. is indeed the most critical issue. We have procured a DC motor with an encoder that will facilitate in these tests.

6.4 Infrastructure

6.4.1 Multi-controller interface board

UM is currently building and debugging a new batch of the UM-built Micro-controller Interface Boards (MCIBs). The MCIBs are very compact hardware units that implement many of the motor and sensor control functions needed on a mobile robot. Our lab uses these boards on most of our mobile robots.

The assembly of these highly miniaturized boards is actually done by a commercial assembly house because we have designed the boards with miniature components that are difficult to work with without special tools. Last month we spent an unexpectedly large amount of time on debugging these boards because it appears that there are intermitteant problems with this latest batch. Boards from earlier batches worked all right.

6.4.2 Conversion to Linux

We have begun the process of switching our operating system for our robot onboard computers from DOS to LINUX. This move has become necessary because of inherent limitations of the DOS operating system (lack of device drivers, limited use of memory, and a 16-bit instruction set). Since this conversion deeply impacts all operations at the lab, we focused substantial resources on this job.
W reorganized the software in such a way that the low-level function calls (serial and parallel communications, use of the real time clock, screen output) were insulated from the high-level routines (control, positioning system, obstacle avoidance, mapping). This modification reduces the time and effort required for porting the program to Linux or any other operating system. We made an extra effort to make the software portable and compilable in both DOS and LINUX. Since the programs were already working in DOS, being able to run them under two different operating systems is an advantage.

So far the programs have been compiled and they run under LINUX but we have not yet tested them extensively. Since LINUX is a multitasking operating system, its real-time capability has to be evaluated carefully. Specifically we will need to conduct more tests in order to verify and demonstrate that our real-time control programs perform better and faster than under DOS. We have also installed LINUX on the Librettos PCs onboard both of our Pioneer AT platforms and we made the necessary changes in the software to make it compatible with the LINUX libraries.

6.5 Vision for Navigation and Mapping

The first trial run using the range sensor mounted on the Omnimate robot has been performed. This trial run uses an enhancement to the stripe generation software to perform both row and column striping, which allows us to rotate the camera and capture a greater vertical field of view. We can now capture a vertical field of view of approximately 10 feet at a distance of 10 feet. Vibration of the camera and projector appear to be well damped, and are not likely to cause significant error. Also, we found that a travel distance of about three feet between views seems to give a sufficient overlap. However, there was considerable distortion in the reconstructed views due to poor calibration, which prevented us from running a second trial run. While reconstruction was good in the region near the distance to the calibration target about six feet away, errors greater than one foot were recorded at twelve feet. To deal with this, we will first attempt to use multiple images to better estimate intrinsic parameters of camera and projector. If this does not work, we will use a larger calibration setup, placing markers evenly within the entire sensor field of view.

6.6 Radiation Detection and Imaging

To investigate "Industrial Gamma Ray Imaging," we are focused on adapting an "improved system response modeling" method for list mode most likelihood imaging reconstruction algorithm, developed by Wilderman *et al*., into a hybrid camera. The hybrid camera uses Electronic Collimation (EC) and Mechanical Collimation (MC) to cover a large gamma ray energy range. Improvement of the angular resolution of existing hybrid camera would be highly desirable for most applications. The improvement can be achieved in 3 ways: more accurate modeling of the system through a reconstruction algorithm, better spatial resolution for the detectors, and better energy resolution for the detectors. We are now focused on the image reconstruction algorithm.

The image reconstruction method used on hybrid cameras is List Mode Most Likelihood method. The algorithm actually has 2 steps -- building the system matrix based on measured data first, and then solving the equation for source distribution by using iterative Most Likelihood method, where the equation describes the whole system as: <u>*source distribution*</u> = <u>*system matrix*</u> * <u>*measured data*</u>. We adopt Wilderman's algorithm, which unlike the thin-cone algorithm used in the existing hybrid camera, explicitly takes in account the detector energy resolution in building the system matrix. We applied this new algorithm with the data collected from existing camera for the EC mode image reconstruction and the results show great improvement over the thin-cone method.

To adopt the new algorithm for Hybrid Collimation (HC) mode image reconstruction, there are 2 additional steps: accounting for the mechanical collimator's attenuation factor when building the electronic mode system matrix, and stacking EC matrix with MC matrix as a hybrid system matrix. We tried applying only the first step into the new algorithm, the results don't show any significant difference from EC only image reconstruction. We also tried applying the second step, stacking the matrices, into the thin-cone algorithm, the HC mode reconstructed images show big improvement over EC reconstruction. We expect that applying step 2 into the new algorithm could further improve the HC image reconstruction over the EC reconstruction.

The problem we have now is that the algorithm crashes after stacking EC and MC matrices into one hybrid matrix. The reason for this crashing is that the new algorithm looks at neighborhood pixels in the equation solving step. While the neighbors are clearly defined in the EC matrix and data, they are not applicable in the MC part of the hybrid matrix. It will probably be necessary to force the algorithm to stop looking at neighbors whenever it gets into the MC part.

The reconstruction algorithm is the greatest source for improvement of existing camera. The next step after finishing with algorithm will be to design and build a new camera to achieve further better angular resolution. We have done analysis that proves higher detector spatial resolution and energy resolution could further improve system angular resolution. Moreover, when the detectors' energy resolution is good enough, we can use the camera to measure unknown energy gamma rays.

UM also performed imaging experiments with the UFL at our nuclear reactor facility. The results of these demonstrations will be reported next month after we have had a chance to process and review the data.

☐ 7. MAJOR ACCOMPLISHMENTS:

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

Our paper, Chung, H., Ojeda, L., and Borenstein, J., 2000, “Accurate Mobile Robot Dead-reckoning With a Precision-calibrated Fiber Optic Gyroscope” has been accepted for publication in the IEEE Transactions on Robotics and Automation.

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.

pm/12-05-00