We continued our work on perception-based planning and execution:

- In the area of visual tracking, Greg Hager and his students have demonstrated the ability to perform distraction- and occlusion-resistant tracking of closed contours. The novel features of our approach are: a foveal/peripheral approach to image processing that is used to detect approaching contours, and a discrete-event system which is used to predict the possible appearances of a feature if an approaching contour were to cross it. Tests of the system have shown it to be extremely robust to distractions (objects moving behind the tracked target) and robust to occlusion provided sufficient unoccluded area remains to maintain contact with the contour. We are currently working to improve the performance of the system, and to incorporate these ideas into other systems using feature tracking.

- In the area of visual servoing, we have for the first time demonstrated full six degree-of-freedom visual servoing using calibration insensitive feedback algorithms. Based on this demonstration, we are designing a more ambitious visual servoing system that will support fast and easy reconfiguration for a variety of manipulation tasks.

- Sean Engelson completed the experiments for his dissertation on robot mapping. The last experiment involved the “trash collection” domain, a simulated world in which the robot had to find randomly strewn pieces of trash and find trash cans to put them into. The experiment compare the behavior of Engelson’s map-based planner with a purely reactive system that search randomly for a trash can each time. The map-based system recorded the positions of trash cans when first sighted, and was able to navigate back to them later. At first, the two systems performed about equally well, because they both tended to find trash near a can. As trash was collected, however, the map-based system did much better, because the time it took to find a can did not rise precipitously. These results will be reported at greater length in a journal publication.

- Work by Hemant Tagare and Drew McDermott on visual object recognition continued. In earlier periods, we worked on finding object-contour fragments in the image, and matching them to the model of the object sought. In the period being reported, our focus was on combining fragment matches into an overall interpretation. The problem is to avoid potential combinatorics. We have begun tests with a “greedy” algorithm that seems to work well. The algorithm keeps track of a set of interpretations, each consisting of a set of contour-fragment matches. On each iteration, each interpretation is extended by adding a match that is consistent with it; i.e., for which there is a pose and scale of the object model which would give rise to the edges seen in the augmented interpretation. Once a fragment match is added to a feasible interpretation, it is discarded, so that it does not give rise to any further interpretations, thus minimizing the combinatorial explosion.

**Activities:**

- Drew McDermott, presentation on “Probabilistic Projection for Planning.” Georgia Tech. Feb. 3
- Drew McDermott, presentation on “Probabilistic Projection for Planning.” March 30
IN REPLY REFER TO
DTIC-OCC

SUBJECT: Distribution Statements on Technical Documents

TO: Office of the Chief of Naval Research
800 north Quincy Street
Arlington, VA 22217-5000
Code A. Watson


2. The Defense Technical Information Center received the enclosed report (referenced below) which is not marked in accordance with the above reference.

   Contract No. N00014-93-I-1235
   Quarterly Progress Rpt Feb 1994 - Apr 1994

3. We request the appropriate distribution statement be assigned and the report returned to DTIC within 5 working days.

4. Approved distribution statements are listed on the reverse of this letter. If you have any questions regarding these statements, call DTIC's Cataloging Branch, (703) 274-6837.

FOR THE ADMINISTRATOR:

Gopalakrishnan Nair
Chief, Cataloging Branch

1 Encl

FL-171
Jul 93
The cited documents has been reviewed by competent authority and the following distribution statement is hereby authorized.

DISTRIBUTION STATEMENT A:
APPROVED FOR PUBLIC RELEASE: DISTRIBUTION IS UNLIMITED

DISTRIBUTION STATEMENT B:
DISTRIBUTION AUTHORIZED TO U.S. GOVERNMENT AGENCIES ONLY; (Indicate Reason and Date Below). OTHER REQUESTS FOR THIS DOCUMENT SHALL BE REFERRED TO (Indicate Controlling DoD Office Below).

DISTRIBUTION STATEMENT C:
DISTRIBUTION AUTHORIZED TO U.S. GOVERNMENT AGENCIES AND THEIR CONTRACTORS; (Indicate Reason and Date Below). OTHER REQUESTS FOR THIS DOCUMENT SHALL BE REFERRED TO (Indicate Controlling DoD Office Below).

DISTRIBUTION STATEMENT D:
DISTRIBUTION AUTHORIZED TO DOD AND U.S. DOD CONTRACTORS ONLY; (Indicate Reason and Date Below). OTHER REQUESTS SHALL BE REFERRED TO (Indicate Controlling DoD Office Below).

DISTRIBUTION STATEMENT E:
DISTRIBUTION AUTHORIZED TO DOD COMPONENTS ONLY; (Indicate Reason and Date Below). OTHER REQUESTS SHALL BE REFERRED TO (Indicate Controlling DoD Office Below).

DISTRIBUTION STATEMENT F:
FURTHER DISSEMINATION ONLY AS DIRECTED BY (Indicate Controlling DoD Office and Date Below) or HIGHER DOD AUTHORITY.

DISTRIBUTION STATEMENT X:
DISTRIBUTION AUTHORIZED TO U.S. GOVERNMENT AGENCIES AND PRIVATE INDIVIDUALS OR ENTERPRISES ELIGIBLE TO OBTAIN EXPORT-CONTROLLED TECHNICAL DATA IN ACCORDANCE WITH DOD DIRECTIVE 5230.25, WITHHOLDING OF UNCLASSIFIED TECHNICAL DATA FROM PUBLIC DISCLOSURE, 6 Nov 1984 (Indicate date of determination). CONTROLLING DOD OFFICE IS (Indicate Controlling DoD Office).

[Signature & Typed Name]
DEBRA T. HUGHES
DEPUTY DIRECTOR
CORPORATE PROGRAMS OFFICE

[Signature & Typed Name]
EBRA T. HUGHES
DEPUTY DIRECTOR
CORPORATE PROGRAMS OFFICE

[Assigning Office]
[Date Statement Assigned]
### LEDGER

<table>
<thead>
<tr>
<th>DESCRIPTION</th>
<th>AMOUNT BUDGETED</th>
<th>COMMITTED (NOT PAID)</th>
<th>PAID TO DATE</th>
<th>TOTAL EXPENSES</th>
<th>REMAINING BALANCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>NON-LADDER ACAD $ RES APPTS</td>
<td>44.765</td>
<td>9.217.32</td>
<td>7.433.35</td>
<td>16,650.67</td>
<td>28,114.33</td>
</tr>
<tr>
<td>FACULTY SUMMER COMP</td>
<td>55.084</td>
<td>38.000.00</td>
<td>0</td>
<td>38,000.00</td>
<td>-17,084.00</td>
</tr>
<tr>
<td>MANAGERIAL &amp; PROFESSIONAL STUDENT ASST.</td>
<td>9.005</td>
<td>12.000.08</td>
<td>8.428.45</td>
<td>20,518.58</td>
<td>-10,613.53</td>
</tr>
<tr>
<td>EMP. BENEFITS</td>
<td>21.310</td>
<td>9.260.67</td>
<td>21.793.03</td>
<td>31,053.70</td>
<td>-9,743.70</td>
</tr>
<tr>
<td>D/P SUPPLIES</td>
<td>36.208</td>
<td>19.613.32</td>
<td>5.163.21</td>
<td>24,776.53</td>
<td>11,431.47</td>
</tr>
<tr>
<td>MINOR, EQUIPMENT &amp; FURNISHINGS</td>
<td>0.00</td>
<td>-220.00</td>
<td>220.00</td>
<td>0.00</td>
<td>-252.95</td>
</tr>
<tr>
<td>D/P SVS.</td>
<td>3.076</td>
<td>15.614.00</td>
<td>5.689.00</td>
<td>21,303.00</td>
<td>-18,227.00</td>
</tr>
<tr>
<td>D/P SOFTWARE</td>
<td>0.00</td>
<td>139.00</td>
<td>139.00</td>
<td>-139.00</td>
<td>-194.13</td>
</tr>
<tr>
<td>FREIGHT &amp; TRANSPORTATION</td>
<td>0.00</td>
<td>95.25</td>
<td>98.88</td>
<td>194.13</td>
<td>-194.13</td>
</tr>
<tr>
<td>PHOTOCOPYING</td>
<td>795.00</td>
<td>501.68</td>
<td>630.50</td>
<td>1,132.18</td>
<td>-337.18</td>
</tr>
</tbody>
</table>

**Publications:**


**Personnel Support:**

- **Graduate Students (full time):** Michael Beetz, Wenhong Zhu, Aage Bendiksen, Kentaro Toyama
- **Post-doc (half-time):** Hemant Tagare
- **Secretary (half-time):** Paula Murano

**Expenditures:**

The accompanying table shows the figures for expenditures to date, including amounts committed but not actually spent.
<table>
<thead>
<tr>
<th>LEDGER DESCRIPTION</th>
<th>AMOUNT BUDGETED</th>
<th>COMMITTED (NOT PAID)</th>
<th>PAID TO DATE</th>
<th>TOTAL EXPENSES</th>
<th>REMAINING BALANCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>MISCELLANEOUS SERVICES</td>
<td>0</td>
<td></td>
<td>36.00</td>
<td>36.00</td>
<td>-36.00</td>
</tr>
<tr>
<td>TRAVEL (DOMESTIC)</td>
<td>0</td>
<td>1,283.00</td>
<td>2,179.01</td>
<td>3,462.01</td>
<td>-3,462.01</td>
</tr>
<tr>
<td>TRAVEL (FOREIGN)</td>
<td>0</td>
<td></td>
<td>2,913.98</td>
<td>2,913.98</td>
<td>-2.91</td>
</tr>
<tr>
<td>CONFERENCE &amp; SEMINAR FEES</td>
<td>150.00</td>
<td></td>
<td>150.00</td>
<td>150.00</td>
<td>-150.00</td>
</tr>
<tr>
<td>OFFICE SUPPLIES</td>
<td>489</td>
<td>138.09</td>
<td>3.93</td>
<td>142.02</td>
<td>346.98</td>
</tr>
<tr>
<td>PERIODICALS</td>
<td>0</td>
<td>.00</td>
<td>219.35</td>
<td>219.35</td>
<td>-219.35</td>
</tr>
<tr>
<td>POSTAGE</td>
<td>0</td>
<td>31.51</td>
<td>282.77</td>
<td>314.28</td>
<td>-314.28</td>
</tr>
<tr>
<td>TUITION REMISSION</td>
<td>2,839</td>
<td></td>
<td>16,880.00</td>
<td>16,880.00</td>
<td>-14,041.00</td>
</tr>
<tr>
<td>HEALTH INSURANCE</td>
<td>0</td>
<td>896.00</td>
<td>896.00</td>
<td>896.00</td>
<td>-896.00</td>
</tr>
<tr>
<td>TELEPHONE</td>
<td>495</td>
<td>173.00</td>
<td>109.66</td>
<td>284.66</td>
<td>210.34</td>
</tr>
<tr>
<td>DATA PROCESSING EQUIPMENT</td>
<td>15,007</td>
<td></td>
<td>4,302.20</td>
<td>4,302.20</td>
<td>10,704.80</td>
</tr>
<tr>
<td>INDIRECT (OVERHEAD 64.0%)</td>
<td>110,162</td>
<td>67,807.93</td>
<td>34,287.78</td>
<td>102,095.71</td>
<td>8,066.29</td>
</tr>
<tr>
<td>TOTAL:</td>
<td>300,135</td>
<td>173,757.85</td>
<td>109,045.07</td>
<td>282,802.92</td>
<td>17,332.08</td>
</tr>
</tbody>
</table>

OVERHEAD ANTICIPATED: 6,763.74

SPENDING BALANCE AVAILABLE AS OF JULY 01, 1994: 10,568.34
Overall Status and Plans:

We are quite happy with the rapid progress we are making on guidance of behavior using feature tracking, and we expect that to continue.