Quarterly Progress Report, Mar 1992 - May 1992
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Here are some of the technical leads we have been following during this quarter:

• We completely revamped our approach to concurrency in plans. In our transformational planner, plans are just programs, which request resources in competition with other plans, and suspend when the resources are in use. However, the system of semaphores, called "valves," used to control access to resources is somewhat more complex than in standard programming systems, because of our attempt to couple the semantics of the valve system to the semantics of the task hierarchy. If one process P_1 is associated with a subtask of another process P_2 — that is, if P_1 is a *subprocess* of P_2 — then P_1 has the right to pre-empt a valve from P_2, causing P_2 to suspend. The rationale for this behavior is that plan P_1 is presumably part of plan P_2, so that P_2's goals will be advanced with minimal interference by allowing P_1 to proceed. (Example: P_2 might be the plan to carry something to a destination, and P_1 might be the plan to open a door along the way; if the two compete for a hand, then P_1 should win; once the door is opened, P_2 can proceed.)

However, there is another level of complexity. In our plan language, a plan P_1 may be a *policy* on another plan P_2. (This is indicated with the construct `(WITH-POLICY` P_1 P_2`)`.) The intent is that P_2 be executed with P_1 serving as a constraint. An example might be to carry an object with the policy of picking it up should it be dropped or put down. Policies clearly should take priority over the tasks they constrain. The way we implement this behavior is to introduce a distinction between a process being *wait-blocked* and a process being *valve-blocked.* A process is wait-blocked if all of its threads are queued on "fluents," that is, registers standing for conditions that may eventually become true. The process that picks up an object when it is dropped is normally wait-blocked, because most of the time its only thread is queued on a fluent connected to the force sensor for the hand carrying the object. If that force sensor should register zero, the thread will resume. A process P is valve-blocked if there is some valve V requested by a superprocess of P such that P is neither a subprocess nor a policy on the owner of V.

The way we implement the policy-priority scheme is this: every time `(WITH-POLICY` A_1 A_2`)` is executed, two new processes are generated, and a hidden valve V_p is created that they contend for. The plan interpreter makes sure the following invariant is satisfied: The process for A_1 owns V_p if and only if the process is not wait-blocked. This rule ensures that the process for A_2 is valve-blocked whenever the process for A_1 is not asleep waiting for some event.

This scheme is much cleaner than our previous scheme, and eliminates some flakey behavior that plagued earlier implementations. We will be writing more complete documention on it soon.

• We have developed a new method for incorporating task information in sensor data fusion algorithms that drastically reduces the amount of computation needed to process information. This result is specifically oriented toward reaching propositional decisions such as a planner would make during the course of its operations. As a consequence, we are one step closer to integrating sensing and planning together in a general, adaptible fashion.

• We have extended our image-tracking algorithms to track image patches under nearly all projective transformations. That is, it is now possible to select a target region of the image, and to track it as it translates, rotates, and scales. These transformations encompass the type of image deformations that a mobile robot would encounter while homing or navigating relative to a chosen landmark. Hence, it should be possible to use this algorithm to implement some of the behaviors used by our mapping algorithm.

Activities:

Drew McDermott, March 3: Talk at Carnegie-Mellon on "Transformational Planning of Reactive Behavior."

Greg Hager, March, "A Constraint-Based View of Selective Perception", presented at the AAAI Spring Symposium on Selective Perception, Stanford, CA.

Drew McDermott, March 25–27: Presented talk "Perceptual Confusion in Reactive Plans," at AAAI Spring Symposium on Computational Considerations in Incremental Modification and Reuse.

Greg Hager, April, "Sensor Data Fusion," a lecture delivered at Red Stone Arsenal, Huntsville, Alabama.

Drew McDermott, April 15: Talk at University of Chicago on "Building and Fixing Diktiometric Maps for Robot Navigation."

Drew McDermott, April 16: Talk at Northwestern University, "Transformational Planning of Reactive Behavior."

Sean Engelson, May, "Error Correction in Mobile Robot Map Learning," presentation at the IEEE International Conference on Robotics and Automation, Nice, France.

Greg Hager, May, "Constraint Solving Methods and Sensor-Based Decision Making," presentation at the IEEE International Conference on Robotics and Automation, Nice, France.

Greg Hager, June, "Sensor-Based Decision Making" presented at the DLR (German Space Organization), Oberpfaffenhofen, Germany.

Publications:

Sean Engelson and Drew McDermott, Error correction in mobile robot map learning. *Proc. IEEE Conf. on Robotics and Automation*, pp. 2555–2560

Greg Hager, "A Constraint-Based View of Selective Perception", Proceedings of the AAAI Spring Symposium on Selective Perception, Stanford, CA, March 1992.

Greg Hager, "Constraint Solving Methods and Sensor-Based Decision Making" *Proc. IEEE Conf. on Robotics and Automation,*

Drew McDermott, "Perceptual Confusion in Reactive Plans," *Proc. of the AAAI Spring Symposium.*

Personnel Support:

We supported one graduate student, Michael Beetz, half-time during this period. In addition, we employed a part-time programmer, Amy Wang, and a secretary, Paula Murano.

Expenditures:

The accompanying table shows the figures for expenditures to date, including amounts committed but not actually spent.

Overall Status and Plans:

We are happy with our progress so far. Over the summer, we plan to focus on making the planner/executor more robust. In particular, now that the valve handler has been rewritten, we can rewrite strategies for breaking deadlocks on valves.

LEDGER DESCRIPTION	AMOUNT BUDGETED	COMMITTED (NOT PAID)	PAID TO DATE	TOTAL EXPENSES	REMAINING BALANCE
TRAVEL ADVANCES	0		2,500	2,500	-2,500.00
FACULTY SALARY	33,223	.28,555.56	21,822	50,377.56	-17,154.56
CLERICAL & TECHNICAL	16,560	13,404.54	16,735.09	30,139.63	-13,579.63
STUDENT ASST.	88,050	13,600.	18,800.14	32,400.14	55,649.86
OTHER YALE STUDENTS	0	5,280.	12,352	17,632	-17,632.
DIRECT WAGES	0	344.00	344.	-344.	
EMP. BENEFITS	18,123.	13,479.65	11,893.48	25,373.13	-7,250.13
D/P SUPPLIES	0	404.	2,658.78	3,062.78	-3,062.78
D/P SVS.	24,840	15,400..	10,452	25,852.	-1,012.
MINOR EQUIPMENT	0	00	379.	379.	-379.
D/P SOFTWARE	6,000	00	2,633	2,633	3,367
FREIGHT & TRANSPORTATION	0	3.00	406.08	409.08.	-409.08
PHOTOCOPYING	4,140		1,306.21	1,306.21	2,833.79

LEDGER DESCRIPTION	AMOUNT BUDGETED	COMMITTED (NOT PAID)	PAID TO DATE	TOTAL EXPENSES	REMAINING BALANCE
PRINTING	0		270.	270.	-270.
MISC SERVICES	0		270	270	-270
COMMISSIONS	0		25.	25.	-25.
D¶EQUIPMENT MAINT	0		372.	372.	-372.
TRAVEL (DOMESTIC)	8,280	928.50	6,299.34	7,227.84	1,052.16
TRAVEL (FOREIGN)		3,000		3,000	-3,000
CONFERENCE & SEMINAR FEES		170.		170.	-170.
OFFICE SUPPLIES	2,070	16.03	588.30	604.33	1,465.67
PERIODICALS	0	20.	1,022.45	1,042.45	-1,042.45
POSTAGE	0	43.51	445.81	489.32	-489.32
TUITION REMISSION	44,532	5,306.64	13,476.	18,782.64	25,749.36
HEALTH INS.	0	540	270.	810.	-810.
TELEPHONE	2,070	290.15	247.68	537.83	1,532.17
DATA PROC. EQUIPMENT	139		38,538	38,538	100,462
INDIRECT (OVERHEAD 68.0%)	138,282	64,691.76	74,552.53	139,244.29	-962.29
TOTAL:	525,170	165,133.34	236,202.69	401,3365.03	123,833.97
		OVERHEAD ANTICIPATED:			50,123.27
		SPENDING BALANCE AVAILABLE AS OF 06/15/92:			73,710.70