GEORGIA INSTITUTE OF TECHNOLOGY — OFFICE OF CONTRACT ADMINISTRATION

PROJECT ADMINISTRATION DATA SHEET

☐ ORIGINAL ☒ REVISION NO. 1

Project No./(Center No.) G-36-666 (R6197-0A0) — GTRC/~~GIT~~ — DATE 2 / 5 / 87

Project Director: J. Kolodner & R. Cullingford — School/~~Lab~~ ICS

Sponsor: Army Research Office

Agreement No.: ~~Grant DAAL03-86- G-0185~~

Award Period: From ~~8/18/86~~ To ~~8/17/88~~ (Performance) ~~10/17/88~~ Reports

Sponsor Amount:

	New With This Change	Total to Date
Contract Value:	$	$
Funded:	$ 69,000	$ ~~140,250~~

Cost Sharing No./(Center No.) 58,000 — Cost Sharing: $ ~~G-36-363~~

Title: ~~Equipment for Artificial Intelligence~~

ADMINISTRATIVE DATA

OCA Contact John B. Schonk X-4820

1) Sponsor Technical Contact:

2) Sponsor Issuing Office:

Donald Calder
ONR RR
~~Georgia Tech~~
~~206 O'Keefe Bldg.~~
~~Atlanta, Ga. 30332~~

Military Security Classification: ~~N/A~~

(or) Company/Industrial Proprietary: ~~N/A~~

ONR Resident Rep. is ACO: ____ Yes ____ No

Defense Priority Rating: ~~N/A~~

RESTRICTIONS

See Attached ~~N/A~~ Supplemental Information Sheet for Additional Requirements.

Travel: Foreign travel must have prior approval — Contact OCA in each case. Domestic travel requires sponsor approval where total will exceed greater of $500 or 125% of approved proposal budget category.

Equipment: Title vests with ~~GIT~~

COMMENTS:

Amendment No. P00001 adds the next funding increment, fully funding this grant.

COPIES TO:

SPONSOR'S I.D. NO. 02.102.001.87N257

Project Director
Research Administrative Network
Research Property Management
Accounting

Procurement/GTRI Supply Services
Research Security Services
Contract Support Div. (OCA)(2)
Research Communications

GTRC
Library
Project File
Other ______

GEORGIA INSTITUTE OF TECHNOLOGY
OFFICE OF CONTRACT ADMINISTRATION

NOTICE OF PROJECT CLOSEOUT

Date 2/7/89

Project No. G-36-666 Center No. R6197-0A0

Project Director J. Kolodner School/Lab ICS

Sponsor ARMY (Research Office)

Contract/Grant No. DAAL03-86-G-0185 GTRC XX GIT ____

Prime Contract No. ____

Title Equipment for Artificial Intelligence

Effective Completion Date 8/17/88 (Performance) 10/17/88 (Reports)

Closeout Actions Required:

- ___ None
- X Final Invoice or Copy of Last Invoice
- X Final Report of Inventions and/or Subcontracts
- X Government Property Inventory & Related Certificate
- ___ Classified Material Certificate
- X Release and Assignment
- ___ Other ____

Includes Subproject No(s). ____

Subproject Under Main Project No. ____

Continues Project No. ____ Continued by Project No. ____

Distribution:

- X Project Director
- X Administrative Network
- X Accounting
- X Procurement/GTRI Supply Services
- X Research Property Management
- ___ Research Security Services
- [redacted]
- X GTRC
- X Project File
- X Contract Support Division (OCA) (2
- ___ Other ____

Final Report: Contract No. DAAL03-86-G-0185

Janet L. Kolodner
Associate Professor
School of Information and Computer Science
Georgia Institute of Technology
Atlanta, GA 30332

January 10, 1989

1 Equipment Bought Under This Grant

Description	Quantity	Army Cost	Official Cost Sharing	Unofficial Cost Sharing
Symbolics 3620E with 1MW Memory	2	$70,675.99	.00	
Symbolics 3650 with CAD Buffer and 1MW Memory	1	$68,226.66	.00	
SUN 3/180s with 4 MB Memory and 340MB Disk Space	1	.00	$58,000.00	$1,600.00
Cabletron ETH XCVR	6	$1,347.35	.00	$326.17
Totals		$140,250.00	$58,000.00	$1,926.17

2 Research Supported By This Equipment

All research projects that used the equipment provided by ARO are listed below. Some were proposed in the original proposal, some were not. Lists of publications resulting from each research project are in an appendix.

2.1 Case-Based Reasoning

PI: Janet Kolodner
Source of Support: ARO
Contract No.: DAAG29-85-K-0023
Dates: December 1, 1984 - November 30, 1987

PI: Janet Kolodner
Source of Support: NSF
Contract No.: IST-8317711
Dates: June 15, 1984 - Nov. 30, 1987

PI: Janet Kolodner
Source of Support: ARO
Contract No.: DAAG29-83-G-0016 (graduate fellowship)
Dates: July 1, 1983 - Sept. 15, 1986

Much of the research supported by this grant was in the area of *case-based reasoning.* Case-based reasoning is a kind of analogical reasoning in which a solution to a new problem is suggested based on what worked and failed to work in previous similar situations. While traditional AI problem solvers solve problems by resorting to first principles, case-based problem solvers resort to first principles only when their experiences don't allow them to solve a problem by "tweaking" an old solution. The major processes involved in case-based reasoning are *remembering* previous cases and *tweaking* or *adapting* them to fit the new situation. Georgia Tech's AI Research Group pioneered the case-based reasoning technology and remains the largest research group working on problems in case-based reasoning. This work has been supported primarily by ARO and NSF.

There are several requirements on a problem solver that can reuse experience. First, it must store its experiences in a memory so that they are accessible at appropriate times. Second, it must be able to recognize and evaluate the similarity of a current case to a previous one. Third, it must be able to focus its attention on potentially applicable parts of any previous cases it finds and extract appropriate guidelines from previous cases. Fourth, it must be able to transform what it finds in previous cases to fit its current case. Fifth, it must be able to judge the reliability for a new case of anything it borrows from an old case. Sixth, it must know when it is appropriate to use advice from a previous case and when from-scratch methods might be more appropriate.

Under these contracts, we developed and pioneered the *case-based reasoning* technology. We implemented many case-based reasoning systems: SHRINK, MEDIA-

TOR, PERSUADER, CAS, JULIA, and MEDIC. We discuss MEDIATOR, PERSUADER, CAS, and the case-based part of JULIA in this section. MEDIATOR was supported in part by all contracts, PERSUADER by the ARO contract, CAS by the ARO fellowship, and JULIA was supported partially by the NSF grant listed above and partially by the one listed below.

2.1.1 Feasibility Study of Case-Based Reasoning

The MEDIATOR was the first case-based problem solver to be built and illustrated the feasibility of case-based reasoning. It mediated resource disputes in a common-sense way by remembering its previous mediation experiences. Thus, upon being presented with the problem "Two sisters want the same orange", it suggested that one of them cut it in half and the other pick her half, this based on an experience of solving a dispute over a candy bar this way. The MEDIATOR used case-based reasoning for a variety of reasoning tasks, including gaining a better understanding of a problem, coming up with a solution, and figuring out what went wrong in the event of a failure. Of particular import in the MEDIATOR was the way in which the problem solver's goals helped it to focus on an appropriate part of a previous case. A case can be arbitrarily large, and if so, there must be some way to focus only on the part of it that has relevance. Relevance in the MEDIATOR was determined by the problem solver's current goal, and the MEDIATOR focussed only on those parts of the previous case that were responsible for achieving its current goal in that case.

2.1.2 Case-Based Reasoning in an Expert Domain; Adaptation Strategies; Integrating Heuristic and Analytic Methods

The PERSUADER was the first case-based reasoner to work in an expert domain. Its task was mediation of labor-management disputes, and it attempted to mediate those disputes as an expert labor mediator would. Like an expert mediator, it developed solutions to new problems by using previous solutions as precedents and adapting solutions to those problems to fit the new situation. While the MEDIATOR served as a feasibility study of case-based reasoning, the PERSUADER allowed us to focus on the processes involved in adapting old cases to fit new situations. The PERSUADER's method was to first make easy changes in an old solution based on area differentials and other "obvious" and "easy" fixes. This provided it with a *ballpark solution.* It then used a set of adaptation heuristics to modify the ballpark solution taking into account harder differences between the old and the new case (e.g., different sets of secondary goals, different makeup of the union, different degrees of danger associated with a job). Its heuristics were of several kinds. First, it had a set of heuristics that were used to adjust a value on a scale. To do this, it needed to know what features of the case those values depended on. Second, it had a set of compensation heuristics. That is, given a change that made one side's position more acceptable, it had to figure out what kinds of changes could be made for the other side to keep the contract acceptable for them. Third, it had specific heuristics associated with each of the goals a side in a dispute is expected to have. These heuristics told it what kinds of changes to make under what circumstances. To decide where changes need to be made to make a previous contract fit the new case, the PERSUADER kept a *goal tree* that related the multiple goals of each party in the dispute to each other and to the goals of the other side. The goal tree was searched using the goals of each party in the dispute as starting points, and the search provided the subgoals that needed to be achieved to make each party happy.

The PERSUADER had several other interesting features. First, when it adapted a previous solution to fit a new case, it kept track of how and why it made the changes it made. Thus, rather than having to figure out how to adapt a later case from scratch, it could use its previous adaptation experience to adapt a new case. Second, the PERSUADER's solutions were *satisficing* solutions over several goals. Almost no goals of either party were ever satisfied completely. Rather, compromises were made that each side was happy with given the entire context. No other problem solving system to date has dealt with this kind of problem solving of this kind. Third, the PERSUADER combined heuristic and analytic methods and illustrated one way heuristic and analytic methods can be integrated.

2.1.3 Plan Adaptation

While the PERSUADER project was an investigation of the ways one might adapt a solution contract to a new situation, it did not deal with the actual timing of plan steps. Work on the *Consumer Advisor* program, or *CAS* addressed that problem. CAS gives advise about the acquisition of household appliances and furniture. We have concentrated on advise about buying and building bookshelves.

Our work on plan modification is based on the premise that a plan's preconditions hold a lot of information with them. Rather than simply being conditions that must be achieved for a plan to be applicable, we see them as conditions that bear on how successful application of a plan might be. Thus, predictions carry a lot of information with them. This information allows the planner to decide if it is worthwhile modifying a plan to eliminate a violation, or if the plan should be applied as is. It also allows the planner to recommend less than optimal plans to the user when those are the only plans available. Each precondition to a plan has the following information stored with it:

1. the state that must exist for the precondition to be satisfied;
2. the plan step or steps that the precondition is required for;
3. the likely result of applying the plan if the precondition is violated; and
4. directives for modifying the plan so that the precondition must no longer be fulfilled.

Each of these items plays a role in the planning process. Item 1 supplies criteria for recognizing whether or not a precondition is satisfied. Items 2 and 3 are used in evaluating whether to modify the plan or ignore the precondition problem. Item 4 is used to fix the plan if the planner decides that the precondition violation is unacceptable.

Directives for plan modification (item 4) provide heuristics for changing the plan so that the offending precondition is either no longer violated or no longer necessary. There are two ways a plan can be modified: *Strategic* modifications affect the overall strategy of a plan. *Tactical* modifications change local plan steps. Examples of strategic changes include (1) adding steps to the plan (i.e., planning to achieve the precondition); (2) deleting steps from the plan (e.g., changing the plan so that the offending step is no longer there); and (3) re-ordering steps of the plan. Examples of tactical changes are (1) replacing a step with another plan or action; and (2) changing a step within some step of the plan.

2.1.4 Integrating Memory and Problem Solving Processes

Work on CAS also included an investigation of how memory and problem solving processes might be integrated. All case-based reasoners previous to CAS and most current case-based reasoners give the problem solver complete control over the memory. That is, whenever the problem solver needs information, whether a case or general information, it asks memory for it, specifying what information it is looking for.

In protocols we have taken of human problem solvers, however, we observe that this does not match the way people seem to have their memory and problem solving processes connected. In particular, planners often interrupt themselves to turn their planning in a different direction. They seem to do this for two reasons: (1) their current planning isn't getting them anywhere for some reason, or (2) they are reminded of something that makes them think the planning will work better in a different direction. And what they are reminded of is not always something they wanted to be reminded of at the moment. Nevertheless, these uncontrolled remindings are often useful. Our interpretation of this type of processing is that at least two separate processes are running in parallel: a memory process and a planning process. When memory is reminded of something pertinent to the planner, it interrupts the planner, and the planner might decide to use the episode the memory is reminded of to redirect its planning. At the same time, memory uses the problem the planner is working on guide its search.

CAS implements this architecture using three modules that run concurrently. Its *memory* process is responsible for searching CAS' memory to provide pertinent plans and experiences for the planner to use. The *planner*, a separate process, can be interrupted by memory whenever memory is reminded of something. Communication between these two processes is controlled by another process, the *referee*, which acts as an intermediary between them. When the memory is reminded of a plan or a previous episode, it sends the memory structure to the referee, which posts it on the system's blackboard. The referee then notifies the planner that a reminding has occurred.

CAS and its successors remain the only case-based reasoners that have autonomous memories. In all other case-based reasoners, the memory runs under command of the problem solver. Making memory autonomous gives it more flexibility. It can take its cues from a variety of places. While the problem solver can ask it for particular information it wants, memory can also consider cues from, e.g., the problem statement, previous reasoning attempts, recent conversations, or its own set of goals, and make its own contributions to problem solving. It can also contribute new information in the form of general knowledge or cases at times when it finds relevant knowledge but when the problem solver has not specifically asked it for new information.

2.1.5 Varieties of Adaptation Processes

In JULIA, we continue to study a variety of adaptation processes, that is, processes that adapt a previous solution to fit a new case. We have discovered several of these strategies and they are implemented in JULIA:

- substitution of neighboring concepts
  - local search
  - abstract/refine
  - delete secondary feature
  - adjust amount of feature

  - substitute feature value
  - add feature value
- "divide and conquer"
- "two birds with one stone"

Each of the strategies for substitution seeks to transform some component of a previous solution into a component suitable for the new case. A meal planner, for example, may want to serve lasagne at a vegetarian meal. Substitution methods can be used to transform lasagne into one of its vegetarian forms. Using the local search strategy, it would search the semantic network for a known form of vegetarian lasagne. Using delete secondary feature, it would simply delete the meat from the lasagne recipe it was planning to use, since meat is only a secondary ingredient. Using substitute feature value, it might substitute tuna or vegetables for the meat. Substitution strategies would also be appropriately used to transform a very spicy dish into one that could be served to less adventurous eaters. In that case, "adjust amount of feature" might be used.

"Divide and conquer" is used when no answer can be found that will solve the problem in all cases but when the set of cases the solution has to satisfy can be divided into subsets. Finding a single main dish for a dinner group that includes both vegetarians and meat and potatoes people might not be possible, but if the group of participants is broken down into functional subgroups (vegetarians, meat and potatoes people), the problem can be solved by accomodating each separately.

"Two birds with one stone" fixes the structure of a partial solution to accomodate a new suggestion. An Italian meal, for example, often has a pasta course. If the case-based reasoner suggests lasagne as the main dish of a planned Italian meal, "two birds with one stone" will notice the redundancy between a pasta course and a pasta main dish and will delete the pasta course from the partial solution.

One of the most interesting things we've found about these strategies is that in addition to being general adaptation strategies for case-based reasoning, they are also useful for iterative design. One way to solve design problems is to propose an almost-good solution and then to critique and iteratively fix that solution to make it acceptable. JULIA uses its adaptation strategies for both case-based reasoning and iterative design.

2.2 Intelligent Advisory Systems

PI: Janet Kolodner, Richard Cullingford
Source of Support: NSF

Contract No.: IST-8608362
Dates: Sept. 15, 1986 - Feb. 28, 1990

The research effort supported by this grant seeks to develop fundamental design principles for intelligent advisory systems that interact with their users in natural language during problem solving episodes. Such a system combines natural language understanding and conversational functions with problem solving functions. This is important for several reasons. First, interesting research on natural language systems requires that the system have some reason for communicating. Integrating a conversational system with a problem solving system, as we are doing, gives the conversational system a set of communication goals. It also provides naturalistic controls on the system. The system asks questions when they are required by the problem solver and interprets answers in the broad context of the problem solving episode that the user and the computer are cooperatively engaging in. Second, our problem solving and planning systems need to get realistic input. Integrating a problem solving system with a conversational system means the problem solver will be getting its input in the same terms in which problems are described in the real world. In this way, we make sure that our problem solving methods don't cheat by dealing only with idealized input.

We have been investigating basic issues in the following areas of artificial intelligence and cognitive science that have bearing on the design of such systems: (1) case-based reasoning, the use of previous experience to support problem solving, (2) models of long-term memory for experience and access to such memory and inferencing power to support case-based reasoning and robust understanding of user's input, (3) the expression of questions, advice, and explanations to a user in fluent natural language, and (4) the *integration* of these processes and other necessary problem solving and learning processes to create a highly mixed initiative conversational system. The research has been conducted primarily within the context of the JULIA system. JULIA is an expert advisory system whose task domain is catering and menu planning. Additional work on integration issues is being done in the context of the MEDIC project, whose task domain is diagnosis of pulmonary disorders.

2.3 Learning and Instruction

PI: Janet Kolodner, Lawrence Barsalou
Source of Support: ARI
Contract No.: MDA903-86-C-0173
Dates: Sept. 1, 1986 - Aug. 31, 1989

In this research project, which is in its third year, we are investigating the problem solving and learning strategies employed by troubleshooters, in particular car mechanics. We are investigating the problem solving methods used by people in an attempt to be able to provide the right kinds of teaching environments for these people. We have thus studied the problem solving of people at many different levels of expertise. The study uses three experimental methodologies: protocol analysis, creation of AI models of the processes we observe, and controlled experimentation on people. Work is joint with faculty in Georgia Tech's psychology department.

In year 1 of the project, we collected and analyzed protocols of students solving several sequences of diagnostic problems in the domain of car mechanics. A theoretical analysis of these protocols led us to several working hypotheses. We found three types of knowledge necessary for diagnosis.

- **Qualitative reasoning rules** provide knowledge about what system behaviors derive from other system behaviors or states.
- **Symptom-fault rules** provide associational knowledge that associates symptoms and other contextual factors with potential faults.
- **Reasoning strategies** provide meta-knowledge about what actions to take in solving a problem.

In learning these three types of knowledge, a student learns two types of descriptive knowledge about the device it is learning about: how the system works and how it malfunctions. This is traditionally called the students *mental model* of the device. The student also learns how to use that knowledge to solve problems or troubleshoot.

We also identified five different learning processes used by students learning how to solve problems better.

- Learning by understanding explanations
- Active gap filling
- Learning by interpreting feedback
- Abstraction
- Case-based reasoning

Based on these findings, work on the AI part of this project has taken four directions:

- an in-depth investigation of *learning by understanding explanations*, a learning process in which the student integrates what the teacher presents into his/her current mental model, implemented in two programs: EDSEL-1 and EDSEL-2,

- investigation of the case-based reasoning processes employed during learning, implemented in a program called CELIA,

- the creation of representations that integrate general knowledge about devices with case knowledge derived from experience, and that represent both the way the device is supposed to work normally and the model of the ways it malfunctions, integrated into all the programs listed above, and

- the creation of memory models that integrate the three different kinds of knowledge problem solvers use and that support the learning processes that we have been investigating, implemented in a program called CORA.

Work in AI distinguishes itself from other work on machine learning by focussing on the learning that happens in real situations in conjunction with a non-ideal teacher.

From the psychology side, the most interesting work based on the first year study was development of an instruction tool called MECH that can be used to run experiments to find out more detail about what people are learning. MECH is an especially important part of the work done under this contract, and has the potential to serve several functions:

- It provides a simulation environment for problem solving, including graphics and help facilities. Thus, with the right knowledge in it, it could be used by students to practice what they have learned without the need for the particular device they have learned about being available.

- It provides an environment for teaching. It has facilities for providing feedback, for providing explanations to students, and for choosing problems to work on. It could therefore be used as a teaching tool.

- It provides an environment for experimentation. It records key strokes and keeps track of latency times. It also allows for different kinds of teaching/learning situations to be set up, thus allowing an experimenter to evaluate the differences between several different teaching strategies.

While MECH has been implemented on an IBM-PC, its design is based largely on simulation work done using the Symbolics machines.

2.4 Robotics and Perception

PI: Ron Arkin
Source of Support: Georgia Tech
Dates: Sept., 1987 - present

The Autonomous Robot Architecture (AuRA) provides a framework for research into action-oriented perception. AuRA is designed as general purpose navigation system; it is geared to be mapped onto many different domains. We have already successfully conducted mobile robot navigation in the interior of buildings, the outdoors of a college campus, and in manufacturing-related settings. We have shown, via simulation, that the basic principles of navigation in AuRA can be used for three dimensional navigation in the context of undersea and aerospace applications. This generalizability is one of the many distinguishing characteristics of the Autonomous Robot Architecture.

Recent research in the application of internal sensing to modify both motor behavior and planning processes has yielded promising results. Homeostatic control is delegated the responsibility of maintaining a safe internal environment for a robot. To make robots truly autonomous, the issues of self-sustenance and self-maintenance must be addressed. This will enable robots to work in more hazardous environments than they would be able to otherwise.

This research expands upon the schema-based navigation techniques already present in AuRA. By creating signal schemas, which use broadcast communication mechanisms between internal sensing devices (ammeters, thermisters, etc.), the robot's overt motor behavior can be modified on-the-fly. Simulation studies have verified that these changes can be readily effected using this technique.

The technique developed exploits an analog of the endocrine control system for much of its development. The salient features of this analogy include broadcast communication, negative feedback control, the concept of "targetability", and management of homeostasis. We anticipate deploying actual sensors on our mobile vehicle to test these concepts further.

Other research, performed in conjunction with the Computer Integrated Manufacturing Systems Program, has led to the development of new motor behaviors and perceptual strategies that are particularly pertinent to the manufacturing domain. Specifically, a docking motor schema has been developed, simulated and tested on our robot as a means for interacting with a workstation.

Several members of the project team are now developing supporting perceptual strategies for this motor behavior. A hough transform methodology (computer vision) is being developed for dock recognition for use with the available spatial uncertainty management information. Adaptive region-segmentation techniques are also being developed to track the dock after it has been discovered. Motion detection as a basis for workstation detection and vehicle localization is being explored. Initial work on follow-the-leader behavior for convoying, using fast visual thresholding techniques, is also underway.

In a related area, we are also exploring the role of cognition and perception in visualization with particular emphasis on biomedical computing. The development of cognitive models of perception and how humans interact with the display of visual data involving multiple levels of abstraction forms the core of this research. In this case we are not concerned with autonomy, but rather facilitating the transfer of information between man and machine.

Cognitive psychology and neuroscientific studies have served for much of the basis of this research. Biological systems solve the difficult problems we are trying to solve; they serve as our existence proof. Although we are not particularly interested in building artificial animals, we believe that theories and models of animal behavior can provide major insights into the development of intelligent robotic systems. Evidence of this approach is present in our schema-based navigation system which performs reactive/reflexive navigation; in our exploitation of an analog of the mammalian endocrine system as a means for enhancing robot survivability in hazardous environments; and the production of computer vision algorithms that exploit principles of action-oriented perception such as focus-of-attention mechanisms and expectation-based perception.

The Symbolics Lisp Machine is one of the workstations used to support our research. It can communicate via GTNET with our MicroVAX II and Gould IP8432L Image Processor which in turn are tied directly to our Denning Mobile Robot. The Lisp machine has been used for the development of image processing algorithms, in particular for the work involving the Hough transform. We will also use this workstation for the development of the high-level component of AuRA's planning subsystem: the mission planner. Additionally, much of the existing spatial uncertainty management subsystem is written in Lisp and currently runs (inefficiently) on the microVAX. It is our intent to port this software to the Symbolics. Another planner level, the pilot, is involved in behavior selection and parameterization. GEST, an expert system shell developed at GTRI, which runs on both the Symbolics and the microVAX will be used for automating our current rudimentary techniques.

Publications Supported Under ARO
Contract No. DAAG29-85-K-0023

1. Kolodner, J. L. (1985). *Experiential Processes in Natural Problem Solving.* Report No. GIT-ICS-85/23. School of Information and Computer Science. Georgia Institute of Technology. Atlanta, GA.

2. Sycara, E. (1985). Persuasive argumentation in resolution of collective bargaining impasses. *Proceedings of the Seventh Annual Conference of the Cognitive Science Society*, August, 1985.

3. Sycara, E. (1985). Arguments of persuasion in labor mediation. *Proceedings of IJCAI-85*, August, 1985.

4. Sycara, E. (1985). *Precedent-Based Reasoning in Expert Labor Mediation.* Report No. GIT-ICS-85/22. School of Information and Computer Science. Georgia Institute of Technology. Atlanta, GA.

5. Simpson, R. L. (1985). *A Computer Model of Case-Based Reasoning in Problem Solving: An Investigation in the Domain of Dispute Mediation.* Ph.D. Thesis. Report No. GIT-ICS-85/18. School of Information and Computer Science. Georgia Institute of Technology. Atlanta, GA.

6. Sycara, E. (1985). *Arguments of Persuasion: Two Papers.* Report No. GIT-ICS-85/19. School of Information and Computer Science. Georgia Institute of Technology. Atlanta, GA.

7. Kolodner, J. L. and Simpson, R. L. (1985). Using experience as a guide for problem solving. *Machine Learning Research.* Kluwer Academic Press.

8. Kolodner, J. L. and Riesbeck, C. (1986). *Experience, Memory, and Reasoning.* Lawrence Erlbaum Associates, Inc. Publishers, Hillsdale, NJ.

9. Kolodner, J. L. and Simpson, R. L. (1986). Case-Based problem solving: A framework. Experience, Memory, and Reasoning.

10. Kolodner, J. L. (1986). Some little-known complexities of case-based inference. *Proceedings of the Third Annual Workshop on Theoretical Issues in Conceptual Information Processing*, April, 1986.

11. Sycara, E. (1987). *Resolving Adversarial Conflicts: An Approach Integrating Case-Based and Analytic Methods.* Ph.D. Thesis. Report No. GIT-ICS-87/26. School of Information and Computer Science. Georgia Institute of Technology. Atlanta, GA.

12. Sycara, E. (1987). Utility theory in conflict resolution. *Annals of Operations Research: Approaches to Intelligent Decision Support*, 1987.

13. Sycara, E. (1987). Finding creative solutions in adversarial impasses. *Proceedings of the Conference of the Cognitive Science Society.*

14. Kolodner, J. L. (1987). Capitalizing on failure through case-based inference. *Proceedings of the Conference of the Cognitive Science Society*, 1987.

15. Kolodner, J. L. Extending problem solver performance through case-based inference. *Proceedings of the Fourth International Machine Learning Workshop*, June, 1987.

16. Sycara, E. (1987). Planning for Negotiation: A Case-Based Approach. *Proceedings of the DARPA Knowledge-Based Planning Workshop*, Austin, TX, December 1987.

17. Kolodner, J. L. and Simpson, R. L. (1988). *The MEDIATOR: A Case Study of a Case-Based Problem Solver.* Report No. GIT-ICS-88/11 School of Information and Computer Science. Georgia Institute of Technology. Atlanta, GA, 1988.

18. Sycara, E. (1988). Computer Aiding in Negotiation (Extended Abstract). Submitted to 2nd Conference on Computer Supported Cooperative Work.

19. Sycara, E. (1988). Multi-Agent Compromise via Negotiation (Extended Abstract). Submitted to the 8th Workshop on Distributed AI.

20. Sycara, E. (1988). Resolving Goal Conflicts via Negotiation. Submitted to AAAI88.

21. Sycara,E. (1988). Using Case-Based Reasoning for Plan Adaptation and Repair. *Proceedings of the DARPA Workshop on Case-Based Reasoning.* May, 1988.

Publications Supported Under ARO Contract No.
DAAG29-83-G-0016 and NSF Grant 8317711

Turner, R. (1986). *A Derivational Approach to Plan Refinement for Advice Giving.* In Proceedings of the 1986 IEEE International Conference on Systems, Man, & Cybernetics. Atlanta, GA. October.

Turner, R. (1987). *Issues in the Design of Advisory Systems: The Consumer-Advisor System.* Technical Report GIT-ICS-87/19. School of Information and Computer Science. Georgia Institute of Technology. Atlanta, GA, 30332. April.

PUBLICATIONS RESULTING FROM RESEARCH UNDER IST-8317711

Kolodner, J.L. (1985). "Experiential Processes in Natural Problem Solving." Technical Report No. GIT-ICS-85/23. School of Information and Computer Science, Georgia Institute of Technology, Atlanta, GA.

Kolodner, J.L. (1985). "'If you want my advice....': Some Protocols of a memory-intensive task," in "Proceedings of the Second Annual Workshop on Theoretical Issues in Conceptual Information Processing," New Haven, CT, May, 1985.

Kolodner, J.L. and Simpson, R.L. (1985). "Machine Learning Research at Georgia Tech: Using Experience as a Guide to Problem Solving." Published in the "Proceedings of the Machine Learning Workshop," Skytop, PA, June 24-26, 1985, pp. 96-99.

Kolodner, J.L. (1985). "Memory for Experience." In Bower, G., ed., The Psychology of Learning and Motivation, Academic Press, New York, 1985, pp. 1-57. Also Technical Report No. GIT-ICS-84/23. School of Information and Computer Science, Georgia Institute of Technology, Atlanta, GA.

Kolodner, J.L., Simpson, R.L. and Sycara, E. (1985). "A Process Model of Case-Based Reasoning in Problem Solving." Published in the "Proceedings of the Seventh International Joint Conference on Artificial Intelligence," Los Angeles, CA Aug., 1985, pp. 284-290. Also Technical Report No. GIT-ICS-85/01. School of Information and Computer Science, Georgia Institute of Technology, Atlanta, GA.

Kolodner, J.L. and Cullingford, R.E., "Interactive Advice-Giving." Published in the "Proceedings of the IEEE International Conference on Systems, Man and Cybernetics," Atlanta, GA, Oct., 1986. Also Technical Report No. GIT-ICS-86/20. School of Information and Computer Science, Georgia Institute of Technology, Atlanta, GA.

Kolodner, J.L. and Simpson, R.L. (1986). "Problem Solving and Dynamic Memory," (long version). In Kolodner, J.L. and Riesbeck, C.K. Experience, Memory and Reasoning, Lawrence Erlbaum Assoc., Hillsdale, NJ. Technical Report No. GIT-ICS-84/24. School of Information and Computer Science, Georgia Institute of Technology, Atlanta, GA.

Kolodner, J.L. (1986). "Some Unknown Complexities of Case-Based Inference." Presented at conference on "Theoretical Issues and Conceptual Information Processing" (TICIP), Atlanta, GA, Nov., 1986.

Kolodner, J.L. and Cullingford, R.E. "Towards a Memory Architecture that Supports Reminding." Published in the "Proceedings of the Eighth Annual Conference of the Cognitive Science Society," Amherst, MA, Aug., 1986. Also Technical Report No. GIT-ICS-86/10. School of Information and Computer Science, Georgia Institute of Technology, Atlanta, GA.

Kolodner, J.L. (1986). "Using Experience as a Guide for Problem Solving in Machine Learning: A Guide to Current Research," Kluwer Academic Press, 1986.

Kolodner, J.L. "Capitalizing on Failure through Case-Based Inference." Published in the "Proceedings of the Ninth Annual Conference of the Cognitive Science Society," July, 1987.

Kolodner, J.L. (1987). "Case-Based Inference: A Collection of Papers." Technical Report No. GIT-ICS-87/18. School of Information and Computer Science, Georgia Institute of Technology, Atlanta, GA.

Kolodner, J.L. "Extending Problem Solver Capabilities through Case-Based Inference." Published in the "Proceedings of the Fourth International Machine Learning Workshop," June, 1987.

Kolodner, J.L. and Kolodner, R.M. (1987). "Using Experience in Clinical Problem Solving: Introduction and Framework." Published in "IEEE Transactions on Systems, Man, and Cybernetics." Technical Report No. GIT-ICS-85/21. School of Information and Computer Science, Georgia Institute of Technology, Atlanta, GA.

Kolodner, J.L. and Simpson, R.L (1988). "The MEDIATOR: A Case Study of a Case-Based Problem Solver." Technical Report No. GIT-ICS-88/11. School of Information and Computer Science, Georgia Institute of Technology, Atlanta, GA.

Turner, R.M. (1988a). "Organizing and Using Schematic Knowledge for Medical Diagnosis." Presented at DARPA Workshop on Case-Based Reasoning, May 11-13, 1988, Clearwater Beach, FL.

Turner, R.M. (1988b). "Using Schemata for Diagnosis." Submitted to the Twelfth Annual Symposium on Computer Applications in Medical Care (SCAMC-88).

Turner, R.M. (1988c). "Opportunistic Use of Schemata for Medical Diagnosis." Submitted to the Tenth Annual Conference of the Cognitive Science Society, Aug., 1988.

Publications Supported Under NSF Grant IST-8608362 (1986 to Present)

Cullingford, R.E. and Hill, E.M. (1987). *Using MOPs for Conversational Control.* Research Report GIT-ICS-87-22. School of Information and Computer Science. Georgia Institute of Technology. Atlanta, Georgia. May.

Cullingford, R.E. and Kolodner, J.L. (1986). *Interactive Advice Giving.* Found in Proceedings of the IEEE International Conference on Systems, Man & Cybernetics, Atlanta, Georgia. October. Also, Technical Report GIT-ICS-86/20. School of Information and Computer Science. Georgia Institute of Technology. Atlanta, Georgia. May.

Cullingford, R.E. and Graves, M. (1988). *Knowledge Acquisition for Natural Language Processing: Two Prospects.* Found in the Proceedings of the 1987 Natural Language Planning Workshop on planning for Future Research: Directions for the Next Decade. Northeast AI Consortium, Minnowbrook.

Graves, M. (1988). *Automatic Lexicon Acquisition Using Machine Readable Dictionaries.* Found in Proceedings of the 26th Annual Southeast Regional Conference of the ACM. Mobile, Alabama. April, 1988.

Hill (now Turner), E. (1987). *Using Conversational MOPs to Guide Cooperative Problem Solving Dialogues.* Unpublished doctoral dissertation proposal. School of Information and Computer Science. Georgia Institute of Technology. Atlanta, Georgia. December.

Hill (now Turner), E., and Cullingford, R.E. (in press). *Making Conversation Flexible.* Submitted to IJCAI-89. Detroit, Michigan. August, 1989.

Hinrichs, T.R. (1988). *Towards an Architecture for Open-World Problem Solving.* Found in the Proceedings of the DARPA Workshop on Case-Based Reasoning. Clearwater Beach, Florida. May. Also submitted to AAAI-88.

Hinrichs, T.R. (1988). *Problem Solving in Open Worlds: Integrating Case-Based Reasoning and Constraint Propogation.* Unpublished doctoral thesis proposal. School of Information and Computer Science. Georgia Institute of Technology. Atlanta, Georgia. February.

Hinrichs, T.R. (in press). *Strategies for Problem Solving in an Open World.* Submitted to IJCAI-89. Detroit, Michigan. August, 1989.

Kolodner, J.L. (1987). *Capitalizing on Failure through Case-Based Inference.* Found in the Proceedings of the Ninth Annual Conference of the Cognitive Science Society. Seattle, Washington. Also published in Technical Report GIT-ICS 87/18. School of Information and Computer Science. Georgia Institute of Technology. Atlanta, Georgia. April.

Kolodner, J.L. (1987). *Extending Problem Solver Capabilities through Case-Based Inference.* Found in the Proceedings of the Fourth International Machine Learning Workshop. Irvine, California. June. Also found in Technical Report GIT-ICS 87/18. School of Information and Computer Science. Georgia Institute of Technology. Atlanta, Georgia. April.

Kolodner, J.L. (1987). *Case-Based Inference: A Collection of Papers.* Research Report GIT-ICS 87/18. School of Information and Computer Science. Georgia Institute of Technology. Atlanta, Georgia. April.

Kolodner, J.L. (1988). *Retrieving Events from a Case Memory: A Parallel Implementation.*

Found in the Proceedings of the DARPA Workshop on Case-Based Reasoning. Clearwater Beach, Florida. May. A shorter version of this paper was submitted to AAAI-88.

Kolodner, J.L. and Thau, R. *Design and Implementation of a Case Memory.* Thinking Machines, Inc., Technical Report. October, 1988. Also Technical Report GIT-ICS 88/34. School of Information and Computer Science. Georgia Institute of Technology. Atlanta, Georgia. October, 1988.

Shinn, H. (1988). *Abstractional Analogy: A Model of Analogical Reasoning.* Found in the Proceedings of the DARPA Workshop on Case-Based Reasoning. Clearwater Beach, Florida. May. Also submitted to AAAI-88.

Shinn, H. (1988). *The Role of Mapping in Analogical Transfer.* Found in the Proceedings of the Tenth Annual Conference of the Cognitive Science Society. Monteal, Canada. August.

Shinn, H. (in press). *Analogy-Based Learning: A Basic Framework.* Submitted to IJCAI-89. Detroit, Michigan. August, 1989.

Turner, E.H. and Cullingford, R.E. (1988). *Using Conversation MOPs in Natural Language Interfaces.* Accepted for publication in *Discourse Processes.* Also Technical Report GIT-ICS 88/14. School of Information and Computer Science. Georgia Institute of Technology. Atlanta, Georgia.

Turner, E.H. and Cullingford, R.E. (1988). *Using Conversation MOPs to Integrate Intention and Convention in Natural Language Processing.* Found in the Proceedings of the Tenth Annual Conference of the Cognitive Science Society. Montreal, Canada.

Turner, R. (1987). *Integrating the Use of Previous Problem-solving Experience into Medical Diagnosis.* Unpublished doctoral dissertation proposal. School of Information and Computer Science. Georgia Institute of Technology. Atlanta, Georgia. December.

Turner, R. (1988). *Organizing and Using Schematic Knowledge for Medical Diagnosis.* Found in the Proceedings of the DARPA Workshop on Case-Based Reasoning. Clearwater Beach, Florida. May. A shorter version of this paper was submitted to AAAI-88.

Turner, R. (1988). *Opportunistic Use of Schemata for Medical Diagnosis.* To appear in the Proceedings of the 10th Annual Conference of the Cognitive Science Society. Montreal, Canada.

Turner, R. (1988). *Using Schemata for Diagnosis.* Found in the Proceedings of the Symposium on Computer Applications in Medical Care (SCAMC-88).

Turner, R. (in press). *When Reactive Planning is Not Enough: Using Contextual Schemas to React Appropriately to Environmental Change.* Submitted to IJCAI-89. Detroit, Michigan. August, 1989.

Turner, R. (in press). *Representing Procedural Knowledge for Interactive Problem Solving.* Submitted to IJCAI-89. Detroit, Michigan. August, 1989.

Publications Supported under ARI Contract
No. MDA903-86-C-0172

Kolodner, J. (1987). *Extending Problem Solving Capabilities Through Case-Based Inference.* Proceedings of the Fourth Machine Learning Workshop, Irvine, CA. June. Also found in Technical Report GIT-ICS 87/18. School of Information and Computer Science. Georgia Institute of Technology. Atlanta, Georgia 30332.

Kolodner, J. (1987). *Capitalizing on Failure through Case-Based Inference.* Proceedings of the Ninth Annual Conference of the Cognitive Science Society. Seattle, Washington. Also published at Technical Report GIT-ICS-87/18. School of Information and Computer Science. Georgia Institute of Technology. Altanta, Georgia 30332. April.

Lancaster, J. and Kolodner, J. (1987). *Problem Solving in a Natural Task as a Function of Experience.* Proceedings of the Ninth Annual Conference of the Cognitive Science Society. Seattle, Washington. August.

Lancaster, J. and Kolodner, J. (1988). *Varieties of Learning from Problem Solving Experience.* Proceedings of the Tenth Annual Conference of the Cognitive Science Society. Montreal, Quebec, Canada. August.

Lancaster, J. and Kolodner, J. (in press). *Problem Solving in a Natural Task Domain.* Submitted to Tenth Anual Cognitive Science Conference. Montreal, Quebec, Canada. November, 1988. Also Technical Report GIT-ICS-89/02. School of Information and Computer Science. Georgia Institute of Technology. Atlanta, Georgia 30332.

Martin, J.D. and Redmond, M. (1988). *The Use of Explanations for Completing and Correcting Causal Models.* Proceedings of the Tenth Annual Conference of the Cognitive Science Society. Montreal, Quebec, Canada. August.

Martin, J. (1988). *CORA: Toward a Best Match Episodic Memory.* Proceedings of the AAAI Workshop on Case-Based Reasoning. Minneapolis/St. Paul, Minnesota. August.

Martin, J.D. (in press). *Focusing Attention for Observational Learning: The Importance of Context.* Submitted to IJCAI-89.

Redmond, M. and Martin, J. (1988). *Learning by Understanding Explanations.* Proceedings of the 26th Annual Conference of the Southeast Region Association for Computing Machinery. Mobile, Alabama. April.

Redmond, M. and Martin, J. (in press). *Learning by Observing and Understanding Expert Problem Solving.* Submitted to IJCAI-89. Detroit, Michigan.

Shinn, H. (1988). *Abstractional Analogy: A Model of Analogical Reasoning.* Proceedings of the DARPA Workshop on Case-Based Reasoning, May 10-13. Clearwater Beach, Florida.

Shinn, H. (1988). *The Role of Mapping in Analogical Transfer.* Found in the Proceedings of the 10th Annual Conference of the Cognitive Science Society. Montreal, Quebec, Canada. August.

Ronald C. Arkin, Assistant Professor in the
School of Information and Computer Science
Georgia Institute of Technology

Most Recent Publications

Refereed Publications:

Arkin, R.C., 1988. *Intelligent Mobile Robots in the Workplace: Leaving the Guide Behind.* Found in the Proceedings of the First International Conference on Industrial and Engineering Applications of Artificial Intelligence and Expert Systems, pp. 553-561. Also appears as GIT-ICS Technical Report 88/08.

Arkin, R.C., 1988. *Spatial Uncertainty Management for a Mobile Robot and its Role in Expectation-Based Perception.* Symposium on Robot Control '88 (Syroco), Karlsruhe, W. Germany, October 1988.

Submitted for Publication

Arkin, R.C., Riseman, E. and Hanson, A., 1988. *Visual Strategies for Mobile Robot Navigation.* submitted to IEEE Transactions of Pattern Analysis and Machine Intelligence.

Arkin, R.C., 1988. *Dynamic Replanning for a Mobile Robot Based on Internal Sensing.* submitted to the 1989 IEEE International Conference on Robotics and Automation, Scottsdale, Arizona.

Arkin, R.C., 1988. *Knowledge Requirements for the Navigation of an Intelligent Mobile Robot.* submitted to IEEE Computer Magazine, special issue on Autonomous Intelligent Machines.

Arkin, R.C. and Murphy, R.A., 1988. *Autonomous Navigation in a Manufacturing Environment.* submitted to IEEE Journal of Robotics and Automation.

Arkin, R.C., 1988. *The Impact of Cybernetics on the Design of a Mobile Robot System: A Case Study.* submitted to IEEE Transactions on Systems, Man, and Cybernetics, special issue on unmanned vehicles.

Accepted for Publication

Arkin, R.C., 1988. *Navigational Path Planning for a Vision-based Mobile Robot.* Accepted for publication in Robotica.

Arkin R.C., 1988. *Homeostatic Control for a Mobile Robot: Dynamic Replanning in Hazardous Environments.* to appear in the Proceedings of the SPIE Conference on Mobile Robots III, Cambridge Symposium on Advances in Intelligent Robotics Systems.

Arkin, R.C., 1988. *Motor Schema-Based Mobile Robot Navigation.* accepted for publication in the International Journal of Robotics Research.

Arkin, R.C., 1988. *Three Dimensional Motor Schema Based Navigation.* to appear in the Proceedings of the NASA Conference on Spcae Telerobitcs, Pasadena, CA, January 1989.

Books and Book Chapters

Arkin, R.C., 1988. *Neuroscience in motion: The Application of Schema Theory to Mobile Robotics.* chapter to appear in Visuomotor Coordination: Amphibians, Experiments, Models, and Robots, ed. P. Evert and M. Arbib, Plenum Publishing Co., 1988.

Arkin, R.C., 1988. *Autonomous Mobile Robots.* chapter to appear in Knowledge Engineering, Vol. 2, Ed. H. Adeli, McGraw-Hill.