CONF-8905109--1

CESAR-89/14

Review of the 1988 Workshop on Human-Machine Symbiotic Systems*

Lynne E. Parker and Charles R. Weisbin

Center for Engineering Systems Advanced Research
Oak Ridge National Laboratory
P.O. Box 2008
Building 6025, MS-6364
Oak Ridge, TN 37831-6364

CONF-8905109--1

DE89 008743

Invited Presentation: Workshop on Integration of AI and Robotic Systems, Scottsdale, Arizona, May 19, 1989

* Research sponsored by the Engineering Research Program of the Office of Basic Energy Sciences, of the U.S. Department of Energy, under contract No. DE-AC05-84OR21400 with Martin Marietta Energy Systems, Inc.

Review of the 1988 Workshop on Human-Machine Symbiotic Systems

Lynne E. Parker and Charles R. Weisbin

Oak Ridge National Laboratory, Center for Engineering Systems
Advanced Research, P.O. Box 2008, Oak Ridge, TN 37831-6364

Abstract

This report presents a review of the 1988 Workshop on Human-Machine Symbiotic Systems. Held December 5-6, 1988 in Oak Ridge, Tennessee, the workshop served as a forum for the discussion of several critical issues in human-machine symbiosis: human-machine communication, autonomous task planning and execution monitoring for heterogeneous agents, dynamic task allocation, human-machine system architecture, and machine learning via experience and human observation. The presentation of overview papers by invited keynote speakers provided a background for the breakout session discussions in these five areas. A summary of the conclusions and recommendations for future work resulting from the workshop is reported.

Workshop Review

In recent years, a growing research interest has focused on the development of methods facilitating a cooperative problem-solving relationship between humans and autonomous machines – a relationship the workshop organizers define as "human-machine symbiosis." In a symbiotic system, humans and machines cooperate in the decision making and control of tasks in a complex, dynamic environment, communicating frequently in the exchange of tasks. The function of the symbiotic system is to dynamically optimize the division of work between the human and the machine, with the ultimate goal of improving the admissible task range, accuracy, and work efficiency of the system. The successful creation of such systems requires an effective approach to several fundamental technical issues such as human-machine communication, autonomous task planning and execution monitoring for heterogeneous agents, dynamic task allocation, human-machine system architecture, and machine learning via experience and human observation.

In order to address these key issues of research and to recommend directions for future work in human-machine symbiosis, an invitational workshop was organized by Charles Weisbin and Lynne Parker of Oak Ridge National Laboratory, and by Jim Gumnick of Oak Ridge Associated Universities. The workshop was held December 5-6, 1988, at Oak Ridge Associated Universities in Oak Ridge, Tennessee. The meeting brought together 38 investigators interested in human-machine symbiosis from several research communities, including robotics, artificial intelligence, human factors, and cognitive science. To encourage informality and more open discussions, the attendance size was intentionally restricted, but participants were invited from a broad range of university, laboratory, and industry programs to provide a diversity of viewpoints.

To provide a background for discussion, five keynote presentations were made by internationally recognized experts: Dr. Thomas Sheridan (Massachusetts Institute of Technology) addressed the subject of human-machine communication, Dr. Avi Kak (Purdue University) presented the subject of autonomous task planning, Dr. Scott Harmon (Robot Intelligence International) spoke on the subject of dynamic task allocation and execution monitoring, Dr. Christine Mitchell (Georgia Institute of Technology) addressed human-machine system architectures, and Dr. Thomas Mitchell (Carnegie Mellon University) presented the topic of machine learning. Full papers provided by these speakers (Harmon 89, Kak 88, C. Mitchell 89, T. Mitchell 89, Sheridan 89) address the issues of human-machine symbiosis.

The keynote presentations were followed by breakout sessions whose participants were charged to develop effective research approaches and suggestions for future work in five principal technical areas. To help initiate the discussions in each of these areas, the following questions were posed to the participants in advance of the workshop:

1. Human-Machine Communications: What are the most effective means of communication between man and machine in cooperative control systems involving physical processes?

2. Autonomous Task Planning and Execution Monitoring: What are the most promising approaches to real-time task planning and execution monitoring between heterogeneous agents, at least one of which is human?

3. Dynamic Task Allocation: What are the best methods of allocating cooperative human-machine tasks?

4. Human-Machine System Architecture: What human-machine system architectures allow real-time cooperative interaction between the human and the machine?

5. Machine Learning via Experience and Human Observation: What are the most promising approaches toward providing the intelligence for a machine to learn new tasks through assimilation of experience and human observation?

Written summaries of the recommendations and conclusions of the breakout sessions were prepared by the reporters and are included in the workshop proceedings (Parker 89). It should be noted that the summaries reflect only the opinions of the select group of workshop participants; however, the workshop organizers are hopeful that the session reports will be a valuable assistance to researchers in the Human-Machine Symbiosis field.

It is interesting to note the attitude the attendees had concerning the definition and implications of the term "symbiosis." As defined by Webster's Unabridged Dictionary, and referenced by Thomas Sheridan in his paper (Sheridan 89), symbiosis is "two dissimilar organisms living together in mutual dependence." Although certain life-and-death situations (such as battlefield management) might indeed require the human to be dependent on automated machines for survival, many of the workshop participants were uncomfortable with this implied requirement for all symbiotic systems. Instead, as presented in the Machine Learning session report by Phil Spelt (Parker 89), the group was more willing to accept the first definition of Webster's II New Riverside University Dictionary: "the relationship of two or more ... organisms in close association that may be but is not necessarily of benefit to each" (1984). The term "synergy" was suggested as a possible alternative for describing the human-machine system.

Having somewhat agreed to an appropriate interpretation of symbiosis, the participants generally concurred that some degree of autonomy is a prerequisite for symbiosis, since a machine must have sufficient capabilities and intelligence to cooperate productively with a human. However, full autonomy is not required, since the human can be responsible for tasks or portions of tasks that the machine is unable to perform.

An analysis of the workshop reports reveals two overriding themes recurrent in the breakout sessions: the need for the development of various types of human and machine models, and the need for investigations concerning the roles the human(s) and the machine(s) should play in the symbiotic system. The development of human and machine models was recommended as an important future research topic in the Human-Machine Communication, Dynamic Task Allocation, and Autonomous Task Planning breakout sessions. The emphasis in the Communication group was for human behavioral modeling emphasizing the characteristics present during both normal and abnormal circumstances, while the Dynamic Task Allocation and Planning sessions emphasized the need for the modeling of human and machine capabilities. In his paper (Harmon 89), Scott Harmon reports on several existing techniques that have been used for internal agent modeling, while Christine Mitchell, in her paper (C. Mitchell 89), describes the use of an operator function model in a particular project. The participants, however, agreed that additional research is still needed in this area — both for the development of generic models and for their application to the modeling of individual operators.

The issue of the roles the human(s) and machine(s) should play in the symbiont provided some lively discussions. In most complex systems of today, a hierarchy of control exists in which certain agents (human or machine) dominate some agents, while they are supervised by others. Such a hierarchy will allow humans to be controlled by non-human, or automated, components of the system. However, at the highest level of decision-making and control, current systems always place a human. The workshop opinion inclined toward continuing this system organization by allowing the human to maintain ultimate control in symbiotic systems for most, if not all, applications of the near future. The operator's associate described in Christine Mitchell's paper reflects this superior human/subordinate machine relationship in which the computer assumes control only when the human explicitly delegates responsibility. The advantage to this approach is that by making the human the primary decision maker, he/she will have the knowledge and authority required for effective and safe system operation.

An opposing viewpoint, however, holds that the human may not always be the optimal choice for highest-level system control. The recent Vincennes tragedy (in which a U.S. Navy missile cruiser shot down an Iranian airliner after mistaking it for a military fighter aircraft) was mentioned as a prime example of a situation in which human interaction with a complex, time-critical, automated system is sensitive to extreme human stress and mental overload. Situations such as this may therefore benefit from allowing the automated component to assume ultimate control over the human under specified conditions. It was generally agreed, however, that at the present time, no one knows how to decide when the intelligent machine should be the principal controller. Thus, these discussions led to the recognition of the need for more research on the psychological and physiological impact, and the interface implications of allowing a machine to serve as the highest-level decision maker over a human.

In addition to the issues of agent modeling and the roles of humans and machines, the breakout sessions identified various other critical areas of future research and derived several interesting conclusions. The Human-Machine Communication session emphasized the need for research in the simultaneous and integrated use of multiple modalities, or sensor channels, for communication between human and machine. The goal of this research should be to make better, if not full, use of the human's sensory capabilities. The Machine Learning group determined that learning involves, in part, a transfer of knowledge from the human to the machine, and is useful when complete pre-programming is impossible. They identified two roles the human serves in symbiont learning: to act as a model from which the machine can learn (e.g. using machine vision, watch and emulate human performance), and to function as a teacher/consultant in which the human monitors the performance of the machine and makes corrections when needed. Both the Machine Learning and the Autonomous Task Planning sessions reported the need for continued research on machine learning leading to the capability to generalize. The Autonomous Task Planning group also noted the need for research facilitating the smooth transition between human and machine control for the purpose of planning at different task levels.

The Dynamic Task Allocation session emphasized the need for measurement techniques for quantifying human and machine skills, and for the determination of the appropriate task granularity that assures the smooth transition of control among elemental subtasks as they are assigned to different agents. In addition, this group noted the need for an automated monitoring facility that can dynamically assess the progress and directedness of the agents — a facility also recognized as important by the Machine Learning group.

Finally, the Human-Machine Architecture breakout session determined that a symbiotic system architecture should have a human interface perspective with multiple entry points that provides user access to the various functional modules of the system as needed. One area recommended for future research involves addressing the problem of system stability under hybrid control, in which the portions of the architecture controlled manually or autonomously vary dynamically over time. Another topic recommended for future research concerns the development of metrics defining quality measurements (such as effectiveness versus complexity) of a human-machine system architecture.

Judging by positive feedback both from written evaluations and verbal communication, the workshop organizers believe this 1988 Workshop on Human-Machine Symbiotic Systems was a success. This workshop served to identify key areas of research in five principal areas of human-machine symbiosis that are needed to achieve human-machine cooperative control and intelligence. The authors are hopeful that this workshop will serve as a stepping board toward advancing the state of the art in the area of Human-Machine Symbiosis.

References

Harmon, S. Y. "Dynamic Task Allocation and Execution Monitoring in Teams of Cooperating Humans and Robots." Proceedings of the 1988 Workshop on Human-Machine Symbiotic Systems (1989).

Kak, A. C., S. A. Hutchinson, and K. M. Andress. "Planning and Reasoning in Sensor Based Robotics." IEEE Catalog Number 88TH0234-5 (1988): 239-245.

Mitchell, C. M. "Human-Machine System Architecture: The Design of Cooperative Teams of Human and Computer Decision Makers." Proceedings of the 1988 Workshop on Human-Machine Symbiotic Systems (1989).

Mitchell, T. M., M. T. Mason, and A. D. Christiansen. "Toward a Learning Robot." Proceedings of the 1988 Workshop on Human- Machine Symbiotic Systems (1989).

Parker, L. E. and C. R. Weisbin. Proceedings of the 1988 Workshop on Human-Machine Symbiotic Systems (1989) (in process).

Sheridan, T. B. "Man-Machine Communication for Symbiotic Control." Proceedings of the 1988 Workshop on Human-Machine Symbiotic Systems (1989).