

Multitasking: a Review

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Abstract

Multitasking (often referred to as timesharing) has been extensively studied from a mental workload and human performance perspective. However, a relatively small amount of research has been conducted in the manufacturing domain (Wickens, 1992). As the level of system automation increases, the role of the human has shifted from that of a manual controller to system supervisor (Sheridan and Johanssen, 1976). According to Sheridan (1994), “human operators in AMS make their way among machines, inspecting parts, observing displays, and modifying control settings or keying in commands, most of it through computer-mediated control panels adjacent to various machines.” This role of human operators in AMS has been identified as supervisory control in this paper.

INTRODUCTION

Human Supervisory Control

Supervisory control refers to one or more human operators programming and receiving information from a computer that interconnects through artificial effectors and sensors to the controlled process or task environment (Sheridan, 1987). Ammons, Govindaraj, and Mitchell (1988) described the supervisory controller as “an operator responsible for a group of complex machinery where the operations require intermittent attention and depend on higher-level perceptual and cognitive functions.” Sheridan (1976) defined a general paradigm of supervisory control consisting of five functions: 1) Plan, 2) Teach, 3) Monitor, 4) Intervene, and 5) Learn. For each of the main supervisory functions the computer provides decision-aiding and implementation capabilities, as shown in Figure 1. A description of these functions is presented in Figure 2

Job scheduling, inventory planning, and problem solving (disturbance control) have been among the supervisory control responsibilities commonly assigned to human operators in AMS (Suri and Whitney, 1984; Ammons et al., 1988). The capabilities of humans and computers in AMS planning/scheduling tasks are presented in Table 1 (Nakamura and Salvendy, 1994). Table 2 shows examples of different types of unexpected contingencies (disturbances) in AMS (Kuivanen, 1996). Ammons et al. (1988) stated that two ways in which the unique skills of the human decision maker are used in supervisory control are to fine-tune or refine standard operating procedures for particular system states and to compensate for unplanned events and unexpected contingencies.

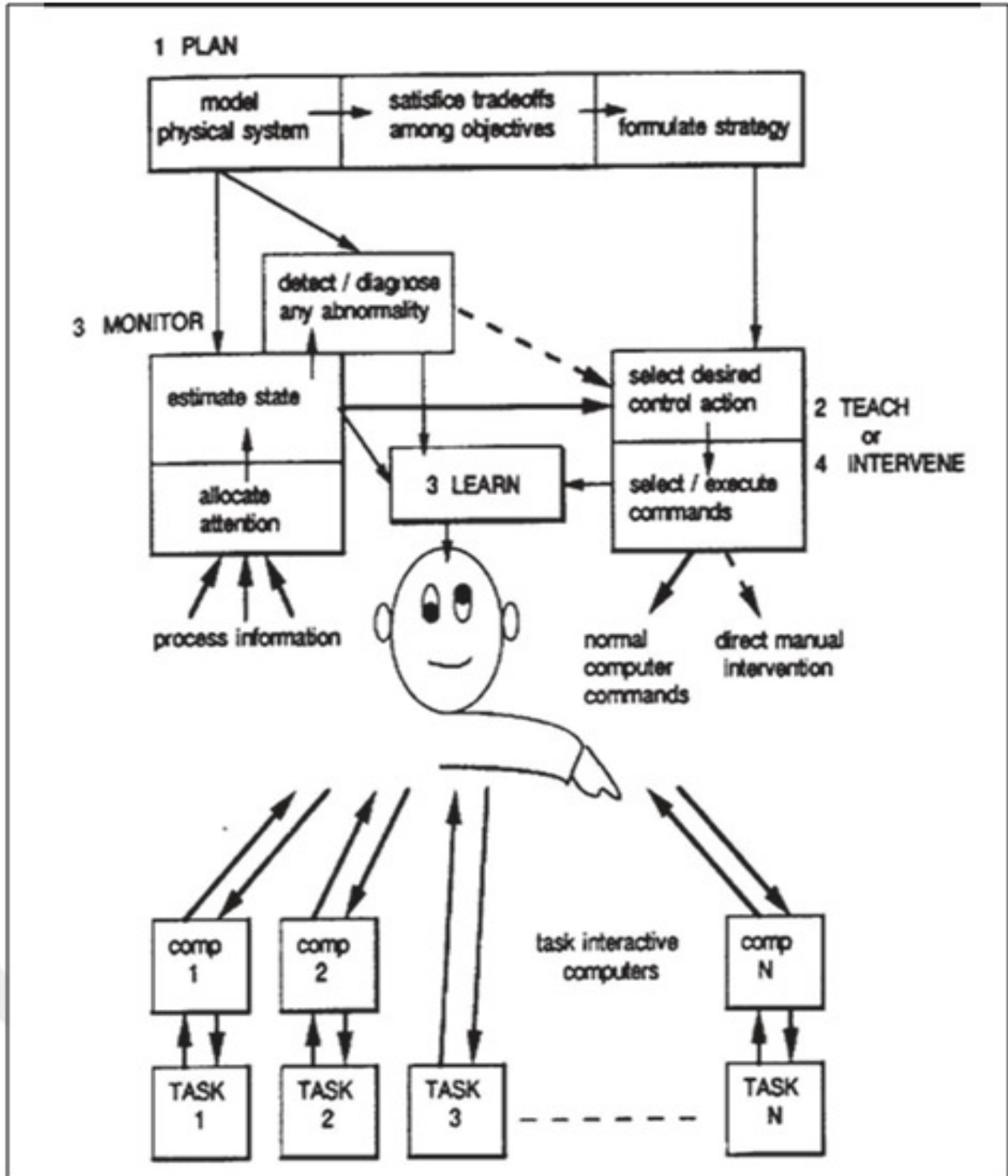


Figure 1 General paradigm of supervisory control

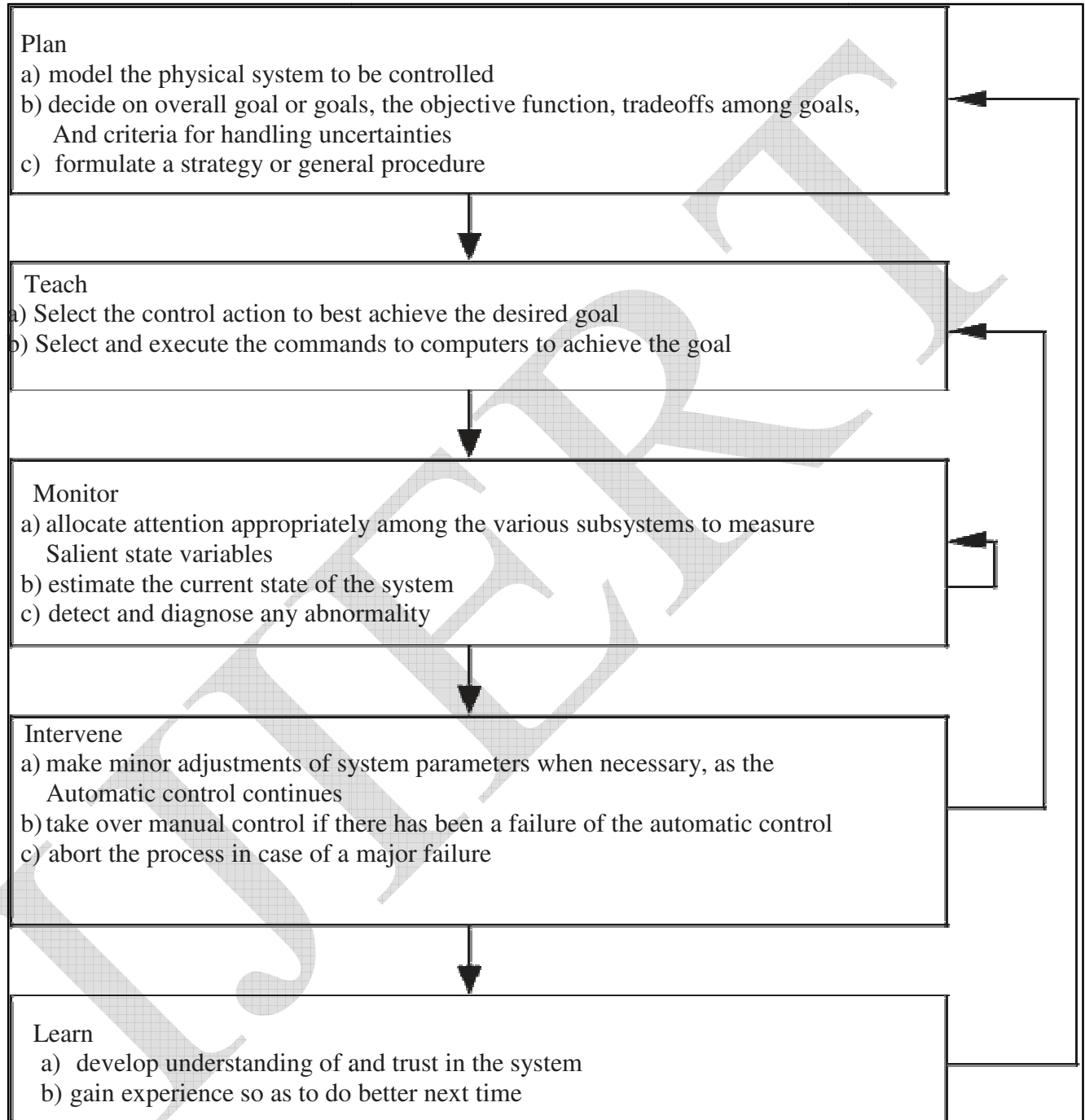


Figure 2 Temporal nesting of the general paradigm of supervisory control functions

Table 1 Capabilities of human and computer in planning/scheduling tasks of AMS

Subtask	Description	Computer	Human
1. Detection	• Detect information and data for jobs and machines.	• Computer can easily detect information and data.	• Human takes a long time to detect the presence of information and data
2. Identification of system status	• Identify the present state of the system.	• If the identified pattern was predetermined, computer can quickly identify it.	• Human can recognize the important features in the planning / scheduling environment. (but this is nonlinguistic knowledge.)
3. Interpretation	• Interpret performance criteria and set the final goal for planning / scheduling.	• Computer can decide if the program connecting the present state with the final goal is stored.	• Human can set the reasonable goal from among many criteria which conflict with each other.
4. Order selection	• Select an order to be scheduled according to a priority.	• Heuristic algorithm can provide a "good" solution, but no guarantee on optimal one.	• Human intuition makes the best feasible solution.
5. Time assignment	• Determine the start time and finish time for each operation of the selected order.	• It is difficult to take balance between job waiting time and machine idle time.	• Coordinating human with computer helps to determine efficient time assignment.
6. Resource allocation	• Select the resources (machines, tools, fixtures, NC program, etc.) to produce an order.	• Computer program can easily check whether machines, tools, fixtures and NC program are available.	• Human selects many alternative solutions.
7. Evaluation and modification	• Evaluate the plan / schedule and if not satisfied, modify it.	• Poor, but updates the overall plan / schedule at least once every minute.	• Human modifies overall plan / schedule with flexible decision making abilities.
8. Generation	• Generate the plan / schedule sheet and issue it to the floor.	• Computer can do it very easily.	• Slow, not suitable.
9. Control	• Check the difference between the plan / schedule and the practice.	• Computer can do it easily under normal conditions.	• Human can adapt at abnormal conditions.

Table 2 Different type of disturbances in AMS

Target Group	Viewpoint	Definition	Example of the Cause of the Disturbance
General	All the situations concerning the organization, technique, or human action	A disturbance is an unplanned or undesirable state or function of the	—a missing work order —machine or device failure —broken tool —overloading —insufficient training
Operator of the system	All the situations that harm the normal working routine	A disturbance is a state or function of the system, which causes extra work	—error in the work program —error in the work —broken tool —machine or device failure
Maintenance	All the situations, that make it necessary for the maintenance personnel to take action towards the systems operation	A disturbance is a state or function of the system that requires remedial actions	—machine or device failure —overloading —maintenance and cleaning
Labor management and design	All the situations that prevent production	A disturbance is a state or function of the system which stops production	—raw materials, tools, or plans missing —machine or device failure —machine or device failure —workers or key personnel taken ill —strike
Production management	All that disables a delivery in agreed time	A disturbance is a state or function of the system, which makes it impossible for the producer to deliver the products to the customer in agreed time	—strike —overloading —machine and device failure —bad quality
Marketing	All the events in production, that complicate marketing	A distance is a state or function of the system, which disables or makes it makes it difficult to make a business	—too long time of delivery —inferior quality

Determinants of Multitasking Performance

Different mental models have been used to describe multitasking performance. Scheduling, switching, confusion, cooperation, and processing resources are mechanisms often identified as determinants of multitasking performance (Damos, 1991; Adams, Tenney, and Pew, 1991; Wickens, 1992). In particular, the concept of processing resources is the basis for understanding the other mechanisms, and hence for multitasking performance. According to Wickens (1991), the resources concept is founded on the underlying assumption that the human operator has a limited capacity for processing resources that may be allocated to task performance; therefore, multitasking can lead to one or more tasks with less resource than required, causing performance deterioration. This deterioration in the performance of one task because of competition with another task for critical resources is known as interference.

Two major processing resources theories of task performance are Single-Resource Theory and Multiple-Resources Theory. The Single-Resource theory proposed by Kahneman (1973) postulates one undifferentiated limited pool of resources available to all tasks and mental activities. According to this theory, multitasking performance declines as the difficulty of one of the tasks increases, because it demands more resources from the limited pool, thus leaving fewer resources for performing the other tasks. Sanders and McCormick (1993) indicated that the Single-Resource Theory has difficulty explaining: 1) why tasks that require the same memory codes or processing modalities interfere more than tasks not sharing the same memory codes or processing modalities, 2) why with some combinations of tasks increasing the difficulty of one task has no effect on the performance of the others, and 3) why some tasks can be time-shared perfectly. According to Sanders and McCormick (1993), these three issues can be explained by the Multiple-Resources Theory proposed by Wickens (1984).

The Multiple-Resources Theory proposes that there are three dimensions along which resources can be allocated. The first dimension is stages (encoding and central processing vs. responding), which explains why tasks requiring response selection and allocation resources are not disrupted by tasks requiring central processing resources.

The second dimension is input modality (auditory vs. visual), which explains why multitasking is better when the tasks do not require resources from the same modality than when they do. The third dimension is processing codes (spatial vs. verbal), which explains why multitasking is performed better when one task involves moving or positioning objects in space and the other involves language or logical operations. In addition to the three dimensions mentioned above, this theory suggests a response dimension (vocal vs. manual), which explains why multitasking is performed better when the tasks responses are of opposite types. Although the Multiple-Resources Theory was developed based on dual task multitasking, it can be used to explain more complex multitasking.

Scheduling and switching are highly influential on performance for both dual-task and more complex multitasking. The operator's scheduling and switching ability depends on an understanding of the temporal constraints, the objective, and the cost associated with each task (Wood, 1982; Moray, Dessouky, Kijowski, and Adapatya, 1990). Poor scheduling, inefficient switching between tasks, or insufficient time to do the multiple tasks sequentially will force the person to engage in concurrent processing. Wickens (1991) indicated that when the operator is engaged in concurrent processing, multitasking performance will be influenced by: 1) confusion (elements of one task become confused with the processing of another task because of their similarity), 2) cooperation between task processes (caused by high similarity of processing routines), and 3) competition for task resources. When the amount of resources demanded by the multiple tasks exceeds the amount of the operator's mental resources available, he or she will experience mental workload, consequently decreasing multitasking

performance (McCoy, Derrick, and Wickens, 1983; Bi and Salvendy, 1994). Figure shows the relationship among the performance-resource function for multitasking (Wickens, 1992). Sheridan (1994) stated that mental workload is very important for supervisory control in AMS where the human operator is constantly called upon to do multiple complex sensory and judgmental tasks. The central issue for vigilance research is to determine the effect of the additional tasks to the vigilance performance (Craig, 1991).

Conclusion

The paper reviews the evolution of multitasking capabilities of machines from the early rise of the concept of multitasking and its benefits in today's era.

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