AI IN MANUFACTURING: THE NBS AMRF AS AN INTELLIGENT MACHINE

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ABSTRACT

Within its Automated Manufacturing Research Facility (AMRF), the U.S. National Bureau of Standards (NBS) is addressing research issues in interface standards for the fully automated factory of the future for the production of small batches of discrete parts. Consisting of robots, machine tools and computers, the AMRF is being integrated using a real-time, sensory-feedback, data-driven hierarchical control architecture. As such, the AMRF is a research tool for investigating the manufacturing enterprise as a system of intelligent machines. This paper: (1) describes the AMRF in terms of its real-time control system architecture; (2) notes the role of symbolic languages, knowledge-representation, sensory-processing and other aspects of artificial intelligence in its development; and (3) speculates on further application of AI in future intelligent manufacturing systems similar in form to the AMRF.

I. INTRODUCTION

Within its Automated Manufacturing Research Facility (AMRF), the U.S. National Bureau of Standards is addressing issues of standardized interfaces for the flexibly-automated, robotics-based, computer-integrated factory of the future. The AMRF as a form of this factory is being built in a modular, easily-integratable, multi-vendor form [19].

As this paper will suggest, the NBS AMRF is conceived and is being implemented as a prototype of an intelligent machine of production. The paper; (1) describes the AMRF in terms of its real-time control system architecture; (2) notes the role as subsystems within the AMRF of the four principal

types of intelligent machines: those of both production and service, both physical and mental; and (3) speculates on eventual realizations of these types of intelligent machines in future AMRF-like production systems.

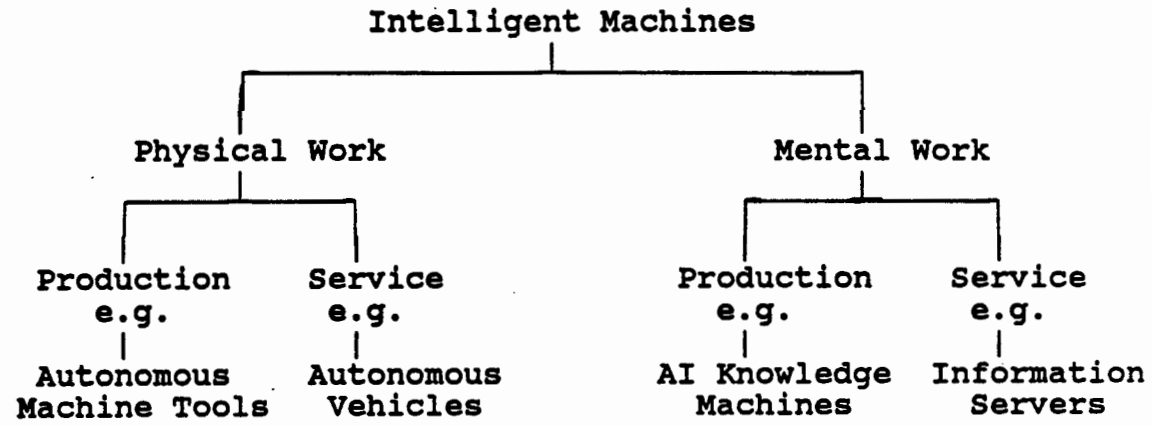
II. THE FAMILY OF INTELLIGENT MACHINE SYSTEMS

In this paper, an intelligent machine is taken to be one capable of autonomous, effective action. As such, an intelligent machine is one which can independently choose and execute a plan of action for the accomplishment of an assigned goal within an uncertain environment.

A. The Four Principal Types of Intelligent Machines

As indicated in Table 1 below, there four types of work that intelligent machines are intended to perform: physical and mental, production and service.

TABLE 1. PRINCIPAL TYPES OF INTELLIGENT MACHINES



Similarly in this scheme, artificial intelligence (AI) machines -- taken to be those based on inferential, non-algorithmic symbol manipulation used, for example, in knowledge representation, heuristic problem solving, machine vision, natural language understanding and related areas-- can be associated with the intelligent machines of mental production, while intelligent database managers and communication systems can be associated with the intelligent machines of mental service.

III. THE FACTORY OF THE FUTURE AS AN INTELLIGENT MANUFACTURING ENTERPRISE

With an intelligent machine defined as above -- one capable of autonomous, effective, goal-directed action -- the factory of the future as an intelligent-machine-system is one capable of autonomously and effectively producing material products to meet customer needs within the uncertain environment of both the shop floor and the marketplace.

To carry out this task, the factory as an intelligent machine of physical production employs as subsystems each of the four principal types of intelligent machines, as illustrated in Table 2 below. (As suggested in the table, the field of robotics is usually associated with intelligent machines of physical work, while the general field of computer science is usually associated with intelligent machines of mental work).

TABLE 2. INTELLIGENT MACHINE SYSTEMS AS COMPONENTS WITHIN THE INTELLIGENT FACTORY

Intelligent Machines	Physical Work ("Robotics")	Mental Work ("Computers")
Production Work	Intelligent Machine Tools	AI-Based CAD/CAE/CAPP/CAM
Service Work	Automated Materials Handling	Intelligent Data Systems

This conceptualization of the factory of the future as an intelligent machine of production -- incorporates the notion of artificial intelligence in various forms: a smart machine tool as an intelligent machine of physical production; a sensory-interactive materials-handling robot as an intelligent machine of physical service; AI-based systems of product design, functional modelling, process planning and control programming as intelligent machines of mental production; and smart data administration and communication systems as intelligent machines of mental service.

IV. THE NBS AMRF AS AN INTELLIGENT MACHINE

As a physical system, the NBS Automated Manufacturing Research Facility (AMRF) consists of machine tools, robots, and computers from a variety of manufacturers which are being integrated by means of NBS-developed uniform interfaces.

-- cell, shop and facility -- levels of the AMRF system this transfer is over a high-speed broadband net.

V. TOWARD HIGHER INTELLIGENCE IN THE AMRF

As a goal-directed, sensory-input, computer-controlled and data-driven manufacturing system, the NBS Automated Manufacturing Research Facility is a realization, in research form, of the factory of the future. At its current level of development, the NBS AMRF as a total system represents very high levels of automation and integration; yet the level of intelligence realized in the AMRF as an intelligent machine of physical production is, in the main, low on the scale of machine intelligence [12] summarized in Table 5 below.

TABLE 5. HIERARCHY OF CONTROL CAPABILITIES OF INTELLIGENT MACHINE SYSTEMS

Reaction	Ability to sense and measure a state of the environment and, in the light of a current internal state, initiate an appropriate response to satisfy some need or goal.
Planning	Ability to hypothesize and specify a plan of action that when carried out will transform the system from an initial to a goal state beyond the range of reaction.
Optimization	Ability to test and evaluate plans by means of modelling, simulation and analysis in order to select the best of a number paths to the goal state.
Learning	Ability to accumulate, filter, interpret and store information in the form of facts, rules and other relations as new knowledge which modifies its basis for action.