Fractal Manufacturing System – Intelligent Control of Manufacturing Industry

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***Abstract* - Fractal manufacturing system is very useful technique of improvement in productivity of system. In this paper, the main focus on brief review of Fractal based systems and its components with its advantages over conventional methods. In the present era, where productivity is very important for growth, FrMS gives a feasible solution for this. FrMS uses CIM as well as artificial intelligence.**

***Index Terms* - Fractal Manufacturing, Artificial Intelligence, CIM, Productivity**

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1. INTRODUCTION

A lot of changes in the manufacturing sector will occur in the future and it is important to transform the actual production systems to evolvable production systems. Fractal, bionic and holonic manufacturing systems are three concepts that have been proposed due their characteristics of flexibility and intelligence. This generation of manufacturing systems is known as intelligent manufacturing systems (IMS). Agent-based software is a technology that can make actions of control or supervision, endowing mechatronics devices with some intelligence. The use of multi-agent based software in operation and control of distributed systems is offering new distributed intelligent control functions (cooperation, planning, scheduling) over wired or wireless networked systems.

Today shortening of the service life of products, increasing of product versions, and shortening of the time from conceiving of the products to their manufacture are faced by us. In spite of the great advances in science and the technology it will be necessary in the future to define the global purpose of the human activities and consequently manufacturing concepts as well. This is particularly important, since the human creativity and the manufacture of goods are obviously the basic needs of human beings. The rational manufacture of goods will no more be the only and central question, but also the global meaning and purpose of goods will be important. Future manufacturing concepts will have to be adapted to the needs of the modern society and, particularly, to the ecosystem more than ever.

In present manufacturing systems, in particular the deterministic approaches are used for synchronization of material, energy, and information flows. It means that the methods based on the exact mathematical findings and the rules of logic are used for modeling, optimization, and functioning of systems. However, production is a very dynamic process with many unexpected events and continuously emerging new requirements. Therefore, exact description of a system is often not possible by conventional methods.

2. FRACTAL CONCEPT

The fractal concepts have origins in mathematics and theory of chaos and indicate new ideas to handle with the inflexibility and rigidity of the actual organizations. The fractal manufacturing system is an open system, and the main characteristic is the self-similarity between their small components, known as fractal entities or fractal units. A fractal unit has the following features

- Self-organization, because don't need external mediation to reorganize. Each unit arranges its internal structure based on previously assigned criteria
- self-similarity, one fractal unit is identical to another fractal unit but the internal structure can be different
- Self-optimized, which means that it continuously search for its best performance. Fractals act as independent units to accomplish their own goals (e.g. production of an output).

However, for the overall goal of the manufacturing system be accomplish, goal coherence should be maintained by cooperation and iteration with other units. In a fractal manufacturing system a predefined organization doesn't exist. Any fractal unit has its own resources with static capabilities and an efficient information system that provides data required to manufacture products and allocate operating resources. These characteristics allow a great dynamic environment inside the unit that make possible to work with constant changes in the enterprise structure and react quickly to external requirements.

3. FRACTAL MANUFACTURING SYSTEM

The FrMS is comprised of a number of ''basic components'', each of which consists of five functional modules: (1) an observer, (2) an analyzer, (3) an organizer, (4) a resolver, and (5) a reporter.

Each of these modules, using agent technology, autonomously cooperates and negotiates with others while processing its own jobs. Facing intensified competition in a growing global market, manufacturing enterprises have been reengineering their production systems to achieve computer integrated manufacturing (CIM). Major goals of CIM include, but are not necessarily limited to, lowering manufacturing costs, rapidly responding to changing customer demands, shortening lead times, and increasing the quality of products [1–3]. However, the development of a CIM system is an incredibly complex activity, and the evolution to CIM has been slower than expected [4,5]. This can be directly attributed to high software development and maintenance costs.

Generally, a central database provides a global view of the overall system, and controllers generate schedules and execute them. Hierarchical control is easy to understand and is less redundant than other distributed control architectures such as hierarchical control. However, it has a crucial weak point, which is that a small change in one level may significantly and adversely affect the other levels in the hierarchy.

Therefore, it is normally said that hierarchical control of CIM systems is much more suitable for production in a steady environment than in a dynamically changing environment because it is so difficult to apply control hierarchy changes immediately to the equipment.

Therefore, the manufacturing system of tomorrow should be flexible, highly reconfigurable, and easily adaptable to the dynamic environment. Furthermore, it should be an intelligent, autonomous, and distributed system composed of independent functional modules.

An FrMS is a new manufacturing concept derived from the fractal factory introduced by Warnecke. It is based on the concept of autonomously cooperating multi-agents referred to as fractals. The basic component of the FrMS, referred to as a basic fractal unit (BFU), consists of five functional modules including an observer, an analyzer, a resolver, an organizer, and a reporter. The fractal architectural model represents a hierarchical structure built from the elements of a BFU, and the design of a basic unit incorporates a set of pertinent attributes that can fully represent any level in the hierarchy.

In other words, the term ‘fractal’ can represent an entire manufacturing shop at the highest level or a physical machine at the bottom-level. Each BFU provides services according to an individual-level goal and acts independently while attempting to achieve the shop level goal. An FrMS has many advantages for a distributed and dynamic manufacturing environment. Automatic reconfiguration of a system through a dynamic restructuring process (DRP) is the most distinctive characteristic of the FrMS. In this paper, the scope of the reconfiguration does not include reconfigurable hardware and external layout design. Rather, it focuses on the interior structure of software components that can be reorganized with software manipulations. The reconfiguration or restructuring in this paper considers both dynamic clustering of the agents and construction/destruction/cloning of agents, which affect the number of agents in the system. The function of a fractal is not specifically designated at the time of its first installation in the FrMS. The reconfiguration addressed in this paper also includes situations where the agents’ enrollments are changed, meaning that the agents are assigned a new goal and new jobs, but their composition does not change.

To have a flexible and robust manufacturing system it is necessary an intelligent control system that makes an efficient use of the flexibility and agent-based software is the technology that can deal with the control and supervision of intelligent mechatronics components. The use of multi-agent based software in operation and control of distributed systems can offer distributed intelligent control functions and cover the mechatronic and production specifications. Many and new mechatronics components (e.g. intelligent sensors and actuators) are appearing at the markets with functionalities that promise good results in the integration on IMS. However, agent-based control strategies are yet emerging and are crucial for the distributed control needed in future manufacturing systems.

Agent

Because the definition of agent it was not consensual, in 1996, Franklin tried to fix a definition for autonomous agent. However, he admitted that the definition it is very general because it could include undesirable entities. Silva, Leitão and Colombo have definitions with more practical usefulness when they are looked from the point of view of a DMS. Thus, we present the main characteristics of an autonomous agents based in a mix from the definitions of these three authors. Therefore, an agent is a software entity that:

- is autonomous
- can represent physical resources (e.g. robots)
- can represent logical objects (e.g. schedulers, orders)
- has intelligence to make own decisions and act in order to achieved its goals (process planning, scheduling, etc)
- has the capability to interact with other agents (also with humans) and cooperate if it doesn’t possess knowledge and skills to reach alone its objectives
- can interact in the environment where is inserted (e.g. production environment) feeling and changing it based on the knowledge that it contains
- reacts to context incentives and defines actuation plans based in his knowledge
- can to decide if it accepts or rejects a service requested by other agent, based in its knowledge and skills.
- has capacity to acquire and to memorize new knowledge.

4. CONCLUSION

The FrMS has autonomy, flexibility, and a high degree of self-similarity, and it is based on the concept of autonomous cooperating multi-agents referred to as fractals. The FrMS has many advantages that arise from fractal-specific characteristics including self-similarity, self-organization, and goal-orientation, particularly in a distributed and dynamic environment.

The most outstanding function of the FrMS is the dynamic restructuring process, and it allows the FrMS to be more efficient and effective by reconfiguring fractals.

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