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ARTICLE

Holonic Manufacturing System: the Holonic Revolution

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ABSTRACT

This work shows how to develop a methodology to support and integrate the concepts and projects of the Holonic Manufacturing System (HMS) with the other areas of the organization for full organizational management success, being a new entrepreneurial management, with support of this new technology in the reduction of costs and increased value added. HMS is in the process of being developed in the so-called "Consortium of the Rich Countries for the 21st Century", which involves governments, companies and universities from the first world countries, developing technology and knowledge related to the Holonic Manufacturing System (HMS). This new concept, under development by the above consortium, will allow the countries that hold this advancement to overcome the challenges of the globalized market and gain even more international competitiveness.

1. Introduction

The main objective of this work is to develop an integration methodology between the holons manufacture and the holons management that will be supported by analysis and operation tools that should be used in order to investigate the elements that form this system, the Holonic Manufacturing System that is already in developed countries through an international consortium involving its governments, companies and universities, in the pursuit of mastery of globalized markets and gains in competitiveness.

All the concepts that will emerge from this work must be analyzed before the Brazilian reality and its relationship with the developed countries community, serving as a new paradigm of national companies acting as a new strategy of action, providing local and global competitiveness. It will also serve as a small contribution to academic circles and the community, in general, for the development of Brazil. According to Wilber (1995)[9], who tried to generalize ideas about holonic manufacture, observing the universe around us, one must take into account the whole (part and all), that is, any observable unit is at the same time a whole that is composed of smaller parts When we systematically apply the whole / part conceptual relation, or the equivalent of contained and contained, we see that the universe presents itself as a hierarchy of holons; that is, as a holarchy.

With this work, we will try to develop a dynamics of the holonic systems that help in the resolution of problems in the industrial environments, with resources to the specialization and decentralization of tasks, presented as an architecture and negotiation[5] protocol for the dynamic scheduling of activities, where a community

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of holons representing resources and tasks, establish a negotiation[5] to ensure that the latter are carried out in a way that meets a certain type of constraints (deadlines, quality, cost, etc.) and can be fully carried out in the interests of the organization. Therefore, the concept of holon and holarchy have been adopted, especially in recent times, by many authors from a variety of disciplines and in different contexts and have been rapidly spreading to all sectors of research. After discussing the original meaning, this brief theoretical essay will examine in what sense the holonic vision is spreading to the field of management, business administration[3], accounting, organizational theory, and manufacturing systems (Mella, 2009)[15].

The system will also have the ability to learn how to react in case of extreme situations or exceptions (machinery breakdown, priority ordering etc.) according to the past or past history (eg learning by examples or cases and generating hypotheses). Therefore, we hope to be able to direct an integration of the operation and management activities in a Multiagent System. We will employ all the valences, such as cooperation, coordination, rationality, intelligence, that will give body to the system that will emanate from this presupposition. The Multiagent Systems that will form the appropriate strategies for the hierarchical distribution of responsibilities consists of creating a community of agents that interact with each other in the sense of cooperating to solve problems, which presupposes a certain form of social organization.

The holonic manufacturing system is a structural change project, which many authors seek to develop agile and intelligent factories for the 21st century by encouraging the flexible production and assembly of low volume and high variety products, eg automobiles and electronics, needs of the users[14]. Structurally, each holon comprises elements of knowledge and software compulsory and optional elements (manufacturing-based) of hardware and human.

In production systems, these conceptions gave rise to the Intelligent Manufacturing System and, more recently, to the Holonic Manufacturing System (HMS). The Intelligent Manufacturing System allows an advanced view of the problem and uses a prudent judgment to better harmonize the available resources; human or material; consolidating them, from the conception of the product to its delivery to the client, from production to distribution, seeking to increase productivity and quality. The Intelligent Manufacturing System provides the ability to respond immediately and correctly to the constant stimuli and changes in the marketplace[16,21].

As for the Holonic Manufacturing System (HMS) we can perceive it as a dynamic and decentralized system, of which we humans are a part. The HMS is based on the concept of holon (Koestler-1967)[12]. Holon can be understood either as the whole as a part; i.e., a holon may consist of other holons or be a part of a third. The concept of holarchy provides us with a vision of how a system of holons cooperate with each other to achieve a goal. The holarchy defines the basic rules of cooperation between holons, thus limiting their autonomy. In a manufacturing system we can consider physical resources (machines, equipment and tools) as holons that group together to form a cell or manufacturing line. We can have the most diverse logical holons, such as: the holon of process planning, production planning, logistics, etc. In a manufacturing system, you can have holons representing both the resources and the tasks to perform.

While in terms of its behavior, a holon is characterized primarily by its autonomy and cooperation and what these attributes mean in relation to keeping the system available to unpredictable failures within the holons software / hardware dualism, Information system. Therefore, holons must be equipped with fault-tolerant behavior to aid in rapid reaction, graceful degradation and elegant system recovery. This fault tolerance is based on a combination of rescheduling tasks within a holon (online solution) and the recovery of a large grain functional component within the holon [10].

When we debate about globalization, we can perceive that the State has the conditions and instruments to elaborate the necessary reforms so that Brazil can obtain the advantages and prosperity with globalization without taking risks of unemployment and exclusions within the society, with adequate industrial policy, educational structuralism and systemic performance for scientific and technological development. We can, with positive projects and actions, not only stabilize the country, but also make it grow and build an even bigger nation, investing in education and technological development, with the resources coming from the transnationals, with the opening of the economy and the realization of the reforms that have been postulated and fought in Congress to give our country a modern and reliable attitude towards the capital exporting nations, thus allowing a global future for our economy and society.

The research show us the unpreparedness in which the national companies are, to face the globalization of the economy. This situation puts our industries in terrible disarray with transnational and first world organizations in general. And the biggest problem is the lack of an industrial policy that supports the growing need for human and physical development of organizations, as well as

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funding for research and development, which punishes the national productive. system. The important points of this work are:

1. Develop the fundamental concepts of Holonic Manufacturing System Architecture, creating fundamentals and specific work plans;

2. Compare manufacturing systems, such as; agile, lean with HMS, aiming to highlight the architectural differences between them, thus allowing the development of a virtual model for comparative analysis between a Holonic Manufacturing system and a traditional system with the aid of computational tools, allowing us to define the parameters basic of the;

3. Establish a methodology to support the design and planning of the Holistic Manufacturing System, highlighting the competitive advantages[17] of the system;

4. To demonstrate through practical use the enormous advantages and competitiveness factors that will come from the use of the Holonic Manufacturing System;

5. Develop, based on strategic planning, a management approach to the Holonic Manufacturing System, adapting its concepts to business reality[7];

6. Disseminate the concepts and research developed in this work to the country's academic and business communities, through the media and the internet, seeking to stimulate similar initiatives in both academic and business areas to contribute to its development and national growth.

In view of the main objectives of this work, which intends to present new concepts and tools for the management and operation of manufacturing[7], and which companies will dispose them with the element of competitive advantage[17] to the challenges of this new century. The results obtained here will serve as support and help for new ideas and projects, since the HMS technology is in the beginning of its development, and still only in the main countries of the first world, the most developed ones have initiated a work of vanguard.

2. Review of the Literature

A recent study prepared jointly by (BNDES 2009; CNI 2010 and Sebrae 2015) highlighted the critical situation of our industries and their difficulty in facing the existing global economy process. With the lack of financial resources and an international vision, national industries use very little of modern business management techniques and tools. The impressive data of this research show us the following percentage use of the modern administrative techniques[3] in the researched universe, according to table 1, below:

Table 1. Use of modern management techniques in Brazil[3]

TECHNIQUES	% IN USE
Strategic Planning	21
Quality ISO- 9000	37
Just-In-Time	16
Automation	*11
Outsourcing	17
Kanban	16
Reengineering	9

Source: Sebrae (2015)* intelligent manufacturing, agile, lean, cells etc.

The acceleration of world trade, which continues to grow and spread throughout the world, shows us that transnational organizations have evolved dynamically towards globalized products - final products composed of components elaborated in different parts of the world, such as computers, electronics, consumer products and automobiles. Globalization is increasingly seeking the emerging nations, which stabilize economically and socially, in the face of the great market that arises in the increase of the capacity of the purchasing power, of the enormous mass that appears to the market with this new power.

2.1. The Holonic Manufacturing System

The Holonic Manufacturing System (HMS) will be one of the ways that organizations will have, in the next century, to meet the needs of manufacturing processes, capable of rapidly and continuously producing small production lots, tending to unity, drastically reducing their costs and making their prices low and positioning themselves as highly competitive organizations.

The Manufacturing Systems holonic approach is one form of manufacturing whose goal is to provide agile manufacturing systems; that is, highly flexible and atomized production systems[14], utilizing the complex use of machines, robots, work cells, and labor units capable of dealing with the rapidly changing manufacturing business, information flow with variety, and uncertainty of demand, changes in tastes, reductions in the life cycle and the need to reduce time to market. The basic operational elements that characterize such Manufacturing Systems can be considered as holons: a set of processors that form a functioning holographic network, but on the condition that their operation is considered fundamental for the obtaining of information and operation holons of some kind, such as: models, objectives, decisions, responsibilities, etc. with variability and variability over time.

One of difficulties in achieving actory wide coordination and control is that decisions are made at different times, and in different places by people with different responsabilities, and priorities. Frequentely, the decisions made by one individual may undetermined and negate managed by someone else. The result is that most actories are managed by operational personnel running fromcrises to cises, with no opportunity for even local organization. Holonic Manufacturing principles rely upon control coordination by cooperation through negotations. In crises when a cenralized control or coordination. Is not possible, the HMS still permit autonomous operations. Thus, the focus of the HMS is to criete integrad manufacturing system.

The typical configuration of HMS provides a template to meet the production, assembly, inspection and storage process and the transportation of products, as well as information management. The process is supported by connected holons of various classes, including machines, equipment, control and automated drive systems Individual holons exchange knowledge through (a) synchronous communication to obtain a degree of flexibility greater than that offered in shop-floors [20]. The research developed by the Consortium of the Rich Countries for the 21st Century shows that the best way to achieve these needs is through an open, distributed, intelligent, autonomous and cooperative system, capable of allowing modularity and high flexibility, of being recomposed and reusable.

The systems will have the ability to reconfigure in an easy, agile and fast way, allowing to produce a very wide variety of products. They will also be able to organize themselves according to the needs of the moment, intelligently facing and improving the unforeseen variables that occur in the external environment. According to Van Leeuwen & Norrie [23], HMS will consist of holons (cooperative and autonomous elements), people, communication networks and methods for cooperation, including procedures for negotiation[5] and division of resources.

The system will include hardware, software, system architecture, information architecture, the role of human resources and, above all, the organization as a whole. It will seek to establish the technological and organizational bases to be achieved in the next century, with the following global goals in mind:

(1) Compatible HMS development, marketing and support;

(2) Design, implementation and support of HMS in end-user applications;

(3) Increased understanding, systematization and acceptance of HMS concepts;

(4) Support the development of international standards to achieve goals;

(5) Action of a new Entrepreneurial Management.

It is of the utmost importance for our country to also develop research in this field that will be the great differential of companies and countries for this new century and that Brazil can further advance in the search for a leading position in the globalized market. The development of state-of-the-art manufacturing systems research, such as intelligent manufacturing, agile manufacturing, lean manufacturing and especially the concept of the holonic system, will certainly be a key factor in driving us to the podium of countries with high competitiveness and economic growth.

2.2. Lean Manufacturing

According to Womack (1998)[24], lean manufacturing is based on the principle of continuously adding value to the product through a manufacturing system without waste or delays. By creating such a system, processes that add value must be physically linked in order to create the smooth flow of a part between operations. The end result will be a manufacturing system made up of cells producing according to customer demand. By adopting such a system, a company will be able to produce at the right pace with the minimum inventory, quick answers and flexibility to change according to the changes of their needs. In this system, the flow of information, from the sales order to the delivery of the product, will occur without undue delay, waste or additional costs. In this way, a significant competitive differential is created for the market.

The manufacture of goods and services is present in all kinds of economic activities. It is characterized by the transformation of raw material, in its various states, into final products available to consumers [1]. An important feature of modern manufacturing systems is the valuation of knowledge, as part of the active capital of companies: intellectual capital [20]. The information system, the knowledge acquired by employees and the social value to society should be considered when the value of the company is raised. Manufacturing systems design, a manufacturing system begins with defining the functional requirements that will meet the needs of its internal (operator) and external (manufacturing consumer) customers. Next, the design parameters that meet these functional requirements must be developed. Design[22] is then defined as the creation of a solution in the form of devices, systems, or processes that meet the needs raised by the relationship between functional requirements and design parameters [13].

Lean manufacturing stems from pioneering production concepts that led to the Toyota Production System and the principles of ohnism. They have emerged as a way to meet the needs of Japanese industry to produce low

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cost and small series of assorted products. This was not possible with the traditional system of mass production[18] introduced by Henry Ford at the beginning of the century. Today, this Japanese system of production is known as lean manufacturing [4,6,13]. Lean manufacturing is basically the combination of two principles: just-in-time and self-activating production.

Lean manufacturing is of great value to the agile business, since small lead times and labor with multiple specializations are imperative to respond quickly to changes in the market. The adoption of lean manufacturing provides results such as: reduction of the production cycle and intermediate stocks between processes, consequently reducing the necessary capital, increases in productivity and capacity and decrease the response time for the customer's request.

2.3. Intelligent Manufacturing

An intelligent manufacturing definition came from a report commissioned by Iaccocca Institute Bethlehem P.A., 1991 - "Manufacturing Firm Strategy for the 21st Century," by Nagel & Dove authors. According to them, Smart Manufacturing is: "The ability to thrive in a competitive environment where continuous and unexpected changes occur, and respond quickly to the abrupt changes of the market driven by customers, valuing their products. It is clear that the effects of globalization on the world market make it increasingly necessary for companies to adopt measures to achieve intelligent or agile manufacturing, which are made up of the following parameters:

(1) A solution provider no longer makes a product but builds a relationship with customers, a long-lasting relationship that goes well beyond a product, encompassing services that deliver customer value and are its most significant source of wealth;

(2) Collaborative, both inside and outside the company. This usually means company partnerships with "virtual organizations" outside the company. Agile companies act collaboratively to explore market opportunities, to meet new market demands created by customers;

(3) Innovative, through its human talents and scalable or reconfigurable production facilities, with a workforce that has the initiative and flexibility to creatively respond to customer needs.

The traditional paradigm focuses on a high volume of production and a low variety of products, but trends show that this approach is disappearing as consumers are developing a new posture, through demands that change the characteristics of the market. One response to this requirement is fragmentation of the market, leading to mass customization (products need to be manufactured to meet particular consumer requirements, with mass-like costs [8], in which the traditional mass-production system is demanded to the utmost to provide individualized or unique solutions to the specific market segment [23]. Owen and Kruse [19] also present a definition for Intelligent Manufacturing: "Intelligent Manufacturing is the ability of a company to manage change, in the unpredictable world of commerce and industry, and to survive in the market that demands a rapid response to unexpected changes in consumer demands, competitive challenges and technological breakthroughs.

According to Gould [8], "Intelligent Manufacturing is conceptually different from lean manufacturing and requires different style of operation and organizational structure." Another aspect that Gould [8] points out from Paul Kidd's book[11] is that, to achieve Intelligent Manufacturing, the company must focus on the functions and interrelations between (and among) its three primary resources:

(1) People: qualification (knowledge ability) and people with empowerment;

(2) Organization: innovative and organizational management structure;

(3) Technology: flexible and intelligent technology[14], adapted according to the people.

In figure 1, extracted from Gould [8], one can see, for different manufacturing systems, the characteristics of each one and the evolution for the agility.

Figure 1. The evolution of manufacturing systems, their characteristics for agility

	Artesanal	Massa	Enxuta	Inteligente
Reconfig-urável				
Flexível				
Fixa				
Abrangente				

Source: Gould [8]

Finally, for a company that uses Smart Manufacturing to become agile, it must make changes in its culture, in its business practice and in relations with other companies around the world. Gould [8], analyzing companies in Great Britain (UK), states that: "Moving quickly from the traditional model to a model is emerging. This template will vary for different types of organization, but it will likely contain a number of generic elements. Agility is a snap on old paths that are doing things that are no longer appropriate, changing patterns of traditional operation. The challenge is to find out what is appropriate for the UK and what level people will have to drive the implementation of agility in manufacturing companies. "

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3. Analysis and Results

A system that controls the manufacturing process in an industry is composed of software modules as well as different physical elements of the production environment, being:

(1) resources,

(2) products,

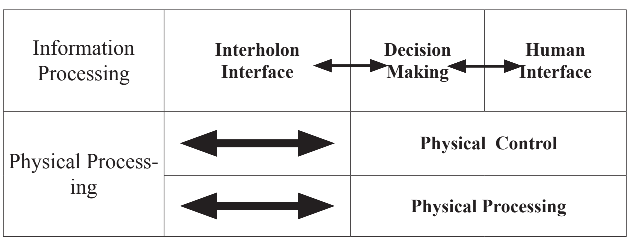
(3) customer work orders,

(4) coordination operations, etc.

The software module and system[2], linked by a comprehensive communication network, which will represent a holon within a manufacturing system. This holon will be able to reason, make decisions and communicate interactively with other holons. The number and types of modules that make up the softwares and how the set communicates with the physical entities are interconnected connect the different approaches of holon architectures. The physical processing part is the hardware that performs manufacturing.

According to the holonic point of view, each member of the organization can be considered a base holon. The member-holon is a whole if observed as an organ and a part if observed as a component of a larger organ. Moreover, several similar elements can be included in modules that constitute organs so as to form a modular systemic structure conceived of as a holonic organization and and how schematically it is a general architecture of holon as shown in Figure 2.

Figure 2. Holon general architecture



Source: Giret and Botti, 2004: 648

The cooperation in holon is not feasible by itself, but there must be at least one member of the holon that can interact and generate continuity of the process and the domains of cooperation will be dynamically created by the execution of the functional components of holons.

A holon can be simultaneously a member of one or more domains of cooperation and therefore a holonic system is structured in at least one domain of cooperation. Each and every domain is driven by a coordinator who is the interface with the outside. A holon can join a cooperative domain, consult its attributes, exchange information with other holons, and leave the domain whenever the holon completes its task.

5. Conclusion

The Holonic Manufacturing Systems aims to meet the constant challenges of the manufacturing industries to increase organizational agility and decrease engineering and production costs. This article proposed a multiagent architecture for incorporating fault tolerance into holon based manufacturing systems in which each autonomous holon cooperates to support task rescheduling and component recovery.

The more active fields are those related to developing holonic control systems. From these developments we can conclude that currently multi-agent system tech- nology is the tool most utilized for developing HMS. Nevertheless, there is very little work on methods for HMS development.

The final result of this process is the strategic plan of the company, a document that will define all the functions of each sector of the organization, its objectives, its strategies, necessary resources, necessary systems: information, manufacturing, management, control etc. This plan, if well developed and implemented, can lead the company to success, since it guides the actions of the company. It should be reviewed and updated whenever environment conditions change, so that the company has agility to the market and competitors.

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