THE HOLONIC PERSPECTIVE IN ORGANIZATION AND MANAGEMENT

Mella Piero

University of Pavia - Faculty of Economics, Via San Felice, 7 - 27100 Pavia - ITALY

Tel: +39.0382 986263 - Fax: +39.0382 986228, E-mail: piero.mella@unipv.it

Abstract

The notions of holon and holarchy are more and more frequently found in the literature of organizational studies, management science, business administration and entrepreneurship. By systematically applying the whole/part conceptual relation, we can reconsider the very same ideas of organization, management and manufacturing. Connected to these ideas are those of holonic networks, holonic and virtual enterprises, virtual organizations, agile manufacturing networks, holonic manufacturing systems, fractal enterprise and bionic manufacturing.

Holons and Holarchies

In the world of firms, management and control in general, a silent conceptual movement has been under way for less than forty years now, beginning in 1967 with the publication of Arthur Koestler's *The Ghost in the Machine,* which formally introduced the concepts of *holon* and of *holarchy*, which is conceived of as a hierarchical structure of holons (Mella, 2005a).

Holon – which derives from the combination of the Greek "holos", which means "all", and the suffix "-on", which indicates the neutral form and means "particle" or "part" (as in proton, neutron and electron) – is the term coined to represent the basic element of the *holonic view* – which considers relevant not so much the connection among elements as their inclusion in each other.

"Parts and wholes in an absolute sense do not exist in the domain of life.... The organism is to be regarded as a multi-leveled hierarchy of semi-autonomous sub-wholes, branching into sub-wholes of a lower order, and so on. Sub-wholes on any level of the hierarchy are referred to as holons." (Koestler, 1967, Appendix I.1).

Ken Wilber (1995) tried to generalize the idea of a holon by pointing out its *relative* and *conceptual* nature.

"The world is not composed of atoms or symbols or cells or concepts. It is composed of holons.". (Wilber, 2001: 21).

Koestler viewed the *holon* as a *Janus-faced entity*: if it observes its own *interior* it considers itself a *whole* formed by (containing) subordinate *parts*; if it observes its *exterior*, it considers itself a *part* or *element* of (contained in) a vaster *whole* (Barlow, 1991). However, in observing itself it sees itself as a s*elf-reliant* and *unique* individual that tries both to survive (it is a *viable system*) and to integrate with other holons:

"Every holon has the dual dendency to preserve and assert its individuality as a quasi-autonomous whole; and to function as an integrated part of a larger whole. This polarity between the Self-Asservive and Integrative tendencies is inherent in the concept of hierarchic order; an universal characteristic of life.": (Koestler, 1967: 343).

Each holon includes those from a lower level, but it cannot be reduced to these; it *transcends* them at the same time that it *includes* them, and it has emerging properties (Edwards, 2003; Simon, 1969).

In attempting to interpret the nature, structure and the dynamics of biological and social systems (organizations), Koestler defines a holon as an entity that is:

- *autonomous,* having a function and dynamics that depends on the context;
- *viable*, in that it has a stable form that enables it to deal with environmental disturbances in order to survive as a viable system (Beer, 1979, 1981; Maturana and Varela, 1980);
- *independent* (self-reliant); that is, characterized by a *self-assertive tendency*;
- *dependent*, at the same time, since it is subject to some form of "control" by the superordinate entity, being important for the survival of the vaster structure that includes it (Capra, 1982);
- *interactive,* that is vertically connected to the superior and inferior entities, and demonstrating an *integrative tendency*;
- characterized by a behavioural *canon* that defines the constraints on its actions due to its being both a *whole* and a *part* (Koestler, 1967: 55).

Holarchies Everywhere

According to Koestler, due to their Janus-faced nature holons must necessarily be connected to other holons in a typical *vertical arborising structure* known as a *holarchy* that can be viewed as a *multi-layer* system (multi-strata) (in the sense of Mesarovic et al., 1970) or *multi-level* system, with a tree-structure (Pichler, 2000).

It is relevant to observe that holarchies are not holons but arrangements of holons that represent conceptual entities whose function is to bring out the essentiality of the vertical interactions among holons (Table 1).

Table 1 - Holarchies everywhere. Examples of holons and their levels (Turnbull, 2001).

	DISCIPLINE/SUBJECT	FIRST LEVEL	SECOND LEVEL	THIRD LEVEL
1	PHYSICS	Particles	Atoms	Molecules
2	CHEMISTRY	Molecules	Compounds	Bases
3	GENETICS	Bases	DNA	Genes
4	BIOLOGY	Genes	Chromosomes	Cells
5	ANATOMY	Cells	Organs	Individuals (Biota)
6	ENVIRONMENT	Biota	Ecological systems	Gaia (Earth)
7	ASTRONOMY	Earth	Solar system	Galaxy
8	SOCIOLOGY	Individuals	Families	Communities
9	ORGANISATIONS	Cells/divisions	Firms	Keiretsu /groups
10	MONDRAGÓN CO-OP	Work groups	Social council	General assembly/co-op
11	MONDRAGÓN SYSTEM	Co-operative	Cooperative groups	Mondragón Corporación
12	VISA CARD	Geographic unit	Member bank	VISA International
13	GOVERNMENT	Communities/towns	Regions/States	Nations
14	ENGINEERING	Components	Sub-assemblies	Machine
15	SOFTWARE DESIGN	Sub-routines	Routines	Object-oriented programs

Koestler conceives of the *holarchy* that orders all the biological beings or the social organizations as an Open Hierarchic System (OHS), a type of *machine* that produces general progress in living things through the self-organization of the holons, as if there were a *ghost manipulating the machine* (The Ghost in the Machine).

In the OHS, all the holons of a given level include and coordinate, by means of their cognitive processes, the holons of the lower level, as well as transmit the necessary information to construct the superordinate holon, which transcends them, thereby producing different processes which *trigger* a dynamic evolutionary process.

In this sense, for Koestler the OHS has order and its own evolutionary dynamic process. "[The holarchy] *is open-ended in the downward, as it is in the upward direction"* and is able to self-organize its changes, producing cognitive performances that become more relevant the more they are produced by higher-level holons.

Shimizu's Cognitive Computer

Shimizu (1987) introduced the idea of *bioholonics* as a discipline that studies the holonic applications in biology and theorizes about the construction of an *autonomic cognitive computer*, conceived of as an ***input holarchy*** of holonic modules that process information in parallel.

The *cognitive computer* produces an organized synthesis, which becomes increasingly more complex, of a mass of elementary information from the base holons (*microscopic level*) that is synthesized by the higher-level holons until the *bottom holon* is able to produce a *semantic* formula to give meaning to the final synthesis.

"In a *cognitive computer* elementary signals are related to each other to generate organized information. In this process, relevant correlations between elementary signals are discovered also with the neglect of some correlations. In other words, semantic correlations are found in the assembly of elementary signals. We shall call *autonomic unit processors* for elementary signals, or semantic correlators of elementary signals, "holons". *The holons are local-rule generators.*" (Shimizu, 1987: 211).

The stable holarchy of processors, understood as a *correlator* among signals from different levels, is a *cognitive computer* if its construction, from the highest to the lowest levels, is subsequent to the semantic analysis of the *bottom holon*; it is a true holon if the processors of the higher levels are *spontaneously* created *by* the same

lower level modules, as seems to have occurred in the gradual evolution of inanimate nature toward an intelligent form, or in the gradual hierarchical development of groups, social and political structures.

Holonic Networks as Horizontal Arrangements of Holons

According to the Janus-faced view, a holon maintains its characteristics as a conceptual entity (unity, autonomy, interiority) even if it is considered to be part of a *network of horizontal relations* – with holons of the *same level* – that can be called a holonic network.

Each holon acquires its existence and meaning from the connected elements that are observed as *antecedents* (before) and that make it up and, at the same time, from the connected elements that are observed as *successive* (after) and that the holon helps to comprise.

An important point: like holarchies, the holonic networks are not holons but conceptual entities – horizontal or *grid systems* – whose nodes are holons which are interconnected in order to form a whole; the *grids* can display chains (paths or routes), even ramified ones, along which the holons acquire significance only through their before/after connections with the other holons in the chain (Mella, 2005b).

Holonic Networks Everywhere

I shall examine the following examples of holonic networks:

1. the Holonic Manufacturing Systems,
2. the Bionic Manufacturing Systems
3. the Fractal Manufacturing Systems
4. the Agile Manufacturing Systems
5. the Inter-Company Networks
6. the Virtual Organizations orAgile Manufacturing Networks.

Holonic Manufacturing Systems

The *Holonic Manufacturing Systems* (HMS) are operational modular reticular holarchies (Schilling, 2000) that are typically found in the manufacturing or transport industries (Kawamura, 1997; Jacak, 1999). In this case the holons are *machines* that form increasingly larger structures (parts of successive structures) that carry out elementary processes that are often arranged in modules of identical machines.

Holons at a given level carry out processes that derive from those produced by holons arranged *before* or *below*, and the holons are necessary for the processes of those positioned *after* or *above*.

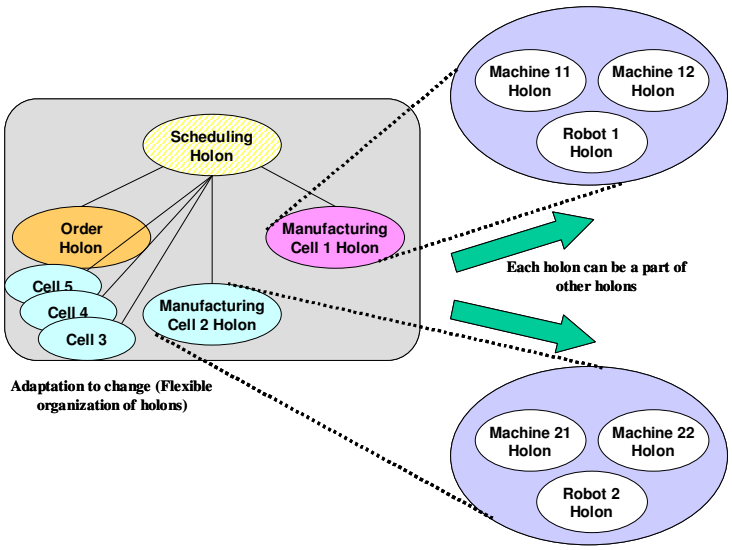
To study the HMS a Consortium has been created that has defined the technical, informational and operational specifications necessary for a network of machines to be considered an HMS.

The "technical specifications" of the HMS Consortium (http://hms.ifw.uni-hannover.de) define a holon as "An autonomous and cooperative building block of a manufacturing system for transforming, transporting, storing and/or validating information and physical objects", possessing autonomy (the capacity to create operational plans and strategies and to control their execution) and capable of cooperating with other nuclei (Adam et al., 2002), in addition to having technical and informational attributes that allow it to plan and carry out its functions and to coordinate with the other holons (Stylios et al.).

A set of *blocks* that process in parallel materials or produce similar services form a *module*; several modules can comprise a super ordinate holon that, in turn, can be included in other *blocks* at a higher level.

The Holonic Manufacturing System is the "holarchy that integrates the entire range of manufacturing activities from order booking through design, production, and marketing to realize the agile manufacturing enterprise".

Fig. 1 - Holonic modules of an Agile Manufacturing System



In a minimal configuration, an HMS for a market-oriented manufacturing firm includes three types of holons: product holons, which are the products in the catalogues and their components (sub-holons); resource holons, which specify the resources available for production; and order holons, which identify the market demand (Wyns, 1996). These holons comprise a holonic network that takes the form of an HMS, as shown in Fig. 1 (other models that imply a greater number of holons are indicated, for example, in: Kanchanasevee et al., 1997).

Bionic Manufacturing Systems

A *Bionic Manufacturing System* (Okino, 1989; Tharumarajah, Wells, & Nemes., 1996) is a special *holonic network* of production units similar to an HMS but conceived of as an interaction of elementary operator holons that are absorbed into autonomous cells that, in turn, are grouped into *modules*, similar to organs, and are arranged in various hierarchical levels that form a holarchy that is similar to a biological organism. By means of the increasingly complex operations occurring at the various holarchic levels, the final holon is able to carry out some high-level operations, functions or process as specified in a *model* "reproducing" the final result (the finished product represents the model "of itself").

The unique feature of a *Bionic Manufacturing System* is the fact that the operational units – or their groupings – are capable of autonomously deciding not only the processes to carry out but also the inputs and the output volumes needed based on two types of information that guide its activity:

a) the *primary information* is represented by that *portion of the complete model* that must be produced by each of the operational units; this *portion of the model* gains significance from the parts the subordinate units must produce, and in turn represents a part of the model which the super ordinate operational units must realize; each part of the *model* is to be conceived of as a *holon*; it is a *model/holon* that, together with the entity that produces it, is called a *modelon*.

b) the *secondary information* is comprised of the state of the processes carried out by the production units at both the same and higher levels.

Thus, the *Bionic Manufacturing System* functions as a top-down holarchy that operates according to the logic of an *Autonomic Cognitive Computer*. The *final* (or *parent*) *modelon* is both the model to be constructed and the entire *Bionic Manufacturing System* (processor system) that produces it, and of which it constitutes the terminal semantics. The *parent modelon* is broken down into second-level *sub-modelons,* and these in turn into third-level *sub-sub-modelons*, and so on down to the base modelons, which are formed by elementary operational entities which themselves are considered as basic processor holons.

At the various levels the operational units are coordinated by units of coordination that – by devising strategies, plans, programmes and procedures to regulate all the production units – function as enzymes (short-term) and hormones (medium-term) do in biological systems.

If the need arises to strengthen the system, the *bionic system* can also develop either through annexing other entities with the same technical and functional specifications as the module entities that need strengthening, or through the creation of smaller entities at a lower level in the holarchy, to which the same *modelon* and the same operational capacity of the original entity is transmitted, through a mechanism similar to that of the transmission of DNA.

Fractal Manufacturing Systems

A different type of holonic structure are the Fractal Manufacturing Systems (Savage, 1996; Warnecke, 1993), which are complex holarchies, typically bottom-up, formed by autonomous modules whose operational logic is repeated at various vertical levels, as a fractal, reproducing at each level the characteristics of the entire structure.

The holonic nature of these structures is not so much the processors (usually men or men-machine production units that self-coordinate) as the subdivision of responsibilities in terms of the objectives they must pursue.

All the high-level objectives – conceived of as *final holons* – are pursued through the recursive attainment of lower-level objectives, which are in turn subdivided into sub-objectives, down to the primary operational entities which are assigned smaller objectives, conceived of as *primal holons*.

At each level every operational entity is responsible only for the objectives of that level, and thus must coordinate with the other entities at its level which, on the one hand, are set up to achieve the subordinate objectives, while on the other are components for the attainment of higher-level objectives.

An efficient information system must underlie the functioning of a *Fractal Manufacturing System*, since each fractal entity must be able to coordinate with the other entities, and this can be achieved only through monitoring in real time the state of the attainment of the objectives of the other entities at the same level.

Agile Manufacturing Systems

According to the holonic approach, *Holonic, Bionic* and *Fractal* Manufacturing Systems are different forms of production organizations whose objective is to create *agile manufacturing systems*; that is, atomised, highly-flexible production systems – making wide use of machines, robots, work-cells and labour units – that are able to deal with the rapid changes that all the mechanized-production manufacturing enterprises, flow or special order. must face: variety and uncertainty of demand, changes in tastes, reductions in the life cycle, and need to reduce *time to market*.

The basic operational entities that characterize such Manufacturing Systems can be considered as *processor holons* that form a holarchy or an operational holonic network, but on the condition that their functioning is viewed as instrumental for the achievement of *information holons* of some type (models, objectives, decisions, responsibilities, and so on) that have a lot of variety and variability over time.

Interfirm Holonic Networks and Holonic Firms

In general terms the *production* or *enterprise networks* are *holonic networks* comprised of autonomous firms that are variously located – characterized by different roles and different operations (Grandori & Soda, 1995; Gulati, 1998; Dyer, 1997) but integrated in terms of mission, vision and aim of their common businesses – and connected through a *holonic network*, real or virtual, often oriented, in order to achieve a common objective through the sharing of resources, information and necessary competencies (Grandori, 1997), without any hierarchical constraints of subordination (Håkansson & Snehota, 1995; Kinoshita, Takine, Murakami, & Terada, 1997).

In the Japanese literature the *holonic networks* are also called *holonic firms* or *enterprises,* or *holonic organizations*, and in North American terminology *virtual firms* or *virtual enterprises*. In fact, they are *orgonic networks.*

Cooperation among the holonic components of the network is carried out through a guiding firm (nodal firm). We must emphasize that in the holonic networks the holons are not, in fact, the interconnected organizations but the capacities (functionalities) that result from the stock of know-how, information, resources and competencies that they possess and that find common meaning and functionality precisely from the reticular interconnections. Thus the *holonic network* has a similar function to an *Autonomic Cognitive Computer* or a *Bionic Manufacturing System*.

Agile Manufacturing Network

Due to the flexibility that characterizes them, holonic networks represent the most efficient means for creating an *agile manufacturing network* (Huang et al., 2002), an *holonic production system* (similar in inspiration to an Agile Manufacturing System), which is flexible and open to the needs of the market and able to plan, carry out and market various product models to satisfy in real time the demands of clients from all the participating entities (Youssef, 1992).

The various operational units that comprise *the manufacturing network* can fully be considered holonic organizations, characterized by an autonomous existence, a decision-making capacity (consciousness), and a willingness to accept coordination.

If the relations among holons is achieved through an information network, the organizational network becomes a true *virtual organization*, in the form of both a virtual firm whose cognitive and operational boundaries are not clear, defined only by the interconnections (Davidow & Malone, 1992), and a network of common competencies put together in an opportunistic way by autonomous and independent holons that are virtually connected (Goldman et al., 1995).

Present-day ITCs allow us also to conceive of purely informational networks in which the component holons are connected by information flows and not production flows. In this case the network becomes a communication network (D'Amours et al., 1999), similar to a *neural network*, which can develop both knowledge that transcends that possessed by the individual connected entities as well as possibly consciousness, thereby favouring the development of the *Networked-Digital-Economy*.

Conclusions and Challenges

At the planetary level we are witnessing the continual and accelerated economic progress of mankind. There is an increase in the quantity and quality of needs that have been and that still need to be satisfied, as well as in the aspirations that have been and still need to be achieved. The increase in productivity and quality is unstoppable and seems to guide the other variables in the system.

It is natural to ask ourselves who is creating and governing these phenomena. The answer is that they are self-generating and self-organizing in the context of holarchies and of holonic networks whose base holons are the production organizations that form the integrated process of global production: the *Production Kosmos* (Mella, 2006).

So now we see the *function* of the Production Kosmos: just like a OHS or an HMS it spreads the improvements in productivity and quality, which occur at the local level, throughout the entire structure of the holarchy or along the entire network chain, both in a top-down direction (the improvements produce other improvements down the line) or a bottom-up direction (the improvements require other improvements up the line).

In this sense the *Production Kosmos* must no longer be viewed simply as a global producer composed of interconnected org*o*nizations (Mella, 2205b) that tries to maximize internal efficiency, but must instead be thought of as a system with the capacity to perceive, on the one hand, the requests for needs and aspirations to satisfy, and on the other the availabile labor supply.

Paraphrasing Koestler, it does indeed seem that there is *A Ghost in the Economic Machine*.

There is no *ghost* that moves the machine toward ever more advanced states; each production network is in fact an *Open Hierarchic System*.

It is useful to conclude with a bibliographical note.

The conceptual revolution that began in 1967 has not yet produced a significant number of monographs. On the other hand, there are a large number of journal articles, convention papers, collections of opinions, and discussion forum documents on the topic. The Internet has become a fundamental aid for accessing the recent material.

In the citations I have indicated the page of the source only for monographs and articles. The citations taken from the Internet, though placed in quotation marks, do not indicate the page but only the author and the URL of the site they were taken from.

References:

1. Adam E., Mandiau R., Kolski C., "Une Methode de modelisation et de conception d'organizations Multi-Agents holoniques", Hermes, Paris, 2002.
2. Barlow C., "From Gaia to Selfish Genes", MIT Press, Cambridge, 1991: pp. 87-100.
3. Beer S., "The Heart of Enterprise", Wiley, London and New York, 1979.
4. Beer S., "Brain of the Firm" (2nd edition), Wiley, London and New York, 1981.
5. Capra F., "The turning point: Science, society, and the rising culture", Bantam Books, New York, 1982.
6. D'Amours S., Montreuil B., Lefrançois P., Soumis F., "Networked manufacturing: The impact of information sharing", International Journal of Production Economics 58, 1999: pp. 63-79.
7. Davidow W. H., Malone M., "The virtual corporation", Harper Business, New York, 1992.
8. Dyer J. H., "Effective Interfirm Collaboration how firms minimize transaction costs and maximise transaction value", Strategic Management Journal 18 (7), John Wiley & Sons, 1997.
9. Edwards M., "A Brief History of Holons", 2003 website: http://www.integralworld.net/edwards13x.html.
10. Goldman S. L., Nagel R. N., Preiss K., "Agile Competitors and Virtual Organizations", Van Nostrand Reinhold, New York, 1995.
11. Grandori A., Soda G., "Inter-firm networks: Antecedents, mechanisms, and forms", Organization Studies 16 (2), 1995: pp. 183-214.
12. Gulati R., "Alliances and networks", Strategic Management Journal 19, 1998: pp. 293-317.
13. Håkansson H., Snehota I., "Developing Relationships in Business Networks", Routledge, London, 1995.

14. Huang B. Gou H., Liu W., Li Y., Xie M., "A Framework for Virtual Enterprise Control with the Holonic Manufacturing Paradigm", Computers in Industry, Elsevier Science, Vol. 49, No. 3, 2002: pp. 299-310.
15. Jacak W., "Intelligent Robotic System: Control, Planning and Design", Kluwer Verlag Plenum, New York, 1999.
16. Kanchanasevee P., Biswas G., Kawamura K., Tamura S., "Contract-Net Based Scheduling for Holonic Manufacturing Systems", Proceedings of SPIE, Pittsburgh, Pennsylvania, 1997: pp. 108-115.
17. Kawamura K., "Holonic Manufacturing Systems: An Overview and Key Technical Issues", Proceedings of the 4th IFAC Workshop on Intelligent Manufacturing Systems: IMS'97, Seoul, Korea, 1997: pp. 33-36.
18. Kinoshita K., Takine T., Murakami K., Terada H., "Holonic Network: A New Network Architecture for Personalized Multimedia", Communications Based on Autonomous Routing, 1997: IEICE Transactions on Communications, E80-B (2): pp. 282-288.
19. Koestler A., "The Ghost in the Machine", Arkana, London, 1967.
20. Maturana H., Varela F., "Autopoiesis and Cognition: The Realization of the Living", Boston Studies. Philosophy of Science 42, 1980.
21. Mella P., "The Production Kosmos", Economia Aziendale 2000 web, 1/2006, website: www.ea2000.it: pp. 87-99.
22. Mella P., "La rivoluzione olonica. Oloni, olarchie e reti oloniche. Il fantasma nel kosmos produttivo". MILANO: FrancoAngeli, 2005a.
23. Mella P., "Organizations and Orgonizations. The Holonic View of Organizations". International Journal of Knowledge, Culture and Change Management, vol. 5/4, Common Ground, 2005b: pp. 111-123,.
24. Mesarovic M., Macko D., Takahara Y., "Theory of Hierarchical, Multi-Level Systems", Academic Press, New York, 1970.
25. Okino N., "Bionical manufacturing systems", in Sata T. (ed.), Organization of Engineering Knowledge for Product Modelling in Computer Integrated Manufacture, Elsevier, Netherlands, 1989.
26. Pichler F., "On the Construction of A. Koestler's Holarchical networks", 2000, website:
27. http://www.cast.uni-linz.ac.at/Department/Publications/Pubs1998/holons.doc.
28. Savage C. M., "5th Generation Management: Co-creating through Virtual Enterprising, Dynamic Teaming, and Knowledge Networking", Butterworth Heinemann, 1996.
29. Schilling M. A., "Toward a general modular systems theory and its application to interfirm product modularity", Academy of Management Review 25, 2000: pp. 312-334.
30. Shimizu H., "A General Approach to Complex Systems in Bioholonics' in Lasers and Synergetics", by R. Graham and A. Wunderlin (eds.), Springer-Verlag, Berlin, 1987.
31. Stylios C., Groumpos P., Langer G., Sørensen C., Tak Hyun Y., Weck M., Iung B., "Discipline research contributions to the modelling and design of Intelligent Manufacturing systems", 2000, website: http://www.ici.ro/ici/revista/sic2000_2/art04.htm.
32. Tharumarajah A., Wells A.J., Nemes L., "Comparison of the bionic, fractal and holonic manufacturing system concept", International Journal of Computer Integrated Manufacturing 9 (3), 1996.
33. von Bertalanffy L., "General System Theory: Foundations, Development, Applications", George Braziller, 1976.
34. Turnbull S., "Design criteria for a Global Brain", Gbrain O, July 3-5, 2001, website: http://pespmc1.vub.ac.be/Conf/Turnbull.doc.
35. Youssef M.A., "Agile manufacturing. A necessary condition for competing in global markets", *Industrial Engineering* 24(12), 1992: 18-20.
36. Warnecke H. J., "Fractal Company: A Revolution In Corporate Culture", Springer-Verlag, Frankfurt-New York, 1993.
37. Wilber K., "*Sex, Ecology, Spirituality: The Spirit of Evolution",* Shambhala Publications, 1995 (2nd edition, 2000).
38. Wyns J., "PMA Holonic Manufacturing Systems Group: 1996", website: http://www.mech.kuleuven.ac.be/pma/project/goa/prosa.htm.

Note: all the sites mentioned have been visited in April 2007.