Beliefs, Certainty and Complex Systems Structure

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Abstract - **In the multi-agent systems field the notion of belief as a primary justification of an agent's decisions has been extensively studied. On the other hand, the concepts of holon and informon developed by Koestler, Sulis, Alonso, Pazos *et al.* have proved to be a very useful way of to model evolving complex dynamic systems. In this work the relationship between holons, informons, randomness and uncertainty (as the opposed to certainty) in a holonic system that reacts to events, and how the beliefs (and, in some cases, the uncertainty) could influence the way the holons get structured is analyzed.**

Keywords: holon, informon, beliefs, self-organization, emergence conditions.

I. INTRODUCTION

The whole Universe is formed by interactions between holons and informons. Holons process information that can be certain or uncertain in different degrees, being these degrees of certainty reflected in the beliefs, for example, in the BDI approach used in the multi-agents systems (MAS) field. Although authors such as Dubois [1] distinguish between uncertainty and randomness, both of them can be seen as the holon incapacity of to give precise answers or to make sure decisions in many cases. In this work we will discuss some aspects of the lack of certainty (let us call it non-certainty in order to use a term without extra connotations linked with the way of representing it: probability, fuzzy logic, plausibility functions, etc.), we will see its relation with the holons and the informons and how it affects the way the holons structure. Additionally, given that many holons are human made (for example, organizational groups, workgroups, software agents systems, etc.), it would be interesting to see what can be done in order to obtain an "optimal" design, in the sense of minimize the non-certainty in their answers or decisions. A general idea of hw could it be done is explained.

This work is organized as follows: next, an outline on the basic concepts of holon, informon, event and uncertainty is given together with some related works. In the section III how the non-certainty can influence the holons' formation is described; an example is given in the section IV, ideas of how to measure the lack of certainty in an indirect way are sketched in section V. The conclusions and future work altogether the bibliography complete this work.

II. PRELIMINARY CONCEPTS AND RELATED WORKS

In this work we study the structuring as related to the self-organization from the standpoint of the beliefs of its elements. In turn, self-organization of a MAS will be understood as the "process enabling a systems to change its organization without explicit command during its execution time" [2] and we could rephrase it as "... during its lifetime" in order to include living systems, such as social groups. More precisely, we'll be concerned with the strong self-organization (that is, without any specialized control unit [2]).

Numerous works have been done on the self-organization, an extensive bibliographic account can be found in [2].

General rules governing complex systems are difficult to find, and one must be careful of not to force general principles in very dissimilar systems [3]. Nevertheless, we'll try to deduce a couple of simple rules affecting the organization of many self-organized systems.

Beliefs represent here the informational state of holon, as in the MAS theory is for the agents, in other words its beliefs (knowledge in a given moment) about the world (including itself and other holons). Beliefs can also include inference rules, allowing forward chaining to lead to new beliefs. Note that given the broad spectrum of the reality covered by the holons, a cell and a corporation have both beliefs, of a physic-chemical or collective types.

A. Holon: In 1926 Smuts introduced the concept of holism [4] and later (1967) Koestler coined the term holon based in that "whole" and "part" in the absolute sense do not exist anywhere [5]. The holons applications in the industry have been broadly studied , for example see [6] [7] [8-10].

Holons have a multiple granularity that is manifested through the replication in auto-similar structures of fractal type with multiple resolution levels: the holarchy. Whole cosmologies have been developed ([11-12],[13]) based in these concepts.

Turnbull [14] distinguishes between strong holons and weak holons. Strong holons can exist autonomously while weak holons cannot exist without the rest of the holarchy. In this work we'll consider the strong ones.

Finally, in many fields of the physics the term holon is used as synonym of chargon [15-17].

We will adopt the meaning given by Koestler and Wilber [11] [18].

Holons have been related to abstract agents [6] and could be seen as embodied abstract agents (that is, agents that have a physical part interacting with their environment) [19].

The holonic approach allows to have structures that evolves through time, energy-free (not far-from-equilibrium) based on simple local rules [2].

B. Informon: Today, two stances (definitions) exist, one of them associated with the conscience.

Unrelated with the conscience are basically the definitions of Sulis and of Alonso *et al.* Sulis states that informon is an aspect of reality that possesses the capacity to inform. An informon is an aspect of the reality that exist prior to any interpretation (semantic frame)" [20]. Concomitantly, Alonso et al. [21] define: "informon is the basic element of information that has sense for a holon and that allows it to make the right decisions and to execute the proper actions". In both definitions the informon is a unit of (or that gives) meaningful information that affects the behavior of an entity.

On the other hand, for Zeleznikar [22], an informon is a conscious emergent informational (v.g. that gives information) entity.

We'll adopt the definition of Alonso et al..

There exists a relationship of co-dependent existence between holons and informons: cannot exist a holon without informons (for example, corresponding to its status or its environment status) neither informons without holons (because of the definition of informon [21].

Informons can be seen as perturbations from the environment to the holons, a series of stimuli that are received and affects the holons [2].

Given that every holon can be considered as an informon, but not conversely and that Wilber assigns degrees of conscience to holons, many (not all) informons could have a certain level of conscience, as Zeleznikar states in his definition

C. Entity: An entity is, in this context, a generator of informons [23]. Entities generate collections of informons that form dynamically coherent histories (which in turn are another informons, as we'll see).

D. Event: An event will be anything that happens, that occurs. Kolmogorov [24] uses the term in this sense. An event will exist as long it is meaningful for someone, that is, if it generates informons that influence the behavior of some holon ("Equivalence law": *I inform, therefore, I exist* [23]). Events will be then entities.

Events can be thought as decomposing/grouping themselves in/from other events; Kolmogorov refers to this when mentions "events" and "elemental events" [24] and so suggests De Finetti [25] with the idea that a "case" can be expressed as a combination of so many events as necessary. Some sets of holons will conform another holon, which in turn can interpret some sets of events as other events.

E. Uncertainty: In this context, when referring to uncertainty we are talking about a continuum that ranges from the absolute certainty to the impossibility. Uncertainty can be associated to a state of a subject with which it must make decisions, that must be represented and communicated [26]. Uncertainty appears, then, connected with the decision making process. We won't review all the different approaches taken so far (probability, plausibility, fuzzy logic, etc. etc.) to handle it and we'll just mention this lack of certainty as non-certainty.

III. BELIEFS, CERTAINTY AND HOLONS STRUCTURING

By definition, informons influence the behavior of holons, that is, the former have effect in the actions and decisions of the latter. Let us consider an informon corresponding to the k-th level[1]: α^k (generated by some event E) and a set of holons of the same level for which it is meaningful: $\{H_1^k, H_2^k, ...H_n^k\}$ .Suppose that in this holonic system the necessary conditions for

[1] We are referring here to the levels in which holons and informons stratify, as it was already mentioned. $k < k'$ implies that the holon at level k includes the holons at level k'

the auto-organization are met, so that the holons can group/divide through time [27].

Let us also suppose that holons react to α^k so they obtain the maximum utility from their behaviors, no matter what informon is α^k. By utility we means a number associated to the consequences of an action (or attitude), not necessarily an economic value. These consequences could include aspects such as related with faith or emotions and would represent the holons preferences [28]. Utility doesn't describe completely the consequences, it is just a number, and can be seen as a goal to be reached. So, given H_i^k there are n-1 additional holons so the reaction of H_i^k to α^k is also influenced by the reactions/decisions of these others and by the reactions stemmed from groups of them (groups of 2,3,... n-1 holons). Hence, the remaining n-1 holons generate $(n-1)n/2$ possible influence relationships, each of one which will correspond with at least an additional informon (assuming that each influence is described by one or more informons). There is an additional informon representing the decision of H_i^k of joining a higher level holon H_i^{k-1} - the decision of to transcend, in the words of Wilber – together with some of the n-1 ones (see Fig. 1), in all, n-1 additional informons (at least). Given that holons only have local communications, not all the informons will affect a given holon at a time (see Fig. 1).

Every informon affecting the holons (at any level) will be given a degree of non-certainty by the holons, so the utility we want to maximize is the expected utility. For example, H_i^k could be a person and H_i^{k-1} a government, as Lindley suggests in [28], even though he doesn't mention holons.

Let's suppose that

a) the n holons are rational (they do what gives them more utility)

b) they are coherent in the utility (the bigger the preference, the greater the utility) [28].

In the context described, we conjecture that, for the emergence of H_i^{k-1} is sufficient that the utility obtained by it is bigger than the maximum utility of the H_j^k $j=1,2...n$. By denoting as $U(H_j^k)$ the scalar[2] representing the expected utility by the reaction of H_j^k given α^k and the rest of the mentioned informons, then the previous condition is:

$$U(H_i^{k-1}) > \max_j\{U(H_j^k)\} \qquad \text{(I)}$$

while the necessary condition for the formation of H_i^{k-1} is

$$U(H_i^{k-1}) \geq \min_j\{U(H_j^k)\} \qquad \text{(II)}$$

Condition (II) means that the holon could emerge even thoug not every H_j^k increases its utility (e.g. the humanitarian activities, or, in a general case, when there is a conflictive decision making).

Suppose now *that the utility obtainable by* H_j^k $j=1...n$ *is approximately the same that the one* H_i^{k-1} *would obtain.* (III)

This would be the case when the utilities of an element barely affect the reachable ones by the others. In this scenario, the optimum decision/reaction is the one that has the larger belief of obtaining the utility; more formally, the one that has beliefs with larger measure (non-certainty)[3] of it [29].

What conditions must satisfy the non-certainties in this system so new holons can emerge? Considering (I), (II) and (III), what is the relation between the non-certainties of one level and the ones of the next level? Considering (III) condition (I) can be re-written:

$$B(H_i^{k-1}) > \max_j\left\{B(H_j^k)\right\} \quad j=1...n \qquad \text{(IV)}$$

with $B(H)$ a measure of the belief of H about to obtain the utility when influenced by α^k (for example, it could be a measure of plausibility [29] or a probability).

Equation (IV) is the sufficient condition of formation of a holon (save exogenous constraints) and the necessary condition for the maintenance of it is

$$B(H_i^{k-1}) \geq \min_j\{B(H_j^k)\} \quad j=1,...n \qquad \text{(V)}$$

again save external constraints. By "save external/exogenous constraints" we mean the existence of rules, laws, physical barriers, etc. that prohibit or turn impossible the holon formation/disintegration. For example, the merge of two companies (two holons) into a monopolistic new one which derives in a organization could be banned by the anti-trust and anti-monopoly regulations of many countries. Analogous

[2] Many authors have proposed vectorial utility functions U; in such a case, our U would be a certain scalar function of the vectorial utility function: U=U(U) so we could define a total order for the utilities.

[3] Following the subjetivistic stance, the firmer beliefs, the ones about we have less doubts, corresponds to bigger non-certainties (bigger probabilities, bigger values of the belief functions, bigger values of plausibility, etc.).

considerations can be made about the maintenance of the holon. In the case of human holons, this result coincides with the theory of the predicted outcomes values (POV) of Sunnafrank [30].

Note that conditions (I),(II), (IV), and (V) are all instantaneous, in the sense that describes a property of the holarchy in an instant of time. They can be used, then, for open systems (assuming that new holons may appear by "spontaneous generation" or by emergence/disintegration from/of others).

Conditions (II) and (V) can be seen as the viability constrains for H_i^{k-1} [31].

One could think that believes (or non-certainty) could increase indefinitely, that is, that at given moment any "doubt" In the holarchy should vanish (considering the doubt as the non-certainty of obtaining the utility, in the case of holons that use the excluded middle principle: the non-certainty of obtaining U is the complement of the non/certainty of not to obtain U). This unlimited growth doesn't happen because:

a) systems present local interactions so the increase in the belief (and the eventual reduction in the doubt) is local too. Informons stratify in levels corresponding with the holons' ones, and, surely α^k is not meaningful for the levels *k-p*, *k-p*-1...for some *p*>1; even more, by considering it, holons would suffer a "paralysis by analysis" (an overload of information and a problem of "bounded rationality" would arise), so the importance of to encapsulate by levels the information handed [32].

b) when informons stratify, the increase in the belief (and possibly the lowering of the non-certainty) of H_i^{k-1} respect α^k will be compensated by the diminish of it (an increase in the non-certainty) respect some α^{k-p} in the level *k-p*.

Many questions arise:

a) Given α^k, how to group the $\{H_j^k \quad j=1,2...n\}$ so the resulting H_i^{k-1} is optimum in the sense that its non-certainty of not obtaining U is the minimum of all possible or, more generally, that the expected utility is maximum? Is this grouping unique? How to realize the joining dynamically, as long informons appear using the minimum of historical information?
b) Is the obtained grouping dynamically robust [32]? That is, do little variants of α^k produce almost no effects in the structure?

These questions are related to the organizational dynamic in the sense that we want to know how to group people, groups, etc. to obtain the result with the biggest utility and, as a special case, with least non-certainty (of not having/reaching U).

IV. AN EXAMPLE

In [33] a holonic model of organization for the resolution of the incidents that takes place during the software projects development was presented. The "solvers" of these incidents are holons formed by the help desk software (expert systems), people (technicians, groups of specialist, outsourced companies, etc.). Let us considerer one of those incidents (which could correspond to an event as defined previously), for example, the fault of the corporate mail systems in a sub-network of the company XX. XX is an organization with dedicated (specialized) staff who maintains the telecommunications services, administers the different servers, the network security, etc. and can also contract external support provided by other enterprises or groups. The aforementioned event will generate a series of informons, such as:

$\alpha^k \equiv$"claims from the users of the Department YY related to the non-reception of many e-mails"

$\beta^k \equiv$"notification in a personal computer that the e-mail client program is working without connection"

$\gamma^k \equiv$"claims that the area ZZ (an area as a part of a Department) cannot send e-mails".

A group (holon) is wanted in order to solve the incident.

There are non-certainties of any kind: from the ones originated due to the intrinsic undecidability proper of the description logics models (used in the holons to represent knowledge), the indetermination produced when different reasoning can be applied at the same time, to the lack of knowledge (technical, of the corporate norms or about the other holons actions). Each of these holons will try to solve the incident based in its knowledge and experience. On the other hand, be

$\alpha^{K-1} \equiv$"some managers did not receive the monthly report of sales"

$\beta^{K-1} = (\alpha^K, \beta^K, \gamma^K) \equiv$"an interruption in the mail service took place"

Informon α^k will be meaningful, for example, for the holons H_1^k (servers administer) , H_2^k (network administer) and H_3^k (help desk receptionist); however we suppose that it won't be significant for H_3^{k-2} (manager of the area PP) and H_2^{k-2} (Human Resources area) but α^{k-1} will affect H_1^{k-1} (IT manager) as

β^{K-1} will do. A practical consequence of this is that the validity of the solution found [33] will be checked only a few times (in the holons levels for which the informon is meaningful), avoiding a problem of infinite regress.

If H_1^k, H_2^k and H_3^k try to solve the same problem (the failure of the mail service) in a parallelized way, they will form a workgroup H_1^{k-1} if they have a bigger belief that in this way will be more able to do it then if they try separately, that is, the non-certainty of not solving the incident (not to obtain the utility) is less for H_1^{k-1} tan the least of H_1^k, H_2^k and H_3^k.

On the other hand, if we want to group (to structure the system formed by H_1^k, H_2^k and H_3^k) them in pairs: a) ($H_1^k + H_2^k$, H_3^k) or b) (H_1^k, H_2^k + H_3^k)[4] or c) ($H_1^k + H_3^k$, H_2^k), the problem would be what of the three configurations to choose in order that the belief of solving the problem for the "team" (holon) H_2^k + H_3^k is bigger than the ones of H_2^k y H_3^k separately and, yet better, tan the one of $H_1^k + H_2^k$ + H_3^k. Assume that the right option is a) (see Fig. 2).

If the non-certainty of solving the problem (according to each H_i^k) by $H_1^k + H_2^k$ + H_3^k is I^{k-2}, less than the minimum of H_1^k and H_2^{k-1}, a holon H_3^{k-1} will form "naturally" because they all admit that working together have better perspectives of success; if I^{k-2} were only less or equal tan the maximum of I_1^{k-2} and I_2^{k-2}, the holon that would emerge might exist because causes not related to the proper problem to solve, e.g. because there is a corporate disposition about how must the workgroups be formed.

V. NON-CERTAINTY MEASUREMENT

In this section we will not develop a theory of measure of non-certainty as it was already done with the probability theory, fuzzy sets theory, etc, but we are interested in how to measure it from the relationship between the holons using it of groups them in a dynamic form so the dynamic formation/dissolution of the holons is reflected in the used criteria. Turnbull [14, 34] proposed the Transactions Byte Analysis (TBA) which would lead to a holonic decomposition. On the other hand, for many researches in the psychology field, the increase in the certainty (in the sense of reduction of doubt) is a an important motivation for the communication between the persons (human holons) [35], and could be the main cause of it (for example, for Berger and Calabrese [36-37] with their "Uncertainty Reduction Theory" (URT). Hence, it seems likely that there could exist a relationship between the quantity of exchanged data between holons and the beliefs they have in getting the utility. The relationship between TBA and the decomposition seek here will be investigated in future works.

VI. CONCLUSIONS AND FUTURE WORK

In this work we have analyzed how the beliefs and the lack of certainty influences the structure of the holonic systems, conjecturing that is necessary that it diminishes as long as new holons generate.

Necessary and sufficient conditions were given for the emergence of an holon from a set of rational and coherent holons of lower level.

This work is just an initial reflection about the indetermination and uncertainty using the holons and informons approach; many future works could stem from it such as:

a) How to calculate the belief (non-certainty) of the emergent holon, that is, from the non-certainties of the individual holons deduce the non-certainty that could have the emergent holon (if it would exist, given the conditions presented)

b) How to obtain dynamic hierarchies that achieves maximum utilities and, as a particular case, with maximum beliefs in getting the wanted utility/objective. This would be the general case of many problems, such as the one of the distributed autonomous explorations [38], and finally,

c) How to perform a distributed reasoning using holons that represent non-certainty in different forms (for example, probability, fuzzy logic, etc.).

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[4] The notation **a+b** should be understood as "the holon formed by **a** and **b**"

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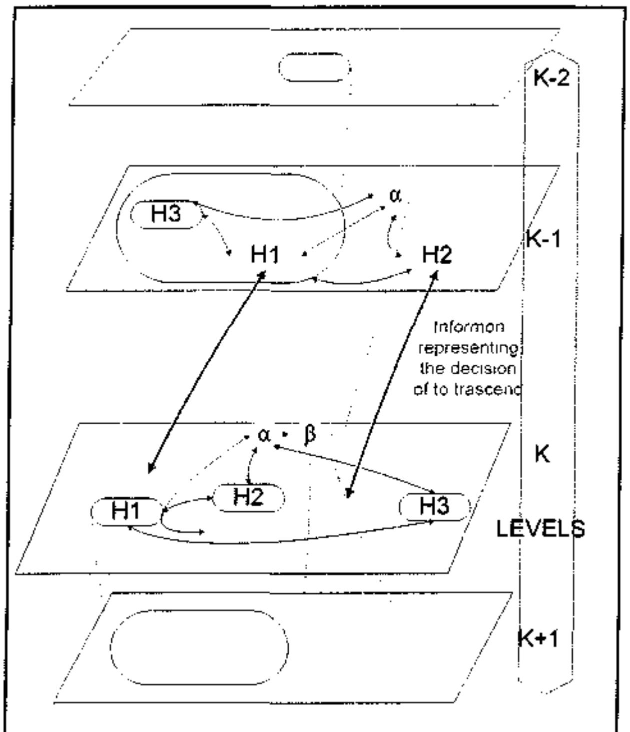

Fig. 1

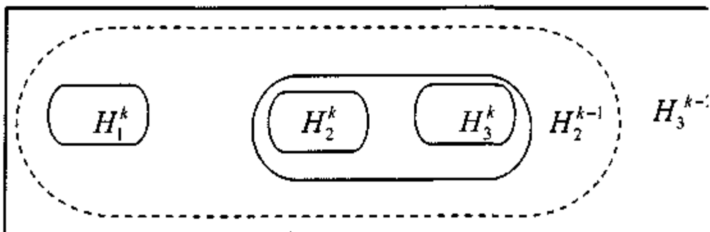

Fig. 2