Cognitive and Semiotic Approach Lead by Risks Perception and Evaluation for Complex Projects

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Abstract
This paper proposes an approach for a complex and innovative project calling international contribution from different communities of knowledge and expertise. Designing a Human Space Autonomous system for Mars exploration needs a cognitive and semiotic approach lead by risks perception and evaluation. The objective is to solve complex problems and facilitate communication and cooperation at the early stages of the project. The specialized languages, norms and representations tend to separate knowledges in different fields. This process is emphasized by the tendency of discursive thought to reduce the multiple to the unity. Designing an open, self-learning and reliable exploration system[1] able to self-adapt in dangerous and unforeseen situations implies a collective networked intelligence led by a safe process that organizes interaction between the actors and the project finality.
Keywords : Human space exploration, cognitive and semiotic approach, management of complex project, dialogical modelling, cooperation, autonomous system.

1 Introduction

The objective is to help design a Human space autonomous system for the Human Mars exploration. Our research initialized in 2003 concerns the conditions of a safe design that firstly protect Man and its humanity by giving him its free place at the heart of this audacious scientific exploration mission [1]. A reliable and safe design for Mars mission implies a collective networked intelligence for success. Cooperation is required at the early stage of the project and the quality of the result is fundamentally inseparable from the problem formulation perceived from different semiotic points of views. To place Man at the core of the project leads us to consider a design process Human and inter-cultural oriented lead by risks perception and evaluation. Firstly the design process must be organized to generate a reliable and safe technical system for the team of

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explorers. The difficulty is to conceive an open, self-learning and reliable system[2] able to self-adapt in dangerous and unforeseen situations during the flight and stay on Mars. We have considered that the exploration entity is a real aware newborn child stemming from mother Earth. With a fine and evolutionary consciousness of its internal states and with a multi-scale perception of its external environment, the Human Exploration system is like a cognitive entity both wide ranges of anticipatory actions [2]. Perceptions of new dangers in different unknowns, to forecast environment is a great stake for the success of the mission.

The foremost risk that we have identified with respect to the design process is to conceive the exploration system (which will support the mission) as a closed system, and not as an open one[3]. The second risk is our concern that the centralized models of safety available today may well not be sufficient to respond to the safety challenges of human long distance and long-life exploration missions [3]. This risk is enhanced by the multiple forms or configurations the exploration system might take during the travel. These configurations are unpredictable because of the complexity of the inter-cultural organization and the use of a large and various range of technology.

The design of a technical system for the Mars exploration is not an object given "apriori", it has never been realised before. The requirements for a such complex project required contributions from many disciplines, communities of knowledges (with theoretical and practical expertise). Those different separate fields of knowledge generate some difficulties of communication and cooperation between partners [4]. The challenge is to create a dynamic simultaneously common and heterogeneous vision(s) of the requirements and especially during the phase of definition of the system.

The definition of the technical exploration system will be progressively built up by negotiating intentions, meaning of signs, drawing, formulas, representations in order to satisfy the objectives, constraints, criterion of the project and its numerous requirements. All these forms have a virtual existence and we can define them as semiotic constructs that even when they were represented projected their behavior far behind their origin.

2 Systemic Risks, Signs and Human Reliable Communication

In our research, we see that systemic risks may arise due to the limits of the centralized models of organization, limits which are indeed very perceptible on earth and in orbit (in the case of systemic accidents) [5]. From this problematic emerge certain first specific requirements for the design. It is necessary to :

- Give to the exploration system new capabilities, such as autonomy and cognition

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[3] First definition : system that does exchange matter as well as energy with the surroundings

- Organize a safe and reliable conception process, especially concerning the socio-technical integration of the Global EXploration system (GEX - Coupling Human(s)-System(s)-Machine(s)).

We need a framework for understanding the processes that such a complex project-work entails, in particular to think about the inter-dependencies between individuals and the project and between human and technology. For these reasons, it is necessary to consider interdisciplinary and organizational semiotic especially during the design stage. The complex safety problems concern each and every actor in the network of the exploration organization. Intrinsic safety is founded on the quality of the process of the entire life cycle of the project. A safety culture is a group responsibility that should be founded on a common reference fund (and this is also a semiotic construction) between the designer, the manufacturer and users (the team of astronauts) which is partially interdisciplinary.

Interdisciplinary could be defined as a novelty (paradigm and methodology) which emerges from the dynamic group interaction and will lay the basis for a safety culture. The key point to keep in mind is first to favor the emergence of an open space for discussion "in-between" the different partners of the project. This is the way to address and to push the limits of actual knowledges and to find new types of problems and solutions for Human space exploration. The problem is that classical structured organization tend to reduce interactions between people and separate fields of knowledges.

The other point is that the qualification process tends to take objectivity (historically constituted) as a unique reference for collective action and decision. The notion of network can help us to think about a collective entity, but it is also necessary to find individual cognition, on which lies recursively collective cognition. Every knowledge relative to an object (material or not) for a given person is the result of a direct experience or information which he acquires as member of a network. The second experience is fundamental because it organizes the first. This is a "by signs knowledge" and the informations transferred by the network are informations on the object under a specific cognitive relation. The effect of a sign on a person is to produce an Interpretant (for Pierce : "cognition of a mind). In the interpretation of signs the person is informed that the qualities configurations which belong to the sign are similar to another object which is a "not present" object of knowledge in the field of its actual experience. The interpretant (sense) constructs its conception of the object and organizes the knowledge with experience accumulations followed by some reconfiguration that implies at each moment a possible revision of the conception [6].

According to Pierce every person lives under a "perfusion" of signs. An approach of collective cognition needs to take care of the social network and the semiotic fact which is co-extensive for knowledge acquisition. In this frame, the nodes of the networks are occupied by agents that are also channels of communications. The triadic Peircien sign is interesting because it can individualize the relation of every agent with any object in

function of its personal implication in the institution of significance. These institutions produce some kind of cultural codes [7].

In our work we are trying to construct the link between information and action for the members of the project team. We consider that a complex project is a network of actors in interactions. Our aim is to create an institutional space of meaning to improve human interpersonal communication and cooperation. The effort of individual thought seems to reduce the multiple to the unity, this is the sign of the need which animates one to preserve oneself against the others [8]. Semiotic is in relation with the cultural part of the agents, but action is always interaction and could be seen as a semiotic doing of a free agent in a situation of confrontation with the intentions of other agents. This can generate some paradox and conflicts that we want to manage at the early stage of the design process. A human being needs to make meaning in order to act and its actions are founded on desires, ethics and values and these are a very essential parts for understanding Human relations and communications (logical strategies).

3 Cooperation Process and Human Reliable Communication

In a previous article we proposed a new path for co-construction of a common semiotic representation and the issue of guidance for durable cooperation in a complex project [9]. In this path the free space in between two subject (interpreter), two actors embedded in a world of shared meaning makes possible the coupling of each actor's information transfer and action. If we want to develop a trust strategy, we can make a virtual coupling (by free will) of their gains. This coupling which is perceived and decided by the actors is an expression of the trust level that one actor allow to the other.

This kind of reasoning can stabilize the cooperation process with some conditions that are in link with what the actors accept to realize in common. The intensity of the feeling dilemma depend on the coupling / UN-coupling that the actors accept to do "in their mind" in link with their perception of risks. Such a structure : Unity of interaction allows to create a new language representation in which the actors can express three types of feeling: Attraction, Fear, Temptation (A, F, T). In themselves and in their relations with other people. The unity of interaction is defined as an elementary situation for two actors, who are free and conscious [10]. They can not have free access to their choice because they depend on each other. Because of their mission, they can interact and determine the common event.

Astronauts Designers	Choice 0	Choice 1
Choice 0	e1	e2
Choice 1	e3	e4

Figure 1: Unity of interaction.

The AFT, is a new language representation which is very useful for the actors because they can tell the possible feeling in a dilemma and the expression is relatively

universal (symbolic level is addressed). With a simplistic calculation, we can show that the positive coupling of the gains can permit to reduce Fear and Temptation and to increase Attraction. This can create the stabilization of the cooperation process. In a few words, we can make a link between an actor's motivations in an interaction situation and the feeling of Fear, Attraction and temptation.

"Information is a difference that makes a difference" said Gregory Bateson [11], and communication is a complex and interactive process. When two people communicate, their cognitive systems generate differences and they will progressively understand their identity. The way they will manage differences in a cooperative or in a competitive manner will build a good or a bad climax for relation and give (or not) some possibilities of a good management of their interactions. The level of trust fixes the possibilities of stabilization of the cooperation process. In the model, we can distinguish four communication processes [12]. This allows to understand the complexity of a such interaction between humans :

1. Information transfer (Criterion of quality: Truth)
2. Managing common action (Criterion of quality: Cooperation)
3. Creation of relation and confidence (Criterion: Trust)
4. Discovering identity (Criterion: Estime)

The first two processes : Information transfer and managing action(s) are visible processes that are already described in a lot of communication theories, but the others are not visible and they are the key for understanding the communication actions and their impact on cooperation in a complex project.

These allow building a shared evidence fund between the actors, to evaluate the reliability of their relations and to make them discover their specific identity. (*)

As we see in some research, if we want to increase cognitive abilities between information and action we need the other dimension, some hidden dialogics can generate specific dilemma in one of the four communication process and in one of the seven steps of the model (1. Presence, 2. Definition of the project, 3. Qualification of the project, 4. Realization of the project, 5. Evaluation of the results, 6. Sharing of issues, 7. Absence).

This approach allows to solve some human communication difficulties encountered in the management of such a complex project because it takes care of dialogics, recursivity and include a hollogramatic principle; Those three conditions seem to appear as factors that create some innovative solutions which are adapted to the complexity of the exploration system. The methodology address semiotics because it allows to see some stable structures that may correspond to the culture of the agents, but the key point is that recommendations are made by the actors, and they are directly adapted to practical difficulties encountered [13]. Then a durable cooperation can be established with dynamical meaning founded from a renewed partial common semiotic representation of the project

4 Towards a Modeling Insuring the Transition from Simple to Complex

Towards the current spatial systems, the exploration disposal to be conceived is autonomous and piloted. The technical system is at the service of the embedded team. This motive implies a design which integrates a specification of needs made by the astronauts around a shared reference between the designers and the manufacturers. We have to consider during design the systematic reassurance of all the phases of the mission. We can not tolerate the choice of a logical and calculated architecture which would depend on one or some unique critical components. As we see in the previous part, it is a necessity to use systemic tools to gather with reductionist methods. Although undeniably successful they have limitations especially for complex system in an unknown environment. We can see this by disastrous consequences shown by a serial of high technology accident cases [14].

It is thus a necessity to integrate the definition of the specifications of the exploration system into a very wide perspective centered on the idea to think first of all about the "viability" (of the support system for exploration) and to make potentially actionable " Human safety " throughout the mission. Our works resulted in the implementation of a practice of the modeling of a man-organization-environment [M-O-E]. The purpose is to improve the management of the socio-technical risks before the development stage of the technical system of exploration. This practice of modeling [M-O-O] which is not in line with the classical normative methods considers that the project of exploration is a combination of the individual project of each actors and not a heavy pre-established organization that fix almost totally the project of the actors. We have considered the interest to realize an interactive specification of requirements which takes care about the sensibility and the creativity of all the authors of the project in their variety of experiences.

A simplistic description of a mission of reference [15] allowed us to show the interest to consider a definition of the system of exploration in a triadic perspective.
Here :

- the object (fragment of reality that fixes the sign in the peircien frame) is the technical system (composed of 22 elements),
- the sign (connection which is constructed by culture (a micro social institution in the meaning of the traditional constitutional analysis) is the information system,
- and the interpretant is the system of actors (the place in which micro institution are manifested, the place of their particularity).

The transition from the definition of a mission of reference to the modeling of a system [H-O-E] passes through several plans of modeling. Each stage is scaled from the least complex to the most complex (from deterministic to the most chaotic levels).

These distinctions of levels aim to avoid the design of an open system in a closed one. We consider that every path of modeling is compounded by a "complex unit" shaped by at least two parts that are irreducible one from the other (couples).

The couples represent the progression of the knowledge which is necessary to realize the Martian mission.

For the Mars manned mission, the first challenge is to transport a quantity of material on Mars (couple n°1: Trajectory-propulsion).
The second stage is to be able to maintain alive Man in a favorable environment for life (couple n°2: Man-life).
The third step is to be equipped with scientific disposal for the Mars surface exploration (n°3: Mars-exploration). And finally we can consider the possibility of implanting a long-lasting home on the fourth planet of the solar system (couple n°4: Mars-civilization). These four couples are guides accomplishing the definition, the modeling and the simulation of the system of exploration. This dialogical (couples): trajectory-systems of propulsion, man-ways of life, Mars-systems of exploration, Martians-Mars-civilization are the expressions of an open modeling which does not reduce the immaterial aspect to a material system.

The initiative for driving the modeling project with 4 couples allows us to aggregate heterogeneous requirements and be able to face the combinatorial explosion of the uncountable dangerous configurations. The main advantage is to answer to the high need of integration of the the technical system that will support the mission. A part of the « complex unit » represents the need to satisfy and the other part is an answer which takes a technological shape. The validation of classical technology is made by statistics (and stochastic) methods and for the innovative parts we should use maturity models [16].

This way of proceeding allows to discern carefully the hierarchy of needs to satisfy according to an ordinal evaluation (inter-subjectivity) then, it is possible to launch some objective studies on critical aspect lead by pre-evaluation of risks. The advantage of this initiative is that it allows to be free from a certain extent and evolution of technologies.

5 Conclusion

Designing an Human Space Autonomous system for Mars exploration needs a cognitive and semiotic approach led by the finality of the project (research of life on Mars) and risks evaluation and qualification of knowledges (lead by safety and reliability). An approach of reliable collective cognition needs to take care of the social network and the semiotic fact which co-evolve with acquisition of new knowledges.
Objective and subjective notions of risks are necessary to constitute a shared definition of a new technical system which is design in a multicultural organization context. Some defaults of the technical system possibly at the origin of accidents can be avoided, if we have some ways of understanding their roots. Our approach is linked to a multi-viewpoint framework built on the basis of cognitive reliable interaction with a partial semiotic approach. It appears that managing the process of cooperation between subjective and objective risks at the early stage of the design should prevent some relational accidents (Human Factor), and impulse a continuous innovative learning process at the heart of the project team.

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