Towards the Complex Interface

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Abstract. This paper introduces a new concept for interface based on user perception, according to its definition in phenomenology framework. Based on studies about fractal aesthetics and its effect in human perception, an analogy is made with the scale-free topology of collaborative networks. Properties of this scale invariance characteristic should then be used for a computational implementation of a dynamic and optimized interface, adequate to the user preferences, feelings and perception.

Keywords: Perception, interface, visualization, phenomenology, scale-free networks, fractal.

1 Introduction

The interface can be conceptualized as an entity that allows an interaction between living system and data sets. That is, designing an interface besides giving shape to information connected to a software program, explores the communicative processes between virtual entities revealed by this interface and actual entities revealed by the individual interacting with the program.

One of the lines of research in our group is concerned with investigating the relationship between space, from a point of view of an architect, and perception [1]. This is meaningful because it sheds some light on how we treat the interface.

The first relevant aspect about interface modeling is concerned with the graphic interface is nothing more than the space of action and interaction of the user. There is a resemblance between the creation process of concrete, architectonic space and digital spaces. In this way, we were able to conceive the interactive relationship between user and space in a more comprehensive way. We also noticed that the user of virtual spaces not only interacts with the environment through the interface but he/she also lives, experiences, perceives and "mentally inhabits" virtual space.

In addition to this, the development of an interface project for cyberspace must consider the peculiar dynamics of its configuration, as well as the properties to be implemented that are possible and accessible from a technological point of view. That is, from the spatial configuration point of view one of the peculiarities consists in the fact that this space is constantly submitted to new configurations and reconfigurations of its forms.

F.A. Basile Colugnati et al. (Eds.): OPAALS 2010, LNICST 67, pp. 118–130, 2010.

In the case of virtual environments, the interface serves as a gateway to access users' cognition of such systems, given that the mental processing involved in the interpretation of the informational contents depends on the stimuli that lead to perception motivated by this interface. So, we might state that interface design should be connected to "cognitive ergonomics", metaphorically speaking, that takes into account the interaction between the individual and the virtual environment, based on the exchange of stimuli between users and cognition, via the interface.

It is through the action of registering sensations that we can affirm we have a body that relates to the world. We can say we have a body by analyzing the acts we register (body sensations registered). Then it is possible to make references to physical objects and to space. This space is the basis to all concepts of space and we know our bodied presence because we register sensations. It follows then that there are three fields of perception: the interior, the external and the act of registering both the internal and the external. Intermingled with these fields we have acts from impulses/drives, instincts and reactions. That is to say that we have a body that feels, registers and reacts and is capable of decision, control, reflection/reason, evaluation, understanding and generation of concepts. This occurs at different levels, depending on presence and achievement, individually or in group, depending also on the level of consciousness we have of these acts (quality and amount). This fact points to the structure, to the constitution of the subjects. Consciousness stands as the dimension where human operations are confluent: body, perception, and mental acts are registered.

E.g.: to see (to see an object; here, you are in a room and you see a book) as an example of data assimilation, understanding and interaction in a physical environment.

The sense involved is vision. The act of seeing it is perception (you register what you see). If you remove the book from your vision field, you can remember (an act that makes present something that is not there). In examining the new reality you know the difference between perceiving and remembering.

You can imagine the book where it was. You can analyze it. You can pay attention to it. But you can divert from it by a sound of someone arriving.

What drove your attention to it: motivation?

Did you have the intention of touching that book? Do you evaluate the book? You know that you see the book, you register this.

Remembering, attention, perceiving, imagining, analyzing, diverting, motivation, touching, seeing, evaluating are all ACTS (embodied capacities, mental capacities) and the perceptual experience is also an ACT, the act of perceiving. This synergic system is the intentional arc. The intentional arc is understood as the personification of the interconnection between perception and action, in the phenomenological context. It is the intentional arc "that unites the senses, uniting the senses with intelligence, and sensibility with the motor functions" [2]. In other words, it is the intentional arc that certifies acts of consciousness, certifies experiences of the phenomenological being in the world. According to Merleau-Ponty: "the life of consciousness – cognizant life, the life of desire or the perceptive life – is supported by an 'intentional arc' that projects around us our past, our future, our human environment, our physical situation, our ideological situation, our moral situation, or else leads us into placing ourselves under all these aspects" [3].

From this viewpoint, we support the thesis that the designing of really qualified interfaces leading to significant experiences in the virtual space, should necessarily concern the correct understanding of the perceptive process, a trend widespread in contemporary science of relating cognitive science to phenomenology. We are therefore here discussing the understanding of perception through the perspective of phenomenology. Two other models should be remembered: the serial and the connectionist models. Although important, they do not interest us here as they do not consider subjective experiences on the part of the individual. They are conceived from a representational view of perception. They are based on the principle that perception consists of taking characteristics of a pre-determined world and constructing a copy, or internal image of this world in the perceptual apparatus. Reviving phenomenology seems an appropriate strategy in line with current expectations, given that the principle of its conceptual formulation: *the analysis of consciousness in its intentionality*, functions as a counterpoint to the representational formulation of perception.

The formulations made by researchers such as the philosopher Hubert Dreyfus and the biologist Francisco Varela are examples of this relationship between the cognitive sciences and phenomenology. The idea that forms the basis of the thinking of these researchers is that the spirit forms an organic unit with the body and with the environment. This assumption is very important and must be considered in the creation of virtual environments.

Hubert Dreyfus holds to the thesis that Husserl can be considered as the precursor of the classical theses on Artificial Intelligence. Varela develops a research program referencing classical phenomenology known as the "naturalization of phenomenology". At the beginning, the intention of the project appears to be to create a natural science, a "neuro-phenomenology", incorporating concepts of phenomenology and concepts of the cognitive sciences.

The fundamental assumption orienting phenomenological research subverts the natural attitude characterized by the belief in the absolute external nature of the world's things. For phenomenology, it is consciousness that constitutes the meaning of the world's objects. Consciousness is revealed through the phenomenon: the consciousness of the perceptive experience involved in the observation of the phenomenon and the opening of consciousness to the world, that is to say, the intentionality of consciousness. When for example, I observe a scene of a child riding a bicycle, from the start I am paying attention to the movement in this action: I observe that he turns the handlebars and pedals, etc. But, generally, I am not aware of the perception involved in watching the child's activities, in other words, my perceptive experience involved in the observation of the phenomenon: I am concentrated, involved, thoughtful, etc. My gaze is concentrated on the external action and, therefore, on the direct perception of the object, and not on the internal action, on the perception of the essence of the phenomenon. One could say that this change in our way of looking is, in a simplistic way, what the phenomenological method proposes.

As a philosophical school, phenomenology is not a localized movement nor can it be reduced to a system. "It is always thought of as, even among its philosophers, as a research in movement that can never be summarized as a finished list of precepts and rules" [3].

This being so, we can take the general fundamentals of the phenomenological doctrine introduced by Edmund Husserl (1859) as a reference [4]. In 1900, Husserl published *Logical Investigations I*, with which he became considered the founder of phenomenology as a philosophical method. The fundamental assumption of phenomenology, *the intentionality of consciousness*, was developed by Franz Brentano (1838) [5], of whom Husserl was a student. Husserl's originality consists of having adopted this assumption for the consolidation of a philosophical method. The general fundamentals of phenomenology were to be dealt with by starting with the presentation of the key concepts, around which Husserl based his method, related to the specific sense of how phenomenology conceives its philosophy: as *the analysis of consciousness in its intentionality*.

For phenomenology, consciousness is always the consciousness of something. It is the source or beginning of the other realities in the world. For Husserl, consciousness is a chain of lived experiences, with each experience having its own essence, which in turn defines the way in which the object is revealed to the consciousness. These essences are acts of the consciousness, such as perception, remembering, emotion, etc. Thus, "the analysis of consciousness is the analysis of the acts by which consciousness itself relates to its objects; or, the ways by which these objects are revealed to consciousness. The acts of consciousness, or the ways by which the objects are revealed to consciousness form *the intentionality of consciousness*" [6]. That is, the intentionality of consciousness is the way in which consciousness opens itself to the world of experiences in order to extract its essences.

Pure phenomenology is not a science of facts, but of essences (eidetic science). To get to the essences, once must avoid the affirmation or recognition of the reality and assume the attitude of a spectator, interested in only gathering the essence of the facts, through which consciousness reports to reality. Consciousness should, therefore, assume an attitude of a *disinterested spectator* in relation to the world. This distancing is possible through a methodological artifice created by: the *epoché*. The *epoché* consists of a phenomenological practice; an internal or mental gesture of reduction (eidetic), which leaves the existence of the world in suspension. Through *epoché* one can reach the realm of subjectivity, distancing oneself from the world and assuming the role of a disinterested spectator of the facts, thereby creating a methodological strategy to reach the essences. The attention of the disinterested spectator is turned not toward the world of his reality, but to the phenomena that reveal this world to the consciousness.

According to the phenomenological analysis, the object is not part of the lived experiences. The subject that gives intent to the object does not become an integral part of the object; neither does the object given intent become part of the subject. "The world that in the attitude of *epoché* becomes a transcendental phenomenon is understood from the start as the correlation of occurrences and intentions, of acts and subjective faculties, in which the sense of its unity is constantly changing and which progressively assumes other senses" [7]. Husserl attributes the crisis in the sciences to not taking into account the realm of subjectivity.

The trend widespread in contemporary science of relating phenomenology to cognitive science consists of consolidating a model that emphasizes a practical dimension of phenomenology, giving it potential from a pragmatic dimension.

Supporting an approach that reconciles at least three of these models in a new vision of the perceptive process, Hubert L. Dreyfus says in *The Current Relevance of Merleau-Ponty's Phenomenology of Embodiment*: “I will suggest that neural-network theory supports Merleau-Ponty's phenomenology, but that it still has a long way to go before it can instantiate an intentional arc” [8]. This suggestion by Dreyfus results from the analysis of how Merleau-Ponty thinks of his phenomenological subject. Merleau-Ponty’s phenomenal body, our cognizant apparatus which makes us conscious of the world, is not only a psychic entity, and not only a physiological one, but rather it is a synergic system that takes on and connects the functions of a physical, psychic and cultural order, that define the general movement of a being in the world. “Consciousness projects itself in a physical world and has a body, just as it projects itself in a cultural world and has habits” [9].

The instantiation of the intentional arc of which Dreyfus speaks perhaps occurs in cyberspace, which would promote ideal conditions for its occurrence, as it is a domain in space where phenomenological action and perception gain the status of being one at the same time as they are constituents of this same space.

2 Complex Interface Design

Since the interface measures the informational content offered the user, putting into play his understanding, what he receives depends on the information displayed and on the user’s perception of it. Therefore, within this perspective, the “ideal” interface would be that which is able to neutralize in the most possible efficient way the differences between the external world and the subject inner world, it would be that which manages to touch the user’s perception most directly in such a way that the user feels his body to be an integral part of this simulated context. The experience brought about by means of the interface should touch the essence and being in the most organic, natural and intuitive way possible.

Interface representation in the context of OPAALS proposal is seen as an evolutionary and dynamic system. The conceptualization for understanding and creating a model related to this interface connects concepts as: complex and evolutionary systems analyzed from the chaos theory; cognition and perception analyzed by phenomenology and cognition science; art and scale-free network topology using fractal metaphor.

In OPAALS´ project we have been developing the conceptualization of an evolutionary and dynamic representation system as a synthesis of the relations developed in a knowledge environment, i.e., different knowledge linked with different domain areas and different levels of information; and all of this information also linked with people that provides or demanded it once in the history of use. We have been employing scale-free properties using stochastic dynamic models to forecast links of users and/or contents of interest for another user. The intention is that the system should identify user’s behavior aspects and construct the interface as a graphical representation of these aspects, so that interface could be viewed as a phenomenological result of the system.

To develop this research about complex interface design applied for the OPAALS project implies understanding the most relevant aspects to be considered about the INTERFACE in the OPAALS´ scenario. The main aspect related to that should be the understanding of INTERFACE as an integrated environment of the three different domain areas that interact in the OPAALS´ project: human science, computer science and natural science. So, the challenge in this case was to create an evolutionary and dynamic representation system as a synthesis of the relations developed in a knowledge environment, i.e., different knowledge linked with different domain areas and different levels of information.

The problem was to find a way of creating a graphical representation of an evolutionary and dynamic interface based on the aspects described above. The conceptual connections were clear but the task to create the equivalence among graphical representation and theoretical understanding was very difficult.

In this sense two important connections were established. The first one was Jackson Pollock's work because of the allusion in his work of multiple dimensions and infinity space and also because of the scientific link between Jackson Pollock's painting and fractals [10], i.e., an evidence that in an abstract and apparently at random generated shape, in an artistic process, exists a component that allows the extraction of relationships inside the complex shape created.

The second one was the interconnection between fractal and scale-free networks. It was visualized noted that the concept and technique of scale-free networks could be used in the production of a self-generated interface based on the user's behavior. Using scale-free networks, introduced in 90´s by Barabasi and collaborators, has been applied in many different types of complex systems, from metabolic processes to the economic scenario as well as techno social networks. It could be a way of representing the conceptual idea of complex, evolutionary and dynamic interface that results and transforms itself as a consequence of each new input of people and/or content.

Further applying fractal metaphor for understanding complex interface, allows:

a) Developing a kind of module or mathematical/stochastic reference in a complex system environment (chaotic, evolutionary and dynamic: the 3 things together): a very important aspect because it is a strategy to improve the system's intelligibility, i.e., to make possible a intelligible representation of massive volumes of data;
b) Combination and the re-combination of the agents of the system infinitely, at random, without losing its conceptual and graphical coherence, and therefore this is a way of to keep the coherence of the system in respect to its original function, i.e., its constitutive unit. This coherency, technically speaking, should be guaranteed by the dynamic and stochastic network model developed for this purpose.

The interface design aspects described above take in account both the human visual information processing and the more abstract cognitive information management.

The important thing about complex interface design is to test the correspondence between the conceptualized model and graphical representation. It is important to amplify the realm of study related to the question of interface, as proposed at INDATA project, to obtain a more sophisticated and broad solution interface that we call here sensory interface.

3 Fractals and Scale-Free Networks

In this section, the aim is to connect the concept of fractals to the collaborative process described as a network system. Some concepts and historical facts are introduced.

Since their discovery by Mandelbrot [11], fractals have experienced considerable success in quantifying the complex structure exhibited by many natural patterns and have captured the imaginations of scientists and artists alike. The main property that made fractals so popular for nature and complex systems modeling purpose is the scale invariance. This property states that a same pattern (a geometric pattern, for example) is observed in different magnifications. The simplest example is the case of a line. If one picks a line of length L and split this line in N identical smaller segments, then each of them is scaled by a ratio $1/N$ with respect to the original line. The same can be made, for example, with a square with area L^2 splitting it in N identical squares that has a scale ratio of $1/N^{1/2}$ with respect to the original size. So, this is the scale ratio that governs the called scale-invariance, since we have identical line segments and identical squares that differs from the original only by a scale ratio.

But, as defined above, this ratio depends on the geometrical dimension of the pattern. An important parameter for quantifying a fractal pattern's visual complexity is the fractal dimension, D. This parameter describes how the patterns occurring at different magnifications combine to build the resulting fractal shape. For Euclidean shapes, dimension is described by familiar integer values - for a smooth line (containing no fractal structure) D has a value of one, whilst for a completely filled area (again containing no fractal structure) its value is two. For the repeating patterns of a fractal line, D lies between one and two and, as the complexity and richness of the repeating structure increases, its value moves closer to two [11]. For fractals described by a low D value, the patterns observed at different magnifications repeat in a way that builds a very smooth, sparse shape. However, for fractals with a D value closer to two, the repeating patterns build a shape full of intricate, detailed structure.

The number of patterns, N, one can find in a fractal structure of size L, is a mathematical function of D:

$$N(L,D) = L^{-D} \, (1) \tag{1}$$

In the nature, however, patterns are not always identical rather than similes in terms of structure and topology. So, D can be considered a statistic that describe this scale-invariance, or as some authors argue a self-similarity. These pattern repetitions in different scales can be modeled stochastically using the so called Power-law distribution, which describes the probability and consequently the expected number of patterns of size L.

Many other processes in nature are also modeled nowadays as network systems. Metabolic chains and food web, are just few examples of natural phenomena that are explained as complex network systems. The same applies for social processes too, like scientific collaboration, sexual contacts and social relations.

In terms of network modeling evolution, the first model based topology defined is the Random Network, by Erdös and Rènyi in 1960 [12]. Networks that follow this topology evolve as a set of actors that build social ties randomly. For this reason, at first the actors are connected to a small number of other actors. This can be explained because when an actor is chosen randomly and a tie is established with another actor, the likelihood is that this new tie connects the actor with a low number of others, even if the actor already has some connections.

However, when there is a certain quantity of ties so that the mean degree is one, the fraction of the graph occupied by the largest group of the network suffers a phase shift. It means that the largest group, which was not significantly large before, now occupies almost the whole graph area. This organisation is used to explain several phenomena in nature, where small sets join together to build groups of a higher dimension, gathering every actor until the ties are built [13], [14].

In 2000 Barabási [15] and his team defined a new model for network topology, called *Scale-Free* networks. The authors realised that the degree of distribution does not follow the Poisson or Gaussian distribution, commonly used to model random graphs, but a Power-law distribution instead. The Power-law distribution is differentiated by its format; the maximum point is not found in the average value, the curve starts at its maximum point and decreases towards infinity. There is an exponent that can be calculated in this distribution that shows how the distribution changes along with a variable.

A function that follows a power law distribution can be described by

$$p_k \sim Ck^{\alpha} \tag{2}$$

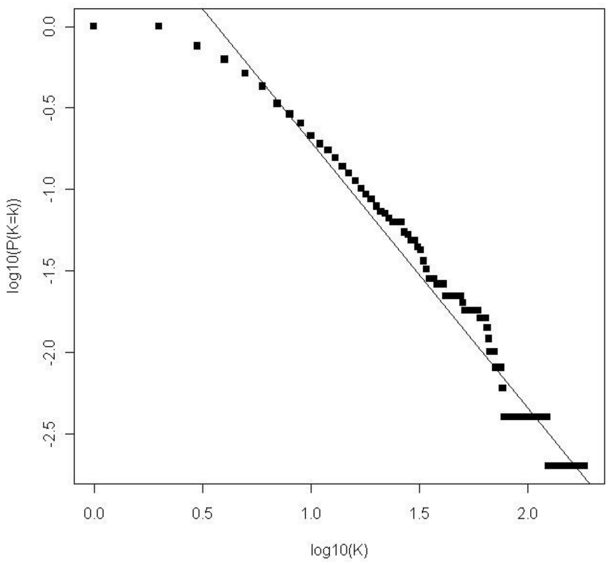
k is the degree, p_k is the probability of actors containing degree of value k, as defined in (1) and α is the function exponent. Another way to represent the Power-law distribution uses the Cumulative Degree Distribution, defined in (2),

$$P_k \sim Ck^{-(\alpha - 1)} \tag{3}$$

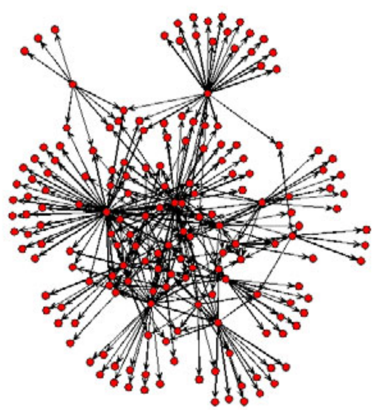
So, to assess scale-freeness in a network, usually the fit of the degree distribution to a Power-law is investigated. The simplest way to do this is taking the logarithm of P_k and k and analyse the scattering of the points. A straight line is expected if the distribution approximately obeys a power law, as shown in Figure 1a). The slope of this line is then used to estimate α, since $\log(P_k) = \log(C) - (\alpha - 1)\log(k)$.

This topology also presents a few nodes with a high quantity of ties, called *hubs*. Then, the majority of the actors have a lower number of social ties and a few (*hubs*) have a higher number of ties. Those networks are more tolerant to failure and node removal. As most nodes have a few connections, the probability of removing one of them is higher than a hub, and they do not impact significantly on the network structure. However, a coordinated node removal focusing the hubs can completely break the network structure.

The scale-free network evolution obeys a process called *Preferential Attachment*, a.k.a. *Rich Gets Richer* effect, such that new nodes have a higher probability of connecting to the older nodes with a high degree. Then, the older nodes have more chances to become hubs, but new nodes may also become hubs depending on its



a)



b)

Fig. 1. a) Cummulative distribution following a power-law havig *α=1.98*, and b) the topology of the respective network

connectivity factor. This process usually leads to a hierarchical structure, where clusters are formed replicating the structure of predecessors, providing a topology like Figure 1b).

From the concepts introduced herein, it is straightforward the analogy of the Scale- free network and fractals. The number of degrees K is the analogue of L, and α parameter describes the degree distribution of Scale-free networks as the D describes the complexity of fractal patterns, so properties of two seemingly different models for different purposes are shared. It can even be said that Scale-free networks are stochastic fractals, if one consider the property of self-similarity described by a probability law, the Power-law distribution in this case.

4 The Role of Stochastic Fractals in Complex Interface

From the perception, discrimination and visual viewpoint, many studies have described the influence of fractal dimension in these psychophysical dimensions. [16]-[17] have shown high correlation between D and the pattern's perceived roughness and complexity, other studies found that discrimination of fractal curves by observers was maximal with dimensions closer to the terrain surfaces fractal models, suggesting that sensitivity of visual systems might be tuned to statistical distribution of environmental fractal frequency (ref). The aesthetic appeal is also closely related to the fractal dimensions. A seminal study conducted by Sprott [18], it was found that the figures considered the most aesthetically appealing had dimensions between 1.1 and 1.5, and the most aesthetically pleasing had D = 1.3. All these studies used experiments with volunteer observers and images, in general, generated by computers or models for real natural structures, like shore coasts and terrains. However, Spehara et al. (2003) [19] performed experiments using paintings by the American artist Jackson Pollock, presenting different parts of masterpieces. This study has showed that for the called Human Fractal the higher preferences for images presented D=1.5 in average.

In the development of a innovative user interface, those experiments supports the idea that a fractal structure might bring further motivation for users, but this is not the only feature that should be evaluated, neither the only quality that can bring advantages in the use of scale-invariance property.

In network research, it is well known that many collaborative processes follows power-law distribution for their degree distribution, and even for clustering coefficients, given the preferential attachment mechanism of evolution. Further, the α in these kinds of networks range from 1.2 to 1.8 [20], a range close to the fractal dimensions observed in the perception studies. If this intended interface should be the environment of a collaborative space, or an OKS, we should expect that collaboration among researchers, and even the semantic network among content tags, will also follow this model. If so, the aesthetic aspect is well done, at least technically. But the properties of a scale-free network can also provide some advantages:

- Order in chaos: the scale-free model is analytically defined and its evolution can be predicted, helping in the mechanism of visualization, since the topology is already known;

- For the same reason, scalability of contents to be shown in this interface can be adequate, allowing a navigation not only in a flat space, but allowing to explore the depth of the network, obeying the hierarchical scale originated by the network evolution;
- As a probability law, new links between researchers that might have a great potential for collaboration can be suggested, since they share any common interest in contents.

These are some prior hypothetical features that can be explored. The next topic presents a use case that will be the first experience in data collection for the development of this complex interface.

5 Use Case: Guigoh and the Social Technology Network

The first use case that will provide a framework to develop the interface model, is the Social Technology Network - RTS. Social Technologies are considered products, techniques and methodologies that are replicable and developed in interaction with local communities and that represent effective solutions for social transformation. With the aim of stimulating the sharing of Social Technologies between people and institutions in Brazil RTS was created in 2005 and now is being also adopted as a knowledge network by other Latin America countries.

RTS is sponsored by several Brazilian partners, mainly by the public sector as the Brazilian Ministry for Science and Technology. RTS unites nowadays more than 680 members, from which a few are networks themselves. They work with solutions in terms of social technologies considering twenty themes, such as water, energy, among others. The goals of RTS include stimulating the adoption of social technologies as public policies, enhancing the appropriation of social technologies by the communities and encouraging the development of new social technologies.

The adoption of Guigoh OKS by RTS intends to amplify the possibilities of sharing and searching of solutions by stimulating the members to publish their technologies in multimedia formats and by reinforcing the sense of knowledge community between them. Besides RTS also aims to enrich the existent social technologies by motivating the sharing of experiences from the application and contextualization of technologies.

RTS knowledge community runs over Guigoh platform with few modifications. Beyond all tools from Guigoh, RTS is implemented with a customized interface and concepts. The main aspect of the customization was giving more relevance to the Social Technologies as well as to RTS themes, as the Social Technologies are directly referred to them. As mentioned before RTS works with solutions in twenty different themes and when users want to publish a new Social Technology they have to relate it to one of those themes. When publishing a Social Technology users have to fill a form with details about their solution and each Technology has a specific web page. Similarly, when users want to retrieve any Social Technology they can easier do it by firstly defining which theme the technology is related to. Next it will be detailed some of the customized interfaces of RTS.

Using the data from the social networks, document collaboration, and content upload, we expect to have enough subside to develop and test the complex interface purpose.

6 Concluding Remarks

In the case of a complex interface design the scale invariance property will be applied in the development of a new paradigm of interface, using the fractal metaphor, once that the way which someone will navigate is a certain level of aggregation of information will not change if this one goes deeper in the content. Also, the Power- law probability distribution, followed by this type of network for connections, clustering among other network characteristics, can be used to forecast and suggest future connections for the user. Complex systems modelled by network models is a brand new area in science, so that the applications and development reached in this project will be a milestone in this research field, bringing a different way to associate art, human-computer interaction and knowledge management.

So, the interface design as understood at the OPAALS´ project take in account both the human visual information processing and the more abstract cognitive information management.

References

1. Piazzalunga, R.: A Virtualização da Arquitetura. Papirus, São Paulo (2005)
2. Merleau-Ponty, M.: Fenomenologia da Percepção. Martins Fontes, São Paulo (1999)
3. Begout, B.: Un air de famille. La Phénoménologie: une philosophie pour notre monde. Magazine Literature (403), 20–22 (2001)
4. Husserl, E.: Logical Investigations. Routledge, London (2001)
5. Brentano, F.: Psychology from an Empirical Standpoint. Routledge, London (1995)
6. Abbagnano, N.: História da Filosofia, vol. XIV, p. 93. Editorial Presença, Lisboa (1993)
7. Idem, ibidem, p. 93
8. Dreyfus, H.L.: The Current Relevance of Merleau-Ponty's Phenomenology of Embodiment (1996), `http://hci.stanford.edu/cs378/reading/dreyfusembodiment.htm`
9. Merleau-Ponty, M.: Fenomenologia da Percepção. Martins Fontes, São Paulo, p.192 (1999)
10. Taylor, R.: Personal reflections on Jackson Pollock´s fractal paintings. Hist. ciênc. saúde-Manguinhos 13(suppl.), 109–123 (Out 2006)
11. Mandelbrot, B.B.: The fractal geometry of nature. Freeman, New York (1977)
12. Erdös, P., Rényi, A.: The ő Evolution of Random Graphs. Magyar Tud. Akad. Mat. Kutató Int. Közl 5, 17–61 (1960)
13. Watts, D.J.: Six Degrees: The Science of a Conected Age. Norton & Company, Inc., New York (2002)
14. Barabási, A.-L., Albert, R.: Emergence of scaling in random networks. Science 286, 509–512 (1999)
15. Barabási, A.L.: Linked. Plume, Cambridge (2003)
16. Cutting, J.E., Garvin, J.J.: Fractal curves and complexity. Perception & Psychophysics 42, 365–370 (1987)

17. Knill, D.C., Field, D., Kersten, D.: Human discrimination of fractal images. Journal of the Optical Society of America 77, 1113–1123 (1990)
18. Sprott, J.C.: Automatic generation of strange attractors. Computer & Graphics 17, 325–332 (1993)
19. Spehara, B., Cliffordb, C.W.G., Newellc, B.R., Taylord, R.P.: Universal aesthetic of fractals. Computers & Graphics 27, 813–820 (2003)
20. Barabási, A.L., Jeong, H., Neda, Z., Ravasz, E., Schubert, A., Vicsek, T.: Evolution of the social network of scientific collaborations. Physica A 311, 590–614 (2002)