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**Prediction and Prescription in the Science of the Artificial:
Information Science and Complexity.**

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Information science and *computer sciences* are two realms of the sciences of the artificial that are faced with new forms of complexity¹. From the point of view of the content, there are new and increasingly more complex informative needs that are being demanded with a growing intensity. From the perspective of agents, there are new forms of interactions between the individuals and the information systems². This relation between users and information brings about new organizations that are strengthened through new advances in technology³. Therefore there are inner and outer factors related to the new forms of complexity.

To face those inner and outer aspects, *information science* and *computer sciences* have to work jointly to bring forward a possible future (prediction) and to give new action guidelines that allow us to solve posed problems (prescription). Here the dynamic aspects of informative systems are highlighted and whose complexity is the topic of this paper. There are three factors that take part in a special way: information, systems for the

¹ In the case of *computer sciences* three aspects take part: the development of cognitive models, artificial intelligence and theory of computation. Cf. THAGARD, P. “Computing in the Philosophy of Science”, in FLORIDI, L. (ed), *Philosophy of Computing and Information*, Blackwell, Oxford, 2004, pp. 307-308.

² Together with information management, time and the attention that people devote to search relevant information have an influence on decision making. Cf. SIMON, H. A., “The Future of Information Systems”, *Annals of Operations Research*, n. 71, (1997), p. 5.

³ It has to be considered that the selection of technologies in project design has strong consequences for later stages of design. About this issue, cf. BERGMAN, M. and MARK, G., “Technology Choice as a First Step in Design: The Interplay of Procedural and Sensemaking Processes”, *Proceedings of the Conference on Designing Interactive Systems*, v. 6, (2002), pp. 224-234.

processes, and users. These three factors are opened to the future, have a close relation between them, and have an applied side.

Information is a dynamic matter from the perspective of its constitution: in its origin, in its development and in its results (that have a feedback effect). First of all, the success of the systems that carry out informative processes depends on the capacity to process information, and secondly, on the active relation with the user (as individuals, a group or an organization). The demand of new forms of information⁴, that has to lead to obtain genuine “knowledge”, are related to human historicity: a human being can be submitted to continuous changes in his circumstances, needs and interactions.

Therefore, it can be said that initially *information science* has a double relation to complexity, at least⁵. On the one hand, from the point of view of the content, it has to face knowledge management to reduce the uncertainties in decision making, both in the theoretical field and in the practical sphere. On the other hand, it has to face up to the interaction with users. This outer aspect means the design of new products that deal with the needs of agents.

Those two aspects –the inner and the outer- are a field of the *information science* as sciences of design⁶. These need the contribution of other disciplines related to cognitive contents (like philosophy or psychology) or related to the nets of social links (sociology or anthropology). Therefore, *information science* studies complex problems to attend to cognitive demands but it is open to interdisciplinary teams⁷.

⁴ At the beginning, scientific advances were aimed to the design focused on information management. Then, to a certain extent, they got to overcome the problem of lack of information. Nevertheless, once that phase was overcome, the problem has precisely become to avoid the excess of information. Irrelevant information is not only useless but it can interfere negatively in decision making processes.

⁵ *Information science* can be approached from two points of view: a) in a broad sense, and b) in a narrow meaning. In the first approach, information science covers the whole of disciplines related to archives, libraries and documentation centres. In the second option, this science deals specifically with informative processes: creation, acquisition, organization, evaluation, storing, transmission, retrieval and spreading of information. Cf. BEREIJO, A., “Caracteres de la predicción en las Ciencias de la Documentación: de la *Information Science* al Análisis Documental”, in GONZALEZ, W. J. (ed.), *Las Ciencias de Diseño. Racionalidad limitada, predicción y prescripción*, Netbiblo, A Coruña, 2007, p. 217. This second aspect highlights the service to users and it is the one that focuses the present paper.

⁶ Sciences of design are a subgroup of the sciences of the artificial. They share the notion of a “model” with the natural sciences and the social sciences: all of them accept that a model can be a “representation” or “resemblance” of the real. Nevertheless, aims, processes and results in the sciences of design are different from the other empirical sciences. This is because they do research on objects with a different ontological nature, which are artificial in this case. Cf. GONZALEZ, W. J., “Configuración de las Ciencias de Diseño como Ciencias de lo Artificial: Papel de la Inteligencia Artificial y de la racionalidad limitada”, in GONZALEZ, W. J. (ed.), *Las Ciencias de Diseño. Racionalidad limitada, predicción y prescripción*, p. 45.

⁷ Globally distributed teams need to have a structure that allows their members to share norms, attitudes and behaviours to reach a common goal. A proposal of some guidelines concerning socialization in GDTs can be seen in OSHRI, I, KOTLARSKY, J, and WILLCOCKS, L. P., “Global Software Development: Exploring Socialization and Face-to-Face Meetings in Distributed Strategic Projects”, *Journal of Strategic Information Systems*, v. 16, (2007), pp. 25-49.

1. Complexity in Dynamical Systems

In my opinion, we can recognize and distinguish three types of complexity in informative systems: a) complexity about information itself (*information science* deals with this specifically); b) complexity about the design of informative systems (*computer sciences* has a main role in this matter); and c) complexity about the feedback that comes from the interaction between the user and the informative systems. In this third aspect, disciplines that are about visual design, usability and accessibility have a fundamental task.

Information science and *computer sciences* deal with an inner aspect. These disciplines develop mechanisms to analyze, represent, store, process, retrieve and manage informative contents into a system. However, there is an outer aspect as well. If the information the user is searching for has no answer or does not have a proper answer, the system is said “not to represent properly” the aim for which it has been designed. The sciences of design that deal with this matter are aimed to improve these questions through research.

In relation to the dynamics of a system and the complexity, it can be said that there are two main aspects: i) how systems can spontaneously self-organize when they are in a state far from equilibrium and there is no external strength that acts on the system; and ii) how systems self-organize to give an answer to the action of the outer environment. Dealing with the first of these questions *science of complexity* propounds to consider those systems as a continuous tension between *competition* and *cooperation*⁸. Competition itself is not enough to successfully guide complex systems. Besides, cooperation between different elements can cause fundamental changes in their dynamics⁹.

1.1. Understanding the complexity of a system

Understanding the complexity of a system involves getting to know how that system is organized. This means paying attention to both the internal elements and its relation to the environment. In this sense, the theory of organizations is useful to understand the complexity of systems such as those related to information and its retrieval. Herbert Simon made important contributions to characterize complexity in different systems. For

⁸ This topic is developed in AXELROD, R., *The Complexity of Co-operation. Agent-Based Models of Competition and Collaboration*, Princeton University Press, Princeton, NJ, 1997.

⁹ Cf. BERTUGLIA, C. S. y VAIO, F., *Nonlinearity, Chaos and Complexity*, p. 6.

him, complexity used to have a structure that has to be understood in terms of the relations that are established among their different components¹⁰.

Simon understands complexity of the systems in terms of organization. He uses the concept of “hierarchy” to deal with systems. His definition of hierarchy is “a system that is composed of interrelated subsystems, each of the latter being in turn hierarchic in structure until we reach some lowest level of elementary subsystems”¹¹. He uses this term to refer to every complex system that is analyzable from consecutive sets of subsystems. Formal hierarchy is about the more specialized systems (firms, governments, universities...) ¹².

From there, Simon considers that a *dynamic system* can be described in terms of a quasi-decomposable set. In this case, the fast evolution of any complex system consists of “a set of stable subsystems, each operating nearly independently of the detailed processes going on within the other subsystems, hence influenced mainly by the net inputs and outputs of the other subsystems. If the near-decomposability condition is met, the efficiency of one component (hence its contribution to the organism’s fitness) does not depend on the detailed structure of other components”¹³.

His approach can be summarized in two main elements. First of all, when a system is quasi-decomposable the short term behaviour of each of its subsystems is practically independent from the behaviour of the other components in the short term. Secondly, the behaviour of each of the components of the systems depends only in an aggregate way on the behaviour of the others. This does not mean that dealing with the components of a system in an independent way involves simplicity. The proposal is different: parsimonious factors are necessary to make a correct description of the system possible¹⁴.

¹⁰ Simon was interested in the procedure to increase information into organizations, but besides he was interested in the matter of how to have organizations more and more adapted to a more and more increasingly complex World. Cf. SIMON, H. A., “Designing Organizations for an Information-rich World”, in GREENBERGER, M. (ed), *Computers, Communications, and the Public Interest*, The Johns Hopkins Press, Baltimore, MD, 1971, pp. 37-72. Compiled in SIMON, H. A., *Models of Bounded Rationality. Vol. 2: Behavioral Economics and Business Organization*, The MIT Press, Cambridge, MA, 1982, pp. 171-185. Some of his contributions about this topic are analyzed in AUGIER, M. and MARCH, J. G. (eds), *Models of a man. Essays in Memory of Herbert A. Simon*, The MIT Press, Cambridge, MA, 2004.

¹¹ SIMON, H. A., *The Sciences of the Artificial*, 3rd ed., The MIT Press, Cambridge MA, 1996, p. 184.

¹² The main contributions of Herbert A. Simon to the topic of organizations in relation to their inner structure and the relation to the environment can be found in SIMON, H. A., *Administrative Behavior*, Macmillan, N. York, 1947, and in MARCH, J. G. y SIMON, H. A., *Organizations*, J. Wiley, N. York, 1958. Some interesting analysis about Simon’s contributions on decomposability and hierarchy can be found in part VI of EARL, P. (ed), *The legacy of Herbert Simon in Economic Analysis. Vol. I*, Edward Elgar, Cheltenham, 2001, pp. 485-548.

¹³ SIMON, H. A., *The Sciences of the Artificial*, p. 198.

¹⁴ This conception is developed in detail in SIMON, H. A., “Science Seeks Parsimony, not Simplicity: Searching for Pattern in Phenomena”, en ZELLNER, A., KEUZERKAMP, H. A. and MCALEER, M. (eds), *Simplicity, Inference and Modelling. Keeping it Sophisticatedly Simple*, Cambridge University Press,

1.2. Interaction in the System

Order and disorder have been traditionally considered opposites in regards to the configuration of systems. Order is related to systems that are open to classification, to interactions that are analyzable into a discourse of rationality. Disorder is connected to the difficulty of being expressed through clear concepts of modern science, except as a limited form of statistical generalization. To deal with the interaction into the systems, science of complexity has developed a radical re-conceptualization of the relation between order and disorder. In this sense, “chaos” is now conceptualized as extremely complex information, instead of being presented as an absence of order¹⁵. Complexity can be said to be a property of the systems and their models that are in the middle of stability and chaos¹⁶.

On the one hand, there are “stable systems”. Predicting their behaviour is possible as far as the changes in the system are easy to control. On the other hand, there are “chaotic systems” where scientific prediction is highly problematic. However, in the middle, there are transitional states between order and disorder that move searching for their own equilibrium. That is the response to the interaction among their components and their response to external actions.

Almost every system consists of numerous elements. Among them are reciprocal and non-linear interactions and *feedback* mechanisms as well. This can be seen in a wide range of scientific fields. It is precisely in this field of interaction where hypertext comes up as a form of representation and transmission of information. Hypertext documents were designed in such a way that the person who is going to read them is able to move into a document in a non-linear way or even to move from one document to another through links. In hypertext, transitions are connected to the mental task of associating ideas¹⁷.

Cambridge, 2001, pp. 32-72. [Spanish version by Pablo Vara and Wenceslao J. Gonzalez: “La Ciencia busca sobriedad, no simplicidad: La búsqueda de pautas en los fenómenos”, in GONZALEZ, W. J. (ed), *Las Ciencias de Diseño: Racionalidad limitada, predicción y prescripción*, Netbiblo, A Coruña, 2007, pp. 71-107.]

¹⁵ Cf. CHIA, R., “From Complexity Science to Complex Thinking: Organization as Simple Location”, *Organization*, (1998), v. 5, n. 3, pp. 341-369. Compiled in MACINTOSH, R., MACLEAN, D., STACEY, R. and GRIFFIN, D., *Complexity and Organization. Readings and Conversations*, Routledge, London, 2006, p. 211

¹⁶ Cf. BERTUGLIA, C. S. and VAIO, F., *Nonlinearity, Chaos and Complexity*, Oxford University Press, Oxford, 2005, p. viii.

¹⁷ The origin for the future design of hypertext system known as World Wide Web was conceived by Vannervar Bush in 1945. He conceived a mechanism where someone could store all his/her books, records and communications and, from there, he/she could access to consult the information in a non-linear way. This mechanism, called Memex, was never developed but it was the inspiration so as to Ted Nelson, and later Tim Berners Lee –in 1989- invent hypertext and Internet.

Science of complexity usually adopts an overall view of the systems. It considers the intricate relation between the systems and their elements. It understands the situation in a holistic sense: each system has to be considered as a whole. The idea is to overcome the point of view of classical mechanics¹⁸. One of the main questions about this approach is precisely its rejection of the stand that considers sets to be reducible to the sum of their parts¹⁹.

Information systems are usually considered to be non-linear systems. Therefore, interaction among their several elements has relations that are mainly multiplicative instead of being simply additive ones. Besides, most of systems in the real world in which human beings are involved do not work in a linear way. They are extremely sensitive to initial conditions and the re-entry of data gives rise to very different results. In this kind of system, "interaction" is a key matter because the relation between two variables can be modified by the value of a third²⁰. This is applied to causality in the social realm: there are numerous causes that usually interact in a non additive way²¹.

2. Difficulties for Prediction in the Design of Interactive Systems

As a sphere related to the sciences of design it is necessary to think about how to create the scientific design. This requires the contribution of knowledge at three different levels: a) in regards to the searched aims, b) about the selection of the most suitable processes, and c) in connection with the criteria to be applied in the assessment of the results²². Every one of the several scientific aspects has a separate development, even though there is a close relation. This gives rise to some shared tasks.

Both the design of the technological instruments and the design of systems to process information draw the limits of what is possible to reach. In this sense, prediction is possible to a certain level. Nevertheless, this design has an implicit feedback process about the use of the systems: how it is used, what information is more relevant or what

¹⁸ Classical mechanics considers three fundamental characteristics in systems: 1) it is reductionist in the sense that it breaks down the systems into simple elements to analyze it; 2) the models that it provides are reversible in time and space; and 3) it is deterministic, because it uses equations with unique solutions dependent on the initial states and on the values of the parameters that describe the system's state. Cf. BERTUGLIA, C. S. and VAIO, F., *Nonlinearity, Chaos and Complexity*, p. 19.

¹⁹ Cf. BYRNE, D., *Complexity Theory and the Social Sciences. An Introduction*, Routledge, London, 1998, p. 7.

²⁰ Cf. *Complexity Theory and the Social Sciences. An Introduction*, p. 19.

²¹ About causality there is a joint paper by Herbert A. Simon and Nicholas Rescher: SIMON, H. A. and RESCHER, N., "Cause and Counterfactual", *Philosophy of Science*, v. 33, (1966), pp. 323-340. Compiled in SIMON, H. A., *Models of Discovery*, Reidel, Boston, 1977, pp. 107-134.

²² Cf. GONALEZ, W. J. "Análisis de las Ciencias de Diseño desde la racionalidad limitada, la predicción y la prescripción", in GONALEZ, W. J. (ed), *Las Ciencias de Diseño. Racionalidad limitada, predicción y prescripción*, pp. 5-6

informative contents are irrelevant. Evolution in the design has to deal with some uncertainties, especially in those tasks related to the interaction user-based system because they are more difficult to predict.

The evolution of the system through time has a particular interest; which is its dynamic. That interest is “justified by the fact that when, on the basis of acquired experience, we succeed in identifying typical reoccurrences in its behaviour, we can then attempt to make predictions about the future behaviour of said system. Obviously we can only do this by assuming that what has occurred in the past will be repeated in the future, an assumption that is often not justified by experience and is sometimes completely arbitrary”²³.

Two different possibilities about prediction can be distinguished depending on the realm where the emphasis is placed: the dynamic of the “inner” or the dynamic of the “outer”. The first one is about how to improve the composition of the systems and the way in which they work (for instance, if it is possible to get a semantic web with the means we have and how). The second one deals with the relation to the environment: prediction about the behaviour of users when they use the systems (for instance how to anticipate the future consequences of social networks).

Information science can make progress towards new goals thanks to the knowledge about future events provided by prediction. Prediction contributes to establishing the aims that are possible to reach then the most convenient ones have to be established. Therefore, prediction in Information Science has a key role to solve specific problems; it serves as a basis for prescription to decide what to do²⁴.

2.1. Kinds of Uncertainty

Information science moves in a social environment whose future has to consider prediction and, as far as possible, has to channel prescription. There, uncertainty, which is an inherent feature of modern society -an opened society- appears. Uncertainty not only has its origin in the absence of information or the lack of knowledge –the “inner” elements of the system- but also it appears because of the strategic and institutional features of the networks that articulate and process problems.

²³ *Nonlinearity, Chaos and Complexity*, Oxford University Press, Oxford, 2005, p. 4.

²⁴ While systems can help to recover from problems, they can also cause problems if they make mistakes about specification, design or implementation. Besides, human users may fail to operate the system correctly. As these failures can be interrelated, it is important that designers take a holistic perspective to solve them better than focus on a single aspect of the systems. Cf. SOMMERVILLE, I., *Software Engineering*, p. 45.

Several different kinds of uncertainty can be distinguished: a) the substantive, b) the strategic, and c) the institutional²⁵. *Substantive uncertainty* refers to the availability of information when we have to face problems of complex entity. This uncertainty is not only related to the question of whether it is possible to have access to information (or, knowledge if that is the case). It happens that “since actors have different perceptions of problems and view them from different frames of reference, they also interpret the available information differently”. As a result, “the different interpretation of the meaning of information is an additional source of substantive uncertainty. More information, therefore, does not necessarily lead to less uncertainty; in fact, it might lead to more uncertainty”²⁶.

Strategic uncertainty appears when cognitive insecurity is amid the interaction among users, those that need information to make decisions. Information users have to respond to the strategic actions of other agents, and to do this they need to anticipate their behaviours. Those mechanisms where several agents take part may make it difficult to predict the results of their interactions. This generates uncertainty to deal with the problem and the process of resolution.

There is *institutional uncertainty* in the sense that informative systems are part of an organized social environment. Therefore, together with the individual factors in the agents (different aims, interests and perceptions of the users about the information) there are some contextual factors: different kind of organizations, social networks and administrative stratifications (local, regional, national). “Interaction between actors is difficult since each will have their behaviour guided by the tasks, opinions, rules and language of their organization, their own administrative level and their own network”²⁷.

Information science works jointly with *computer sciences* and information and communication technologies (ICT) to face these questions about uncertainty. With their help, *information science* has to deal with the following issues: i) the lack of information, ii) the interpretation of information, iii) the excess of information, iv) the needs and desires of users, v) the interaction among different kinds of users, vi) the link with the cultural and organizational environment that surrounds them, and vii) the knowledge users have about the computational systems they are using.

²⁵ Cf. KOPPENJAN, J. and KLIJN, E. H., *Managing Uncertainties in Networks. A Network Approach to Problem Solving and Decision Making*, p. 6-7.

²⁶ *Managing Uncertainties in Networks. A Network Approach to Problem Solving and Decision Making*, p. 6.

²⁷ KOPPENJAN, J. and KLIJN, E. H., *Managing Uncertainties in Networks*, p. 7.

Dealing with these questions requires the consideration of the role of prediction. The sciences of the artificial –*information science* and *computer sciences*- are configured as applied sciences aimed to solve specific problems²⁸. Therefore, these sciences of design use predictive models as an instrument to analyze the behaviour of large complex systems. This means that they have to be able to predict future events and contribute to examine the possible effects of public decisions (among them, the political ones)²⁹.

2.2. Scientific Design and the Management of Uncertainty Problems

To deal with uncertainties of the first kind –the substantive ones that are about the components of the systems and their processes— prediction can be said to be easier. The higher simplicity in this case is due to the better knowledge about the involved variables that are mostly designed, so at first, their behaviour is known. The observation of the results from their work will help to improve their development (for instance, new languages or structures to tag digital documents; new strategies to improve web positioning, to advance towards a semantic indexing or new crawlers for information retrieval).

Nevertheless, when we are dealing with uncertainty where users take part, other variables come into play. These have a much more dynamic behaviour. In this sense, they are much more difficult to predict than the previous ones, as it can be seen from the analysis of the features in complex social systems. In my opinion, prediction about social interaction in the use of informative systems has a feature that makes it different from prediction in other Social Sciences.

The difference is in the close relation between the “inner” and the “outer”. Indeed, there are ways into the systems to collect, record and analyze data about the users’ behaviour. This is carried out by means of a continuous feedback process. Therefore, while a person is interacting with the system, the system has been designed to try to know their intentions, interests, cultural level, and economic level. New research developments are working to analyze user feelings (sadness, happiness...) so that they can find a way to modify those feelings while the user is interacting with the system.

When we talk about *institutional uncertainty*, because informative systems are part of an organized social environment, there is a problem related to prediction and another

²⁸ Sciences of design –as sciences of the artificial- are applied sciences in the sense that they are aimed to goals and they search to solve specific problems. About this issue see NIINILUOTO, I., “The Aim and Structure of Applied Research”, *Erkenntnis*, v. 38, (1993), pp. 1-21.

²⁹ Cf. SIMON, H. A., “Prediction and Prescription in Systems Modelling”, *Operations Research*, v. 38, n. 1, (1990), p. 7.

problem regarding prescription. The problem of prediction regards the information in the future and how to share it. This influences the design of aims, and affects the processes and the subsequent evaluation of the results. In this sense, the creation of international organizations into specific realms is more and more frequent in order to work jointly in the development of predictions.

The problem of prescription in institutional uncertainty can be said to create more difficulties than prediction. The exchange of information among diverse types of organizations causes an increase of situations where decision making has to be shared. The difficulty rests on the capacity to reach agreements about criteria to enable the interaction among organizations belonging to diverse environments³⁰. A common starting point, similar processes, and the evaluation of the results from similar criteria are necessary in order to obtain authentic prescriptions.

Therefore, scientific design has to deal with several different types of uncertainty: substantive, strategic and institutional. Prediction needs to contribute so that the design can be redefined into a more suitable model. In this sense, the web allows an empirical methodology that enables it to analyze itself in real time. In this way, it can check if scientific aims are reached properly, and if this is not the case, it allows it to know where improvements need to be made. We really are not able to predict some consequences in the use of systems; but since a system is the product of a design, we can act so that some things happen and others do not. This is the role of prescription.

3. The Need for Prescription in an Informative Environment.

An information system is an opened space. There every person and every organization has a place to interact with each other. This is a basic question in designing the role of prescriptions in this field and if some aspects of predictability have been mentioned previously, several levels of prescription can be considered here too. The main ones are: the “inner” level, related to tasks about representation, storing, processing and information retrieval; and the “outer” sphere regarding the interaction user-system.

3.1. Prescription in the “Inner” Level

In relation to prescriptions in the “inner” level, we need to emphasize that *information science* —the same as *computer sciences*— has a statute of “science of design”. As an applied science it has a prescriptive side, therefore it develops patterns, standards and

³⁰ Within the realm of *information science*, an example would be IFLA (International Federation of Library Associations and Institutions).

rules that are established as operative instruments to achieve goals. Prescriptions made in the realm of this discipline do not transform reality. The practical knowledge that deals with problems concerning information does not modify or alter its own reality it works with—it indexes, summarizes, classifies, etc.— but it does not alter its own entity in any way. Its aims, processes and results are genuinely artificial³¹.

It can be said that *information science* has prescriptions in the three aspects of aims, processes and results that are characteristic of an applied science of design. This has multiple possibilities: i) there can be specific prescriptions aimed to guide the transfer of information, both formal and informal, ii) it is possible to model prescriptions regarding how information needs are generated into the society, iii) prescriptions can be made to improve both systems and the quality of information by means of developing the proper methods; iv) it is a convenient way for development of standards to improve the knowledge coming from any kind of document, in such a way that the methods for analyzing and representing systems of information can be increased; and v) it can be given rules to increase the relevance of information sources³².

Prescriptive rules and guides have a key role in making it possible to share information. Nevertheless, these cannot be imposed easily in professional practice due to several factors. To mention a few: a) information science has its origin in the scientification of a professional practice with a very deep rooted practicing³³; b) there is such a fast dynamic in the changes in scientific developments that organizations have hardly any time to assume new patterns; c) economic factors here are very deeply involved so they appear inserted into their own scientific research³⁴; and d) scientific developments to manage information are shared both by formal and informal organizations into the same space.

3.2. The “Outer” Sphere of Prescriptions

The “outer” sphere is together with the “inner”. This aspect involves dealing with the matter of prescription related to the interaction user-system and the interaction among

³¹ Cf. BEREJO, A., “Caracteres de la predicción en las Ciencias de la Documentación: de la *Information Science* al Análisis Documental”, in GONZALEZ, W. J. (ed), *Las Ciencias de Diseño. Racionalidad limitada, predicción y prescripción*, pp. 272-273.

³² Cf. INGWERSEN, P. and JÄRVELIN, K., *The Turn: Integration of Information Seeking and Retrieval in Context*, Springer Verlag, Dordrecht, 2005, p. 389.

³³ About this matter, see NIINILUOTO, I., “The Aim and Structure of Applied Research”, *Erkenntnis*, v. 38, (1993), pp. 1-21.

³⁴ About economic aspects in science see GONZÁLEZ, W. J., “Economic Values in the Configuration of Science”, in AGAZZI, E., ECHEVERRÍA, J. and GÓMEZ, A. (eds), *Epistemology and the Social*, Poznan Studies in the Philosophy of the Sciences and the Humanities, Rodopi, Amsterdam, 2008, pp. 85-112.

users. As an informative system is a dynamic complex system “application and interpretation of rules can generate shifts and changes in the sets of network rules. Furthermore, rules can be consciously broken. The fact that rules must be followed means, after all, that they are considered acceptable by the actors in the network”³⁵. In spite of this, both prescriptions –in general and norms in particular- guarantee certain stability in the behaviour of users and so reduce the uncertainty.

The interface between users and the information systems are being improved continually to achieve global communication³⁶. Studies about usability are having an increasing relevance in the development of information systems. The information that the users need not only has to be accessible but also has to be useful to their purposes. Together with rational contents, this communication involves intuition, feelings and emotions, which are aspects involved in the way the systems are used.

Making models of users is related to try to describe which of the user interests should influence the computational means. In this matter, research in Psychology shows that users are not usually wholly aware of what exactly are their desires, even in tasks aimed to get a specific goal³⁷. Therefore, prescription here works considering some standards of behaviour, more or less well defined, to guide users in their searches through the system (giving advice, showing alternatives, providing with information about the utilities of the system, etc.).

To deal with the matter of interaction among heterogeneous sets of users of the web (with their different needs of information) I consider turning to the theory of organizations. Organization is the basic structure through which human beings develop our interactions. Organizations are responsible for storing and transmitting both information and knowledge so that human beings fill their informative gaps and are able to reduce their uncertainties³⁸.

Contributions of Herbert Simon in this matter include the analysis of the mechanisms that allow organizations an influence on the behaviour of their agents, so that they can be integrated into the group and able to share common goals. These mechanisms are the

³⁵ Cf. KOPPENJAN, J. and KLIJN, E. H., *Managing Uncertainties in Networks. A Network Approach to Problem Solving and Decision Making*, p. 80.

³⁶ Governmental institutions promote the use of digital means as a key tool for people to have access to information. For example, the European Union has developed what it calls “Information Society Policy” aimed to develop some directives for their citizens to be able to have and use computational means.

³⁷ Cf. MAINZER, K., *Thinking in Complexity. The Computational Dynamics of Matter, Mind, and Mankind*, p. 399.

³⁸ “Today, the improvement of organizations and the information systems in them is not a matter of making more information available, but of conserving scarce human attention so that it can focus on the information that is most important and most relevant to the decisions that have to be made”. SIMON, H. A., “The Future of Information Systems”, *Annals of Operations Research*, v. 71, (1997), p. 3.

following: 1) the division of labour among their members where every actor performs a specific task and focuses his/her attention; 2) the establishment of standards to determine how things have to be done, avoiding individuals making their own decisions about those matters; 3) the transmission of orders to establish a structure of authority and influence; 4) the implementation of channels of communication, so that information can flow for decision making (these channels can be formal or informal: the previous ones are based in the hierarchical structure of the organization, the latter follow the social relations between individuals); and 5) the training given to users so that they have knowledge, skills, identification and loyalty to the organization, in such a way that they are able to make decisions in the way the organization would do it³⁹.

Although organization of the informative systems –particularly of the web- and the interaction among users from all over the world does not follow a preconceived scheme, it could be said that, into that space, they try to self-organize themselves. In that way they reproduce the same organizational structure that they have in their social life. If we are able to make predictions and prescriptions about the behaviour of human beings in specific environments, we might be able to do the same into the frame of the *World Wide Web*.

This is a task aimed to the future and basically teleological. There the mission of prescription is highlighted, as Herbert Simon says: “our practical concern in planning for the future is what we must do now to bring that future about. We use our future goals to detect what may be irreversible present actions that we must avoid, and to disclose gaps in our knowledge... Our decisions today require us to know our goals, but not the exact path along which we will reach them”⁴⁰.

Nevertheless, so that a system can develop by exploring new possibilities, some margin to creativity has to be permitted. This happens with the new informative systems; above all of these is the web. Ralph Stacey points out that “the science of complexity demonstrates that for a system to be innovative, creative and changeable it must be driven far from equilibrium where it can make use of disorder, irregularity, and difference as essential elements in the process of change. The state a system is in now is the result of every detail of its history, and what it will become can only be known if one knows every detail of its future development, and the only way one can do that is to let the

³⁹ Cf. SIMON, H. A., *Administrative Behavior*, 4th ed., The Free Press, N. York, 1997, p. 112.

⁴⁰ SIMON, H. A., “Prediction and Prescription in Systems Modelling”, *Operations Research*, v. 38, n. 1, (1990), p. 11.

development occur. The future of such a system is open and hence unknowable until it occurs”⁴¹.

To sum up, *information science* has to tackle the complexity of systems that are dynamic. There is an “inner” dynamic to the system that looks for increasing the quantity and the quality of information processes; and there is an “outer” dynamic that corresponds to the interaction with the users of the information and the knowledge, that are agents placed in a changing social environment. Therefore, there are difficulties for prediction that have to be dealt with by this science of design. On the horizon there are three types of uncertainty –substantive, strategic and institutional- that generate problems to anticipate a possible future. At the same time, prescription is necessary to channel the “inner” processes of acquiring and retrieving information and to give answer to the users’ demands. The exponential growth of the web is an example of all this⁴².

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⁴¹ STACEY, R., “The Science of Complexity: An alternative perspective for strategic change processes”, *Strategic Management Journal*, v. 16, (1995), pp. 477-495. Compiled in MCINTOSH, R., MACLEAN, D., STACEY, R. and GRIFFIN, D., *Complexity and Organization. Readings and Conversations*, Routledge, London, 2006, p 92.

⁴² This paper has been developed into the frame of a research project whose title is “The Sciences of Design as Sciences of Complexity: An Epistemological-methodological Analysis of the Dynamic Trait from Bounded Rationality and Parsimonious Factors”. This research project is supported by the Spanish Ministry of Science and Innovation (FFI2008-05948).

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