Smart Interfaces at ESTIA, zer da hori?

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***Abstract*—Smart Interfaces at ESTIA, what is that (zer da hori in the local basque language) ? Smart Interfaces for Engineering is one of the topics of the iaria conference at Venice. This notion emerged as a unifying research theme at the engineering school ESTIA at the end of the year 2014, after several years of common work between researchers in Sciences and Technology and researchers in Management Sciences. There is a good flow of papers on various aspects of smart interfaces, but it is not easy to find in the literature a global approach to this notion. The purpose of this paper is to contribute tio fill this gap. In section 2 we give some historical background, going back to the Macy Conferences and the Palo Alto group, to Levins equation and Action Research, and to Edgar Morins approach to complexity. In section 3 we analyze several recent thesis at ESTIA and show how the notion of smart interfaces for engineering appears on topics as different as, for example, flight critical systems, isolated rural microgrids and the Lean approaches in corporate management. We hope that this survey will contribute to the stucturation of Smart Interfaces for Engineering as a branch of modern research.**

***Index Terms*—smart interfaces for engineering, complex systems, microgrids**

I. Introduction

ESTIA-Recherche started as a research team in 2008, when GRAPHOS (Groupe de Recherches Appliquées Pluridisciplinaire sur l'Hôpital et les Organisations de Santé) and LIPSI (Laboratoire en Ingénierie des Processus et des Services Industriels) decided to merge in order to work together to develop research activities in both Management Sciences and Sciences and Technology, and at the crossroads of these domains.

Research at ESTIA is aimed at:

Giving ESTIA engineering students an opportunity to work with established researchers who belong to both national and international scientific networks.

Developing a synergy between research works and evolution of academic programs.

Proposing innovative answers to technological, economic and societal questions.

Raising awareness among students and companies about the practice of research.

Contributing to the influence of ESTIA and to the attractivity of the territory.

The research project concerns engineering and technology; hence complex systems, open and self-organizing, in which there are also (and mainly) human beings, users, managers, etc. The dynamics of ESTIA-Recherche follows from the action of constraints, goals and objectives which may appear as contradictory: there is a need to obtain applications while producing theoretical contributions, and to contribute to transfert of technology while insuring academic valorization of research results through publications in internationnally recognized journals; also the researchers at ESTIA need to develop scientific links with Bordeaux University, but they are employed by ESTIA, a private entity linked to the Chamber of Commerce and Industry of Bayonne-Pays Basque and their research is partially supported from answers to calls for projects. They have to combinate in investigations about corporate management individual initiative and top-down approach, and to provide a continuous flow of electricity from intermittent sources, etc.

Generally speaking, scientific activity at ESTIA consists in studying interactions inside systems which are often complex.

Hence, researchers at ESTIA try to address simultaneously the need for academic recognition and the need for concrete benefits for firms. This double need lies at the heart of the research strategy of ESTIA. This explains why part of the research, especially the part which involves Creativity, Innovation and Management Sciences is performed through Action-Research, as explained below.

ESTIA-Recherche relies on an interdisciplinary team of researchers working on scientific, technological and societal topics in order to adress transversal projects. Innovation requires common work between specialists in sciences and technologies, but also between specialists in sciences and technologies and researchers in human sciences. Hybridation of ideas, concepts, methods and scientific domains is there a powerful fertilizer.

The prospective discussions within ESTIA-Recherche to prepare the external evaluation performed in January 2015 by ANR (Agence Nationale de la Recherche) led to the elaboration of the concept of Smart Interfaces for Engineering. Before illustrating this concept through examples we will go through a little amount of historical background.

II. Some historical background

A. Interaction: Macy Conferences and the Palo Alto group

The objective of Macy Conferences, organised from 1942 to 1953 (at Hotel Beekman, 575, Park Avenue, New-York, except

for the last one, organized at auberge Nassau, Princeton, New-Jersey), was nothing less than building a general science of the way thinking works. These conferences were organized by a pluridisciplinary group of mathematicians, logicians, anthropologists, psychologists and economists. A description of these ten conferences can be found on Wikipedia [30]. There were two main participating groups, the first wished to establish an interaction between mathematics, physics and well-established psychological sciences, and the second, a group of "cyberneticians", including the famous mathematician Norbert Wiener, that wanted to fight well-established psychological sciences on behalf of mathematical and physical sciences. The group also included John Von Neumann, another prominent mathematician who played an important role at the beginning of computer science. This cycle of conferences played a seminal role in the emergence of Information Theory, Cybernetics and Cognitive Science, and led one of the participants, the anthropologist Gregory Bateson, to form a group, known as the Palo Alto group. The object of this group was to study the "paradox of abstraction in communication". We refer to [35] for more information about this group, whose work led to a deep change in the diagnostic of mental illness. Analyzing a "personnality" is impossible without taking into account the complex network of interpersonal relationships. Schizophrenia can be understood as a way for the patient to adapt to the pathological structure of his relations with his family [9]. They also thought that the best moment for a therapist to intervene was during a crisis, when the patient would be ready to do something to find a new equilibrium, unlike the traditional method of waiting for the patient to "cool down". Of course ESTIA Recherche does not intend to perform mental therapy, but the idea of taking into consideration the interactions of a person or a system with external environment plays an important role in the scientific approach developed at ESTIA.

B. $B = f(P, E)$, Lewin's equation and Action-Research

Action-Research did not arise all of a sudden from nowhere. In the XIX-th century, Karl Marx encouraged workers in industry to think about their living conditions by answering questionnaires (used as militant tools). This tradition of "inquiries" about peasant and/or worker situations and movements was followed more recently by Robert Linhart in his study of the struggle of workers in northeastern sugar areas of Brasil [24]. Of course ESTIA, which was created by the Chamber of Commerce and Industry of Bayonne-Pays Basque, does not have any revolutionnary goal in its research objectives, but Lewin's equation $B = f(P, E)$[23], which states that the behavior B is a function f of the person P and her or his environment E, describes heuristically various aspects of Estia-Recherche investigations. Kurt Lewin was a professor at Berlin University, specialized in Gelstat psychology. At the beginning, he was mostly interested in child psychology, and after moving to the United States he played a crucial role in the development of Action-Research, a research method where the researcher intervenes during the research and in the research, in order to bring positive changes and also to produce knowledge and theory. (He became very influential, and the U.S. government asked him during World War 2 to help dealing with food scarcity by helping customers to learn how to use and cook cheap cuts of cattle, like heart, tongue, tripe and kidneys). These ideas had been introduced by the "Chicago group," which asked sociologists to rely on leaders of communities under consideration (population of poor neighborhoods, ethnic minorities, professional groups) in order to elaborate knowledge which comes from the bottom and goes back to the bottom. Thus, the academic researcher and community leaders become "co-researchers" who produce new knowledge and act together in various domains. We refer to [8] and [19] for modern developments of Action-Research. This approach, which sometimes relies on a thorough investigation of a single case, inspired a lot of the research performed at ESTIA on innovation and on change in corporate management and organization.

C. Complex systems and the principle of dialogy

The dialogy principle is a concept introduced by Edgar Morin to understand complex systems. "The dialogy principle means that two or several different "logics" are linked in a single entity, in a complex way (complementary, concurrently and antagonistically) without the duality getting lost in unity. Hence the unity of european culture is not a judeo-christian-greek-roman synthesis, it is the game not only complementary, but also concurrent and antagonistic, between these cultures which have their own logic: this is their dialogy" [28], p. 28. " "The number and depth of interactions increase when one goes to the level of interactions, not only between particles, but between organized systems, atoms, stars, molecules, and over all living being, societies ..., and the diversity and complexity of effects and transformations produced by these interactions increases as well. Once the organisations that are the atoms and the stars are in place, the rules of the game of interactions may appear as Laws of Nature. Hence interaction is a hub between disorder, order and organization. This means in turn that order, disorder and organization are now tied, via interactions, in a single interdependent loop, where none of them can be conceived without refereeing to the others, and there they have complex (dialogic) relations, that is to say complementary, concurrent and antagonistic [27].

We refer, for example, to [3] for a survey of Edgar Morin's contributions to complexity theory. It is not necessary to perform research at ESTIA to have read the six volumes of La Méthode, or to understand deeply the filiation between the principle of dialogy and the idea of dialectics (Heraclite, de Cruse, Hegel, Marx), but the fact that ESTIA Recherche arose from the union of research groups from Engineering Sciences and Management Sciences which have been working together since 2008 allows all these researchers to have a systemic approach in their various research directions, and one could say that the concept of Smart Interfaces for Industry comes from a sucessful dialogy between these two groups.

The module "Transformées" for second year students, which is taught at ESTIA by the author of the present paper, culminates with the celebrated Shannon sampling theorem, which reconstructs all the values of a square integrable function having a compactly supported Fourier transform from the values it takes on the integers, [22] (théorème 9.5.1 p. 131). Claude Shannon was working as an engineer for Bell Telephone company, and attended the 7th, 8th and 10th Macy Conference, where he presented his Information Theory in which signification was deliberately not taken into account. Reading Edgar Morin during the preparation of this paper, I realized that the approach to noise which was presented during some conferences on signal that I attended rather recently were based on Shannon's approach - where noise is a form of disorder which should be eliminated from the signal, while other appoaches could rely on finding some order in the disorder related to the dialogy order/disorder. Of course experts in signal theory are aware of this.

III. Working on Smart Interfaces for Engineering

We now briefly describe the eight theses completed at ESTIA during the years 2015 and 2016. At first glance the topics look different:

Augmented Reality applied to conception, gestion and maintenance of urban structures and furnitures; use of model reduction algorithms to optimize placement of robotized fibers, reduced model of scavenging to optimize cylinder for a 2-stroke diesel engine; design of an architecture for measurement and diagnosis of physical parameters in critical airborne systems, algorithms and architectures for control and diagnosis of flight critical systems; study of a hybrid fuel cell/turbine system in the context of an isolated rural microgrid; visualization for an informed decision to design space exploration by shopping, accompanying maturation of concepts in eco-innovation, taking in account human factors to overcome the limitations of the Lean approaches.

But, in all situations the researchers dealt with complex systems, for which a smart approach is proposed:

Combining a monocular georeferenced tactile device with a topography laser in order to diminish the edition and interpretation errors of cartography of urban structures;

Using model reduction algorithms to reduce the number of parameters in optimization of placement of robotized fibers, and introducing a cognitive dimension in reduced and separated meta-models of the scavenging by ports in 2-stroke Diesel engines;

Relaxing tolerance to the defects of the processing chain of signal obtained from the captor by improving the mathematical model of the processing chain and introducing dynamical models in measurement, diagnosis and control of flight critical systems;

Combining a fuel cell of type SOFC and a microturbine to reach the best electrical performance with a low environment impact for isolated rural microgrids;

Finding efficient graphs for information visualization in design space exploration according to the paradigm design by shopping, supporting the maturation of eco-innovative concepts to overcome the so-called collective fixations during the development of eco-innovations, defining a performance model supporting an actor vision of man at work to overcome the limitations of the Lean approaches.

From these eight theses, which we now describe briefly, we see why the notion of Smart Interfaces for Engineering emerged at ESTIA.

Environment of Augmented Reality for conception, gestion and maintenance of urban structures and furnitures is the topic of the University of Bordeaux thesis of Emeric Baldisser in computer science, prepared at ESTIA (2013-2016) under a CIFRE contract [18] with SIG-IMAGE, a company located at Technopole Izarbel at Bidart [7]. This work points out the relevance of Augmented Reality in order to diminish the edition and interpretation errors in cartography of structures. A prototype is proposed, evaluated and discussed. It combines a monocular georeferenced tactile device with a topography laser. It allows to draw and consult technical plans on a 2D representation of the site in real-time. The validity of this approach with respect to french reglementation remains limited. Another approach is proposed, which consists in fitting/matching the clouds of dense points obtained from topography scanners with the orthoscopic 2D representation of the site. The interactions in the augmented environment of the site then depend on its cloud of points. They are geolocalized and follow the paradgim of Picking-Outlining-Annotating. These interactions are described in [6].

Development of model reduction algorithms to optimize the PFR process is the topic of the UTC (Université Technologique de Compiègne) thesis of Nicolas Bur, prepared at ESTIA (2012-2015) [15]. The realization by robotized processes of composites parts intends to improve productivity. Nevertheless the "Placement de Fibres Robotisées" (PFR) is still at a stage of maturation and requires numerous developments, in particular in the case of composites with thermoplastic matrix or with dry fibers. The thesis proposes different tools in order to determine in advance the best heating power to implement these composites. The difficulty arises from the fact that this power depends on many parameters, arising not only from the components (density, etc.) but also from the process itself (moving speed, number and orientation of the folds). The technique called Proper Generalized Decomposition (PGD) has been used to construct a reduced multi-parametric model and thus overcome the complexity of the system. The results were compared to those obtained by more conventional methods and also to experimental data, [14].

Reduced and separated meta-models of the scavenging by ports in 2-stroke Diesel engines to use evolutionary algorithms in search space is the topic of the thesis prepared at ESTIA by Stéphanie Cagin [16], [17]. The use of numerical methods to design a product became more and more common over the past 30 years. However, numerical models are still

specialized and they do not run fast which makes their use problematic. So, some reduced models of scavenging have been developed. These models are analytical and generic; they run quickly and avoid the numerical treatment problems. They are also efficient tools in the search of design solutions. The work carried out has led to a new methodology based on a behavioral meta-model called neuro-separated including a neuronal model of state, a pseudo-dynamic neuronal model and a model with separated variables. Then, exploiting the models previously developed, a process of decision with evolutionary algorithms (genetic algorithms) is used to determine optimal designs and the fast behavioral simulation of the optimal designs solutions is done, thanks to the kriging approach. This design approach is multi-viewpoints, multi-criteria and multi-physics. It also includes a cognitive dimension: both free and controlled evolutionary explorations of solution spaces have been done. To validate the method, some qualification criteria have been evaluated for each model. They allow to understand and to assume the gap between the reduced models and the initial CFD base (where the model are coming from). This approach has led to the development of a tool of model and decision aids using Python and Matlab software programs

Study of an hybrid system fuel cell/turbine in the context of an isolated rural microgrid is the topic of the Bordeaux University thesis of Sylvain Baudouin (2012-2015) [11]. Rural areas, often located far away from the main electrical network, are particularly suitable for deploying microgrids (MG), which allow to use efficiently a large number of renewable energy sources. Biogaz, obtained from methanation of agricultural waste, is a renewable energy source available in rural areas which is esay to store in large quantities, and more reliable and less dependent from random phenomena than solar or wind turbine energy.

A study of the state of the art leads to the conclusion that an hybrid system combining a fuel cell of type SOFC and a microturbine (MT) allows to reach the best electrical performance with a low environmenral impact. A unique multilevel converter of type SLNPC has been used to integrate the microgrid to the main electrical network. The first objective of the command strategy applied to the SLNPC converter was to regulate the power of the SOFC fuel cell to its nominal value, and the second objective was to fix the tension and the frequency of the microgrid when it is disconnected from the main electrical network. This system has been tested and validated through simulation and then experimentally on the EnerGea platform [21] of ESTIA.

Design of an architecture for measurement and diagnosis of physical parameters in critical airborne systems is the topic of the University of Bordeaux thesis of Romain Martin (2012-2015) [26]. The objective of this work was to propose a new architecture for measurement of physical parameters as temperature, pression and speed in airborne systems in critical situations. The goal for this architecture is to improve the integrity of the measured data while keeping their level of disponibility and fiability in highly critical airborne systems. The solution consits in relaxing tolerance to the defects of the processing chain of signal obtained from the captor. In order to do this more functions are introduced, including the mathematical model of the processing chain, to make the system smarter. The thesis was supported by a CIFRE contract [18] with the Thales company [34].

Algorithms and architectures for control and diagnosis of flight critical system is the topic of the Bordeaux thesis prepared at the same time by Alexandre Bobrinskoy [12],[13]. Flight-Critical Systems such as Electromechanical Actuators driven by Engine Control Units (ECU) or Flight Control Units (FCU) are designed and developed regarding drastic safety requirements. In this study, an actuator control and monitoring ECU architecture based on analytic redundancy is proposed. In case of fault occurrences, material redundancies in avionic equipment allow certain critical systems to reconfigure or to switch into a safe mode. However, material redundancies increase aircraft equipment size, weight and power (SWaP). Monitoring based on dynamical models is an interesting way to further enhance safetyand availability without increasing the number of redundant items. Model-base default detection and isolation such as observers and parity space are recalled in this study. The properties of differential flatness for nonlinear systems and endogenous feedback linearisation are used with nonlinear diagnosis models. Linear and nonlinear observers are then compared with an application on hybrid stepper motor (HSM). A testing bench was specially designed to observe in real-time the behaviour of the diagnosis models when faults occur on the stator windings of a HSM. The thesis was also supported by a CIFRE contract with the Thales company.

Information Vizualization for an informed decision to design space exploration by shopping is the topic of the Centrale-Supelec thesis prepared by Audrey Abi Akle at ESTIA (2012-2015) [2]. In Design space exploration, the resulting data, from simulation of large amount of new design alternatives, can lead to information overload when one good design solution must be chosen. The design space exploration relates to a multi-criteria optimization method in design but in manual mode, for which appropriate tools to support multi-dimensional data visualization are employed. For the designer, a three-phase process - discovery, optimization, selection - is followed according to a paradigm called Design by Shopping. Exploring the design space helps to gain insight into both feasible and infeasible solutions subspaces, and into solutions presenting good trade-offs. Designers learn during these graphical data manipulations and the selection of an optimal solution is based on a so-called informed decision. The objective of this research is the performance of graphs for design space exploration according to the three phases of the Design by Shopping process.

The results reveal three efficient graphs for the design space exploration: the Scatter Plot Matrix for the discovery phase and for informed decision-making, the Simple Scatter Plot for the optimization phase and the Parallel Coordinate Plot for the selection phase in a multi-attribute as well as multi-objective

situation. In consequence, five graphs, identified as potentially efficient, are tested through two experiments. In the first, thirty participants tested three graphs, in three design scenarios where one car must be chosen out of a total of forty, for the selection phase in a multi-attribute situation where preferences are enounced. A response quality index is proposed to compute the choice quality for each of the three given scenarios, the optimal solutions being compared to the ones resulting from the graphical manipulations. In the second experiment, forty-two novice designers solved two design problems with three graphs. In this case, the performance of graphs is tested for informed decision-making and for the three phases of the process in a multi-objective situation. Part of this work was presented in [1].

How to support the maturation of eco-innovative concepts?: proposition of the method MIRAS to overcome collective lock-ins and explore stakeholder networks is the topic of the thesis prepared at ESTIA by Marion Real [31], [32], using a Research-Action approach inside the support group APESA. During the development of eco-innovations, companies are looking to implement a new activity that can create ruptures with its existing practices and cause many changes in their business model. In such complex situations, the stakeholders of emerging projects have some difficulties to consciously deviate from existing cognitive frameworks to explore alternatives in line with the initial goals of the project. Thus, they take trajectories that may lead to a dilution of the environmental and social values or cause the abandonment of projects. The work presented in the thesis focuses on the maturation of eco-innovative concepts and seeks to develop tools and methods to avoid and overcome such situations called collective fixations. The methodological approach is structured in two steps:- The analysis of three case-studies of eco-innovative projects allowed to characterize supporting practices and deepen the knowledge on the collective fixation present during the maturation of concepts. This first study has fueled the design process of the MIRAS method, the main contribution of this research. The MIRAS method offers a toolkit designed for eco-innovation intermediaries in order to help them to structure their intervention during the stage of concept maturation. Specifically the tools help to improve the sustainability potential of concepts, to analyze project group behaviors during sessions and to revisit stakeholder networks so as to anticipate future mutations and news ways of incubation.

Taking into account the human factor to overcome the limitations of the Lean approaches: proposal for a performance model and an accompanying methodology is the topic of the thesis prepared by Patrick Badets at ESTIA [4], [5]. Lean is an approach aiming at eliminating non-value added operations, used by companies to improve the performance of their production activities. Companies applying this approach are observing rapid gains in operational terms but gradually some observe a fall in operating results or a degradation of the health of work force. The objective of the thesis was to overcome these limits and improve the ability of those of the company to anticipate and to take corrective actions. The performance model and the decision adopted by corporate actors to deploy Lean was questioned. It is proposed that corporate actors evaluate the efficiency of production, processed by the Lean approaches, taking into account not only the operational level of performance, but also the human dimension integrating realwork activity. A performance model that supports a kind of actor vision of man at work is defined. To help corporate actors to change their existing model of Lean performance, a support methodology based on a reengineering approach integrating coaching aimed at changing there presentations of the actors by a sociocognitive learning is offered. This methodology is based on modeling tools to represent the impact of this new performance model on the decision and on the sustainability of the lean benefits.

IV. Conclusion

We hope that this survey will help the researchers in the field of Smart Interfaces to Industry to have a more global vision of scientific activities in this direction and understand how science and technology and management sciences can help each other. We also hope that this paper will help other scientists to discover this emerging subject, and, more generally, to get interested in a systemic approach to complex systems.

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