Abstract. This plenary presentation covers a short history of experience based knowledge structure and representation, its development, implementations, and recent research directions and efforts leading to the idea of smart eResearch tools enhancing capture, storage, usage, and sharing of energy related laboratory research.

Keywords Set of Experience Knowledge Structure, Decisional DNA,

1. Background: the Need of Research Communities and our Vision to Address this Need

How many formal, routine, automatic and semi-automatic research decisions are made each day in research laboratories all over the world? How many of such research experiences are stored? What do we do with those that are stored and remembered? Are they unified, improved, reused, shared, or distributed for future research experiences?

Some four years ago the above questions motivated at the very early stages the approach that placed foundations for the technology that aims at supplying and implementing eResearch tools for capturing, improving and reusing the vast amount of knowledge amassed in past experience of the energy research community.

Typically, research related decisional experiences are not stored and reused. For example, an audit at NASA discovered that they do not know what data, information and knowledge are retained and what may have been lost [9]. Further, in [10], it is stated that “More than 97% of the research data produced by funded projects cannot be located today”. Thus, another pertinent question.” How many times does a laboratory/research group/researcher or generally any decision maker in a research laboratory has to go through the same [or similar] experimental process?”.

In nature, deoxyribonucleic acid (DNA) contains “...the genetic instructions used in the development and functioning of all known living organisms. The main role of DNA molecules is the long-term storage of information. DNA is often compared to a set of blueprints and the DNA segments that carry this genetic information are called
genes” [16,12]. The general idea behind our vision was to develop an artificial system, an architecture, a smart platform that would support discovering, adding, storing, improving and sharing information and knowledge among energy research organisations through experience. We propose to implement the developed tools based on a novel Knowledge Representation (KR) approach in which experiential knowledge is represented by Set of Experience (SOE), and is carried into the future by Decisional DNA (DDNA) (Fig. 1) [15].

Using SOE and DDNA, we develop smart eResearch platform and working implementation creating large scale operational knowledge management infrastructure to benefit energy research community. As future extension of the proposed tool we also establish the principles of eDecisional Energy Community and Knowledge Cloud development.

Our use of the analogy between the combination of the four nucleotides of DNA and the four components that characterise decision making actions is unique and innovative. Some of the principles for such integration and uniqueness from the perspective of capturing experience and history of decision making has been mentioned by others but has never evolved into actual research tool as proposed here. The DNA metaphor has also been used successfully in terms of formalising organisational knowledge in stipulations of organisation performance (decision rights, information, motivators, and structure). In this sense the proposed Decisional DNA complements and significantly expands these directions and adds formalisation of its technological aspects that makes ready to be implemented and thus brought to a wider audience.

**Fig. 1.** Developing Decisional DNA (DDNA) through SOEKS Knowledge representation involving variables, functions, constraints and rules, the four “nucleotides” of DDNA
The unique and innovative role of the proposed approach is to conceptualise, develop and implement a Smart Experience Based Knowledge Engineering Platform centred on SOEKS knowledge representation and Decisional DNA concepts, which can be used to administer the flow of data, information and knowledge generated within the energy research community. The Platform includes the main stages of Knowledge Engineering (KE), and Ontology Engineering (OE) processes from knowledge acquisition through its formalisation, storage, improvement and re-usage. The Platform combines the KM and OE technologies and acts as an integrating mechanism for possibly diverse experimental areas involved in energy research laboratory operation, ensuring that there is no piece of information or knowledge generated during the laboratory decisional and operational experience that is overlooked or forgotten. In our view the proposed approach has substantial technological potential to improve energy related research groups performance by enhancing both quality and quantity of research. It would help laboratories in leveraging their knowledge and, by doing this, contribute to the economic and social well being of the wider community.

In collaboration with Priority Research Centre for Energy (PRC/E), The University of Newcastle we plan to develop final implementation for our proposed smart eResearch KE Platform. Intuitive web-based user interface would help to capture experience of the researcher/laboratory technician who runs experiments. The captured experience would then be processed by the proposed tool as illustrated in Fig. 2.

![Fig.2. Laboratory smart eResearch Knowledge Engineering Platform](image-url)
The fundamental structure of the tool depicted by Figure 2 fully complements and addresses the energy research community need for unified research experience repository that can be mined for new discoveries, re-used for future experiences, and shared nationwide and globally for research collaboration purposes. These functionalities, although central to the energy research community, are currently not supported in a structured, systemic way.

2. SOEKS and DDNA fundamentals

Arnold and Bowie [2] argue that “the mind’s mechanism for storing and retrieving knowledge is transparent to us. When we ‘memorize’ an orange, we simply examine it, think about it for a while, and perhaps eat it. Somehow, during this process, all the essential qualities of the orange are stored [experience]. Later, when someone mentions the word ‘orange’, our senses are activated from within [query], and we see, smell, touch, and taste the orange all over again”. The SOEKS has been developed to keep formal decision events in an explicit way [13]. It is a model based upon existing and available knowledge, which must adjust to the decision event it is built from; besides, it can be expressed in OWL (Ontology Web Language) as an ontology in order to make it shareable and transportable [14,15]. Four basic components surround decision-making events, and are stored in a combined dynamic structure that comprises the SOE. These four components are variables, functions, constraints, and rules.

Additionally, the SOEKS is organized in a DNA shape. The elements of the structure are connected among themselves imitating part of a long strand of DNA, that is, a gene. Thus, a gene can be assimilated to a SOE, and, in the same way as a gene produces a phenotype, a SOE produces a value of decision in terms of the elements it contains; in other words, the SOEKS, itself, stores an answer to a query presented.

A unique SOE cannot rule a whole system, even in a specific area or category. Therefore, more Sets of Experience should be acquired and constructed. The day-to-day operation provides many decisions, and the result of this is a collection of many different SOE. A group of SOE of the same category comprises a decisional chromosome, as DNA does with genes. This decisional chromosome stores decisional “strategies” for a category. In this case, each module of chromosomes forms an entire inference tool, and provides a schematic view for knowledge inside an organization. Subsequently, having a diverse group of SOE chromosomes is like having the Decisional DNA of an organization, because what has been collected is a series of inference strategies related to such enterprise.

In conclusion, the SOEKS is a compound of variables, functions, constraints and rules, which are uniquely combined to represent a formal decision event. Multiple SOE can be collected, classified, and organized according to their efficiency, grouping them into decisional chromosomes. Chromosomes are groups of SOE that can accumulate decisional strategies for a specific area of an organization. Finally, sets of chromosomes comprise what is called the Decisional DNA of the organization [13,14].
3. Knowledge Representation Systems: Current Developments and Implementations

Existing limitations in the area. Since the underlying Drucker’s [6] proposition knowledge representation systems have been the goal of researchers, developers, and engineers alike for over 15 years. However, these problems and their solutions do not appear to have progressed too far. The fundamental limitation of current implementations in this area is that none of the proposed approaches uses experience as ongoing, real-time reference during the decisional process in a way which happens naturally when humans make decisions if confronted with a new situation. We challenge the existing techniques/tools/applications with the proposition that all of them lack the same critical element in assuring progress and useful implementations – they don’t store and reuse experience in an ongoing, real-time manner. The platform we propose is experienced based and captures experience on the day-to-day operation; the knowledge representation we introduce combines logic, rules and frames, and it is experience based as well.

State of the art. Our approach is motivated by the following needs and directions specified by current, cutting-edge international developments in the area:

• First, acquisition of knowledge through efficient transformation of data and information, and then management of such knowledge, becomes the main challenge of knowledge society [6,3,17,5]. Within this general challenge, there is a very specific need formulated recently in [7,8,11,19] – the need to develop a KM System which acts as a knower, i.e. that “has knowledge, develops it, and applies it” [11]. We answer this need by developing a smart administration system able to store, improve and apply knowledge.

• Second, European and Australian studies reported in [8] have established that the primary aim of KM should be to use the vast experience that is accumulating each day within systems, as true knowledge is build up through learning from current and past experiences [6,1,4]. New tools are needed to convert experiences into knowledge that can be improved, accessed and used by decision makers. We develop such tool that focus on the needs of research community.

• Next, Experience Management (EM) as the basis for knowledge generation and representation is capturing increasingly growing attention of practitioners, especially in Europe [17,1,4]. However, the technologies developed so far act as document repository only, and are not yet intelligent decision support systems. The platform that we propose embarks on such an intelligent decision support system development.

• The existing KM systems are human centred and act as information repositories; they do not act as automatic or semiautomatic decision makers, they do not act as “knowers”. Some of the best examples of the above are ExpertSeeker Web Miner by NASA-GSFC (repository of expertise), ExpertSeeker KSC by NASA-KSC (expertise locator), NaCoDAE by the US Navy (conversational based decisional repository) or Universal Knowledge by KPS (document repository) [18]. In our
approach we propose to go beyond repository human centre like systems that are currently used by turning the system into a “knower” system.

Relevant state of the art developments in the area suggest that the question of how to automate experience based knowledge administration using intelligent techniques and software engineering methodologies is still an unsolved issue \[17,19\]. Our proposed approach to the solution of this issue is to systematically create, capture, reuse, improve and distribute experience in the work processes of a energy research laboratory, preventing important decisional steps from being forgotten in the daily operation.

4. Our overall objective

*Develop a smart eResearch platform which is able to gain experiential and decisional knowledge from the day-to-day operations of research community.*

The proposed eResearch tool would be the first instance of infrastructure that can be called LKMS (Laboratory Knowledge Management System) expanding the existing LIMS (Laboratory Information Management System) support tools into the area of knowledge engineering and administration.

There are two major steps in our research efforts: platform development (Step A) and platform implementation (Step B).

**Step A** comprises four development stages: Diagnosis, Prognosis, Solution, and Knowledge Stage (Please refer to Figure 2 above):

*Diagnosis:* This stage develops software mechanisms that consolidate and integrate data, information and sub-decisions provided by multiple applications (experimental infrastructure) working for various groups of energy research. It inputs characteristics and objectives of experiments (or a section of them) at a particular moment.

*Prognosis:* Taking unified information, the Prognosis Stage produces a set of proposed experimental or research strategies. Three layers comprise the Prognosis Development Stage of the software representation of the platform.

*Solution:* In the Solution Stage of the software representation of our Platform, we take the scenarios of the previous layers and, according to priorities established by the end-user, choose the best possible solution under those priorities.

*Knowledge:* The formal model the Knowledge Development Research Stage receives is a coded decisional experience which originated in a defined moment or event, grasping the meaning of the situation. The knowledge macro-process starts
once the Platform establishes the ultimate solved experience-based knowledge structure. This Stage captures such experience by a group of applications, named creators, capable of obtaining knowledge. Additionally, this layer interacts with previous layers during the process of finding a current solution by presenting past alternatives.

The functionalities developed in Step A above are implemented in “DDNA Manager”. The Decisional DNA Manager is a software platform for experience administration based upon a multi-domain knowledge representation structure Set of Experience Knowledge Structure (SOEKS) and the Decisional DNA. This software allows collecting, storing, improving, and reusing research experience from formal decision events in a research laboratory. It can be used as a tool to analyze, query, consolidate and administer semantic experience captured by the means of SOEKS and Decisional DNA. Additionally, the software allows exportation of semantic experience into XML and OWL as a way to share knowledge. We introduced the Beta version of “DDNA Manager” to the research community at 4 international conferences in Europe in 2010/11. Two our presentations were invited plenary lectures. We also run the first European tutorial on DDNA Manager operations. To include full platform capabilities the DDNA Manager is enhanced during Step A of our research with plug-in models of SOEKS, Reflexive Ontologies, similarity metrics, data mining techniques, and heuristics.

**Step B** involves the development of a working final implementation application as part of energy research community infrastructure. The application would work in two ways as follows:

1. When a research group ends an experiment, a local software agent generates a call. Then, the agent platform begins its work starting a majordomo service whose main function is to serve as an intermediary between the user and the platform. The system collects data, information and human-based decisions by the means of software agents. In the end, this represents an experience that is part of the Decisional DNA of the research laboratory.

2. A research group will start some experiments and wishes to discover previous approaches on similar experiments, or take them further in their research. The research group queries the system. Thus, the majordomo handles the events in the knowledge layer repositories through the establishment of a query in order to obtain knowledge from past experiences or similar energy research experimental or decisional experiences. Once the Decisional DNA is queried, the previous experiences are reported to the user in the form of different reports. The research group can decide about using certain results in order to perform new additional experiments or completely re-design the experimental process which in turn will follow the process described above in 1.
4. Conclusion with future directions

To ultimately expand the operations of the proposed Platform, it can be inserted in the future into a collaborative research knowledge supply chain consisting of a number of similar platforms and eResearch tools, where the links feed each other with knowledge, creating eDecisional Research Community. At this envisaged future step, we could develop an architecture supporting a number of collaborating Platforms as a grid of knowledge network which facilitates research groups to share, improve and create knowledge, resulting in greater efficiency, effectiveness, and an increase of collective intelligence of the national and even global research community.

5. References


