

# Computational Intelligence in Decision Making

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## Abstract

In this preface we stress the relevance of the traditional collaboration between Engineering and any field of Mathematics in order to build intelligent decision-aid tools, as it is illustrated by the twelve papers contained in this Special Issue. These papers, selected by means of a standard peer review process after an open call, offer an interesting variety of models, approaches and techniques, to be applied within different specific problems. Each paper is introduced in this preface and is developed in the subsequent article. Moreover, in this preface we also claim for a more intense collaboration between decision engineers and other fields that study human brain behavior, like Neurology, Psychology, Sociology and Linguistics. Because if we really want to procure intelligent tools for decision aid, we should start by taking the human brain as our first reference, as it is the most efficient machinery we have found in order to deal with complex, uncertain, incomplete and even apparently inconsistent information. We hope that readers will enjoy this Special Issue devoted to Computational Intelligence in Decision Making.

*Keywords:* Computational Intelligence, Decision Making.

## 1. Introduction

Technology is increasingly allowing to easily monitorize many aspects of reality, storing data to a level that was difficult to imagine some years ago. Overloaded with such a huge amount of data, we certainly realize that ignorance can be reached not only with the absence of data, but also being overwhelmed by those data. No matter the size of available data, data are meaningless meanwhile they cannot be processed, meanwhile those data are not transformed into information.

Information can be attained in many formats. The key issue is that each format should allow a comprehensive view of the problem we are facing to, in some way enabling a predictive capability that can be checked in

order to reinforce, modify or reject such a view. Somehow, such a view is a simplified representation of reality that should capture the main parameters or characteristics, aiming for a *useful accuracy* (enough accuracy taking into account our *storage capacity*, and our *processing abilities*).

Knowledge acquisition and decision aid need mathematical modeling to capture the essential features of reality, structure data in a meaningful and manageable way, and process the information. No intelligent decision maker will trust on a tool that does not give room to a qualified intuition (*black boxes* in decision making might produce terrible disasters). A good decision aid methodology implies understanding reality in a manageable way. Such a manageability depends on our capabilities and abilities, and should

allow some kind of verifiable experimentation. At this point, it is pertinent to stress with J. Dujmovic [4] that our decision making procedures should be in principle consistent with the global view given by the intuition of experienced professionals and their robust natural reasoning. In complex procedures, we cannot trust certain unstable models, impossible to be monitored.

This Special Issue, conceived during the FLINS 2012 conference, held in Istanbul (August 26-29), comes from an open call that pursued a representative collection of case studies within decision engineering. Thirty-seven papers were received, and twelve papers were finally selected after a standard peer reviewing process. Some illustrative approaches for the intelligent processing of data, information and knowledge, to be considered in specific decision making problems, are presented. These twelve papers show an interesting variety of applications, each paper addressing a different alternative technique that might come from Statistics, Optimization, Soft Computing and/or Multi-Criteria Decision Making. We hope the readers will enjoy with this Special Issue.

## 2. Contents of this special issue

The first part of this Special Issue contains three papers focusing on some applications of statistical techniques.

The first paper of this Special Issue, “Implicit parameter estimation for conditional Gaussian Bayesian networks” (by Aida Jarraya, Philippe Leray and Afif Masmoudi), proposes an approach to avoid the use of priors in Gaussian Bayesian networks, using the implicit estimation method for learning from observations without a prior knowledge.

The second paper, “Bivariate analysis of typical hydrological series of the Yellow River” (by Xin Tong, Dong Wang, Jichun Wu, Yuanfang Chen and Xi Chen), studies the characteristics of the flood and runoff of the Yellow River, China, using a 30-year long time series of annual runoff and annual maximum, by means of three Archimedean copulas.

In the third paper, “Comparison of different inference algorithms for medical decision making” (by Guven Kose, Hayri Sever, Mert Bal and Alp Ustundag), a medical diagnosis system with a Bayesian module and a

rule-based inference model is presented. Validation of the performance of the system shows improvements in medical diagnosis.

A second package of three papers is devoted to some applications of optimization techniques.

In the fourth paper of this Special Issue, “A lexicographical dynamic flow for relief operations” (by Gregorio Tirado, F. Javier Martín-Campo, Begoña Vitoriano and M. Teresa Ortuño), a lexicographical dynamic flow model to solve the problem of designing plans for the distribution of humanitarian aid according to the preferences of the decision maker is presented, extending a previously introduced static flow model. The new model is validated in a realistic case study and a computational study is performed to compare both models, showing how these can be coordinated to improve their overall performance.

The fifth paper, “Workload balancing in identical parallel machine scheduling using a mathematical programming method” (by Yassine Ouazene, Farouk Yalaoui, Hicham chehade and Alice Yalaoui), addresses the workload balancing problem in the context of identical parallel machines, considering a new mathematical formulation based on the minimization of the difference between the workload of the bottleneck machine and the workload of the fastest machine.

The sixth paper, “Replacement policies for a complex system with unobservable components using dynamic bayesian networks” (by Demet Özgür-Ünlüakın and Taner Bilgic), studies maintenance of a complex dynamic system consisting of ageing and unobservable components under a predetermined threshold reliability level. The problem is represented by means of dynamic Bayesian Networks, and it is proven that, under the existence of some predetermined threshold reliability, optimum replacement times are obtained performing replacements at periods when the system reliability falls just below the threshold.

Third part of this Special Issue is devoted to multi-criteria decision making.

In the seventh paper of this Special Issue, “Combining Boolean consistent fuzzy logic and AHP illustrated on

the Web service selection problem” (by Ivana Dragović, Nina Turajlić, Dragan Radojević and Bratislav Petrović), the AHP method is extended in order to define the criteria and goal by means of fuzzy logic. This extension shows that the method can be used at different levels of the AHP, with two different application scenarios on the Web service selection problem.

The eighth paper of this Special Issue, “Criteria weighing and 4P’S planning in marketing using a fuzzy metric distance and AHP hybrid method” (by Tuncay Gürbüz, Y. Esra Albayrak and Elif Alaybeyoğlu), proposes a multi-criteria decision making model characterized by an AHP hybrid method based on a fuzzy metric distance between triangular fuzzy numbers. It is applied to a specific real-life marketing problem in order to deal with the relation that should exist between production and consumption.

The ninth paper of this Special Issue, “Weighting under ambiguous preferences and imprecise differences in a cardinal rank ordering process” (by Mats Danielson, Love Ekenberg, Aron Larsson and Mona Riabacke), proposes a useful weight elicitation method decision making, that built on the ideas of rank-order methods, increases the precision by adding numerically imprecise cardinal information as well.

Last part of this Special Issue is devoted to some techniques traditionally allocated within the core of soft computing.

In the tenth paper of this Special Issue, “Off-line recognition of degraded numeral characters with MMTD-based fuzzy classifiers” (by Weiqing Cheng, Long Hong and Shaobai Zhang), a novel offline degraded numeral recognition method based on the measure of medium truth degree is proposed to identify segmented degraded numeral characters in gray images. The experimental results show that the proposed method performs well on recognizing degraded numeral characters.

In the eleventh paper, “Applicability of Artificial Bee Colony algorithm for nurse scheduling problems” (by Kadir Scuyukozkan and Ahmet Sarucan), the authors describe an approach based on Artificial Bee Colony

and its application to nurse scheduling evaluated under different working environments. Their approach has been successfully applied in a hospital.

Finally, in the last paper of this Special Issue, “Agents and rough sets” (by Germano Resconi and Chris Hinde), the authors propose a more general image of the rough set with a formal logic description of the vague or approximate data. A bridge between fuzzy set, rough set and active set is also suggested.

### 3. Computational intelligence in information and knowledge management

It is important to realize, as already stressed in [9], that data should not be understood as a crude description of reality. There is not such a crude observation of reality once each observation depends on the design of the observing machine and its internal processing components. For example, our eyes can only capture a finite number of frames per second (moreover, these frames are restricted to the visible spectrum). We think that space and time is continuous, but continuity of space and time is basically a *perception* (consistent with those frames we observe, but still a logical construction). What we think we have seen has been already processed by our brain. What we think are crude data, it is already an elaborated product. There are many things that our eyes cannot see, and there are also things that our eyes still see but our brain cannot realize is seeing, or simply we see things our brain cannot process, or even it might happen that our brains do not want to see what our eyes are seeing. What human beings use to call *observation* is already filtered and elaborated *information*.

In fact, a main characteristic of human brain (see, e.g., [7,8]) is its capacity and ability to build up a compact explanation of reality in terms of *concepts*, which efficiently reduce storage needs. Such a representation in terms of concepts, together with its consistent and robust logical management ability, are in the basis of our success as specie (creation of language is also a main achievement, since words allow a representation of those concepts in such a way that they can be communicated between individuals, and particularly between generations, allowing a social and intergenerational continuous learning, which can lead to specie achievements far beyond individual capacities).

The ability to manipulate concepts plays a key role along human evolution.

Anyhow, coming back to the topic of this Special Issue, whatever we consider data should be ready to produce information; information should be ready to produce knowledge; and knowledge should enable intelligent decisions. But we have to be very careful in acknowledging an excessive weight to the last stage of decision making. Quite often it is stressed that our main objective should be decision making, simply because we consider ourselves decision makers that address sequences of problems, and that each problem finishes when such a problem is closed with our final decision. But quoting Plato, *a good decision is based on knowledge and not on numbers* (“The Socratic Dialogue: Laches”, by Plato). Our efforts should increasingly focus on information and knowledge acquisition and management, rather than in pure decision making procedures, certainly useful but not in the core of what we mean as *intelligence*. Data should be seen more as the support for knowledge rather than the support for decision making. In fact, human brain (see, e.g., [1,2]) has different locations for logical analysis and for decision making, the latter being associated to *emotions*. Consistently, most of the past efforts devoted to *decision making* have evolved into *decision aid*.

Although this Special Issue focusses on decision making, we should stress again the relevance of computational intelligence in those previous stages to decision making (observation, information and knowledge). In fact, as pointed out in [11], whenever a decision has to be crisp, fuzziness does not properly fit. Fuzzy models properly fit to concept creation, concept representation and concept management, and to those strategic *political* decisions we make and that by definition are poorly defined since their details will be necessarily fixed depending on yet unknown circumstances (see, e.g., [5] but also [10]). As a Spanish famous poet wrote, *there is no road, you make your path as you walk* (“Songs”, by Antonio Machado). Most of our personal decisions are fuzzy in nature, in part because we know by heart that we cannot control many variables.

In addition, the recent economic crisis in some Western countries should help to realize that flexibility is a need in order to be able to survive in a complex, uncertain changing world. We should also be conscious that many of our life-time decisions are not subject to a proper case by case learning, but that they are one-shot decisions [6]. Sometimes we cannot reach to a true experimentation, and our intuition should take advantage of our logical analytical tools, based upon our general knowledge about reality. Our brain is indeed ready to deal with uncertain and unexpected situations, and although many studies focus on how information should be *defuzzified*, knowledge should be associated to *fuzzifying* techniques. Fuzzifying is associated to concepts, most of them fuzzy, rather than to crisp decisions. Our brain evolution has found concepts as the most compact and efficient approach to store and manipulate information (but a concept should not to be confused with the word we might use to translate to others such a concept, a word that is a representation of such a concept, and that may need a long discourse to be understood by others).

If a main objective in decision aid is to be able to deal with incomplete and uncertain huge amount of data, we cannot forget that our human brain represents the best knowledge machinery we have experience with. It is needed a more intense collaboration (both theoretical and empirical) between soft computing researchers and Neurology, Psychology, Sociology and Linguistic.

For example, as already pointed out, Neurology has proven that our brain works connecting a number of different machineries. Among other things, it has been shown that the region where decisions are made is clearly different from the region where the analysis of alternatives is developed (see, e.g., [1,2]). Intelligent decision aid should focus on the analytical components of our decision process rather than in the selection of a crisp alternative previously defined. Like in democracy, much more important than the final voting process is the previous deliberative process that will lead to the definition of the alternatives to be voted [3].

#### 4. Final comments

Despite previous comments on computational intelligence in information and knowledge management, this Special Issue focuses on decision engineering. With

a few number of selected papers it is shown the relevance of some specific models when addressing particular applications.

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