1 What does Soft Computing mean?

1.1 Definition of Soft Computing

Prior to 1994 when Zadeh (Zadeh 1994) first defined "soft computing", the currently-handled concepts used to be referred to in an isolated way, whereby each was spoken of individually with an indication of the use of fuzzy methodologies. Although the idea of establishing the area of soft computing dates back to 1990 (Zadeh 2001), it was in (Zadeh 1994) that Zadeh established the definition of soft computing in the following terms:

"*Basically, soft computing is not a homogeneous body of concepts and techniques. Rather, it is a partnership of distinct methods that in one way or another conform to its guiding principle. At this juncture, the dominant aim of soft computing is to exploit the tolerance for imprecision and uncertainty to achieve tractability, robustness and low solutions cost. The principal constituents of soft computing are fuzzy logic, neurocomputing, and probabilistic reasoning, with the latter subsuming genetic algorithms, belief networks, chaotic systems, and parts of learning theory. In the partnership of fuzzy logic, neurocomputing, and probabilistic reasoning, fuzzy logic is mainly concerned with imprecision and approximate reasoning; neurocomputing with learning and curve-fitting; and probabilistic reasoning with uncertainty and belief propagation*".

Figure 1: Prof. Lotfi. A. Zadeh.
(adapted from http://www-bisc.eecs.berkeley.edu)

There have been various subsequent attempts to further hone this definition, with differing results, and among the possible alternative definitions, perhaps the most suitable is the one presented in (Li & Ruan & van der Wal 1998):

"*Every computing process that purposely includes imprecision into the calculation on one or more levels and allows this imprecision either to change (decrease) the granularity of the problem, or to "soften" the goal of optimization at some stage, is defined as to belonging to the field of soft computing*".

Soft computing could therefore be seen as a series of techniques and methods so that real practical situations could be dealt with in the same way as humans deal with them, i.e. on the basis of intelligence, common sense, consideration of analogies, approaches, etc. In this sense, soft computing is a family of problem-resolution methods headed by approximate reasoning and functional and optimisation approximation methods, including search methods. Soft computing is therefore the theoretical basis for the area of intelligent systems and it is evident that the difference between the area of artificial intelligence and that of intelligent systems is that the first is based on hard computing and the second on soft computing. Soft Computing is still growing and developing.

From this other viewpoint on a second level, soft computing can be then expanded into other components which contribute to a definition by extension, such as the one first given. From the beginning (Bonissone 2002), the components considered to be the most important in this second level are probabilistic reasoning, fuzzy logic and fuzzy sets, neural networks, and genetic algorithms, which because of their interdisciplinary, applications and results immediately stood out over other methodologies such as the previously mentioned chaos theory, evidence theory, etc. The popularity of genetic algorithms, together with their proven efficiency in a wide variety of areas and applications, their attempt to imitate natural creatures (e.g. plants, animals, humans) which are clearly soft (i.e. flexible, adaptable, creative, intelligent, etc.), and especially the extensions and different versions, transform this fourth second-level ingredient into the well-known evolutionary algorithms which consequently comprise the fourth fundamental component of soft computing, as shown in the following diagram, see Figure 2.

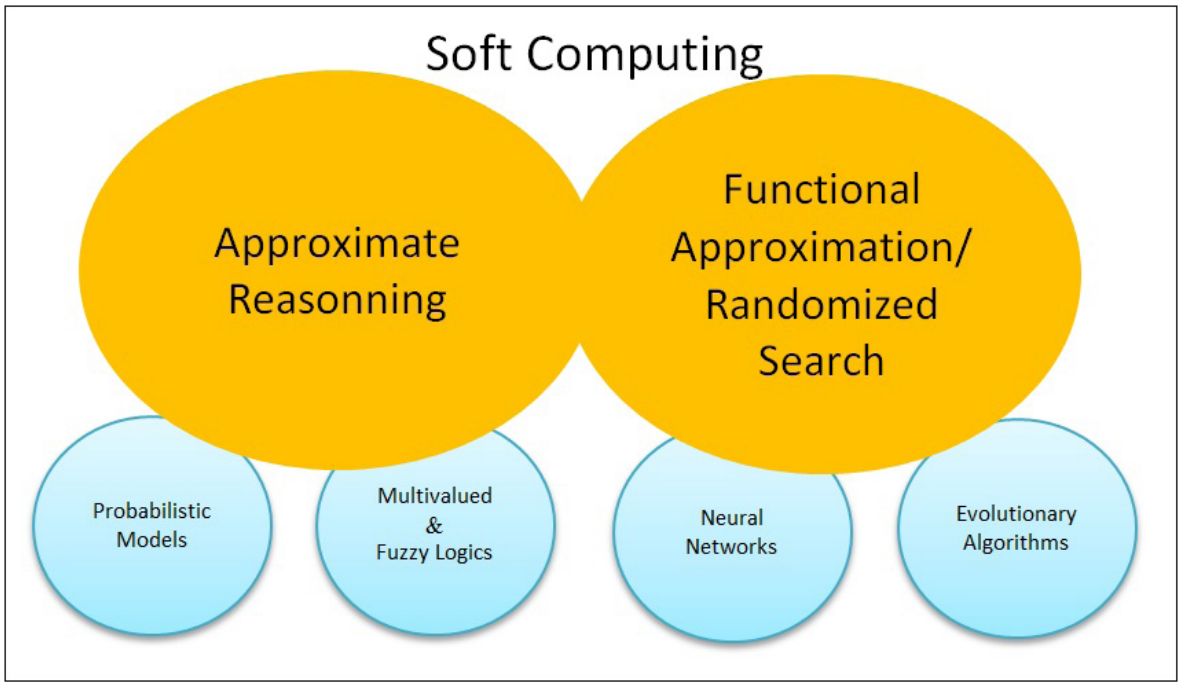

Figure 2: What does Soft Computing mean? (adapted from http://modo.ugr.es)

1.2 Conception of Soft Computing

From this last conception of soft computing playing fuzzy sets and fuzzy logic a necessarily basic role, we can describe the following other areas emerging around it simply by considering some of the possible combinations which can arise:

1. From the first level and beginning with approximate reasoning methods, when we only concentrate on probabilistic models, we encounter the Dempster-Shafer theory and Bayesian networks. However, when we consider probabilistic methods combined with fuzzy logic, and even with some other multi-valued logics, we encounter what we could call hybrid probabilistic models, fundamentally probability theory models for fuzzy events, fuzzy event belief models, and fuzzy influence diagrams.
2. When we look at the developments directly associated with fuzzy logic, fuzzy systems and in particular fuzzy controllers stand out. Then, arising from the combination of fuzzy logic with neural networks and EA are fuzzy logic-based hybrid systems, the foremost exponents of which are fuzzy neural systems, controllers adjusted by neural networks (neural fuzzy systems which differ from the previously mentioned fuzzy neural systems), and fuzzy logic-based controllers which are created and adjusted with evolutionary algorithms.
3. Moving through the first level to the other large area covered by soft computing (functional approach/optimization methods) the first component which appears is that of neural networks and their different models. Arising from the interaction with fuzzy logic methodologies and EA methodologies are hybrid neural systems, and in particular fuzzy control of network parameters, and the formal generation and weight generation in neural networks.
4. The fourth typical component of soft computing and perhaps the newest yet possibly most up-to-date is that of evolutionary algorithms, and associated with these are four large, important areas: evolutionary strategies, evolutionary programming, genetic algorithms, and genetic programming. If we were only to focus on these last areas, we could consider that in this case the amalgam of methodologies and techniques associated with soft computing culminate in three important lines: fuzzy genetic systems, bio inspired systems, and applications for the fuzzy control of evolutionary parameters.

1.3 Importance of Soft Computing

The aim of Soft Computing is to exploit tolerance for imprecision, uncertainty, approximate reasoning, and partial truth in order to achieve close resemblance with human-like decision making. Soft Computing is a new multidisciplinary field, to construct a new generation of Artificial Intelligence, known as *Computational Intelligence*.

The main goal of Soft Computing is to develop intelligent machines and to solve nonlinear and mathematically unmodelled system problems (Zadeh 1994) and (Zadeh 2001). The applications of Soft Computing have proved two main advantages. *First*, it made solving nonlinear problems, in which mathematical models are not available, possible. *Second*, it introduced the human knowledge such as cognition, recognition, understanding, learning, and others into the fields of computing. This resulted in the possibility of constructing intelligent systems such as autonomous self-tuning systems, and automated designed systems.

As stated in (Verdegay 2003), since the fuzzy boom of the 1990s, methodologies based on fuzzy sets (i.e. soft computing) have become a permanent part of all areas of research, development and innovation, and their application has been extended to all areas of our daily life: health, banking, home, and are also the object of study on different educational levels. Similarly, there is no doubt that thanks to the technological potential that we currently have, computers can handle problems of tremendous complexity (both in comprehension and dimension) in a wide variety of new fields.

As we mentioned above, since the 1990s, evolutionary algorithms have proved to be extremely valuable for finding good solutions to specific problems in these fields, and thanks to their scientific attractiveness, the diversity of their applications and the considerable efficiency of their solutions in intelligent systems, they have been incorporated into the second level of soft computing components.

Evolutionary algorithms, however, are merely another class of heuristics, or metaheuristics, in the same way as Tabu Search, Simulated Annealing, Hill Climbing, Variable Neighbourhood Search, Estimation Distribution Algorithms, Scatter Search, Reactive Search and very many others are. Generally speaking, all these heuristic algorithms (metaheuristics) usually provide solutions which are not ideal, but which largely satisfy the decision-maker or the user. When these act on the basis that satisfaction is better than optimization, they perfectly illustrate Zadeh's famous sentence (Zadeh 1994):

"*…in contrast to traditional hard computing, soft computing exploits the tolerance for imprecision, uncertainty, and partial truth to achieve tractability, robustness, low solution-cost, and better rapport with reality*".

1.4 The Soft Computing – development history

The following two schemes[1] show development history of Soft Computing in brief.

SC	=	EC	+	NN	+	FL
Soft Computing		***Evolutionary Computing***		***Neural Network***		***Fuzzy Logic***
Zadeh 1981		**Rechenberg 1960**		**McCulloch 1943**		**Zadeh 1965**

EC	=	GP	+	ES	+	EP	+	GA
Evolutionary Computing		***Genetic Programming***		***Evolution Strategies***		***Evolutionary Programming***		***Genetic Algorithms***
Rechenberg 1960		**Koza 1992**		**Rechenberg 1965**		**Fogel 1962**		**Holland 1970**