Chapter 3
Hierarchies of Architectures of Collaborative Computational Intelligence

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ABSTRACT

Computational Intelligence (CI) supports a wealth of methodologies and a plethora of algorithmic developments essential to the construction of intelligent systems. Being faced with inherently distributed data which become evident, the paradigm of CI calls for further enhancements along the line of designing systems that are hierarchical and collaborative in nature. This emerging direction could be referred to as collaborative Computational Intelligence (or C^2I for brief). The pervasive phenomenon encountered in architectures of C^2I is that collaboration is synonym of knowledge sharing, knowledge reuse and knowledge reconciliation. Knowledge itself comes in different ways: as some structural findings in data and usually formalized in the framework of information granules, locally available models, some action plans, classification schemes, and alike. In such distributed systems sharing data is not feasible given existing technical constraints which are quite often exacerbated by non-technical requirements of privacy or security. In this study, we elaborate on the design of information granules which comes hand in hand with various clustering techniques and fuzzy clustering, in particular.

INTRODUCTION AND MOTIVATING INSIGHTS

Computational Intelligence (Zurada, Yen, and Wang, 2008) dwells on the synergy between its three pillars of Granular Computing (including fuzzy sets, interval calculations, and rough sets), biologically inspired optimization (exemplified through evolutionary algorithms, genetic algorithms, ant colonies, particle swarm optimization) and neurocomputing. Cognitive Informatics (Wang, 2003, 2006) stresses the cognitive facets of intelligent pursuits. The commonly encountered constructs of Granular Computing are concerned with processing individual data sets conveying experimental evidence. Numeric data are available locally by being collected at some single data site, as portrayed in Figure 1. The resulting information granules come as a result of processing of the data. The research agenda of Granular Computing has been predominantly focused on this general framework of data exploitation. For instance, in fuzzy modeling we can commonly witness design scenarios of using a single data set to construct fuzzy sets and afterwards treating them as building blocks (modules) in the realization of the fuzzy model. In particular, fuzzy rule-based models are representative examples of these modeling developments; we construct information granules which afterwards constitute a backbone of any fuzzy model.

There is, however, a growing interest in the design and analysis of distributed systems, multi-agent systems, and distributed modeling, cf. (Acampora and Loia, 2008; Bouchon-Meunier, 1998; Ferrero and Salicone; 2007; Genesereth and Ketchpel, 1994; Pedrycz and Vukovich, 2002). This interest is supported by a wealth of pertinent methodologies and algorithmic developments, cf. (Ayad and Kamel, 2003; Bickel and Scheffer, 2004; Campobello et al., 2006; Silva and Klusch, 2006; Gersho and Gray, 1992; Merugu and Ghosh, 2005; Pedrycz and Vukovich, 2002; Pedrycz, 2002; Pedrycz and Rai, 2008; Skillicorn and Mc-

Figure 1. From data to structure: a case of a single data
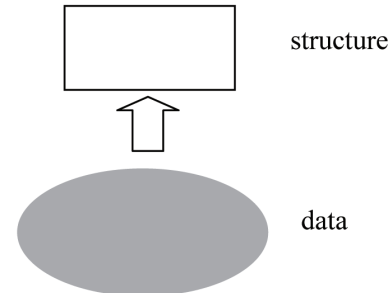
Connell, 2007; Stubberud and Kramer, 2006; Tsoumakas, Angelis, and Vlahavas, 2004; Wang, 2003).

Referring to Figure 2, let us now envision a number of individual data sets, denoted here by D_1, D_2, …, D_p. There are situations in which we encounter a collection of data for which granulation is realized individually and therefore leads to the resulting structures as illustrated in this figure.

We would like to determine a global structure-*metastructure* which is regarded as the most representative topology of the individual structures and reconciles the locally formed information granules to the highest possible extent. Note the use of different graphic symbols in Figure 2 which emphasize the existence of different levels of the hierarchy emerging in this fashion. A task of forming metastructures could be of interest from several points of view. First, one could be interested in the determination of the most profound commonalities one could come across when dealing with the individual structures of some specific characteristics. The discovered commonalities are critical to the better understanding of the phenomenon at the global level. Second, we may identify differences across various perspectives (data sets) which in this way become properly exposed and could be further investigated. Interestingly enough, we are faced with a diversity of topologies with a few further examples included in Figure 3. Instead of the commonly distinguished

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