Toward Rough-Granular Computing

Extended Abstract

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Developing methods for approximation of compound concepts expressing the result of perception belongs to the main challenges of Perception Based Computing (PBC) \cite{70}. The perceived concepts are expressed in natural language. We discuss the rough-granular approach to approximation of such concepts from sensory data and domain knowledge. This additional knowledge, represented by ontology of concepts, is used to make it feasible searching for features (condition attributes) relevant for the approximation of concepts on different levels of the concept hierarchy defined by a given ontology. We report several experiments of the proposed methodology for approximation of compound concepts from sensory data and domain knowledge. The approach is illustrated by examples relative to interactions of agents, ontology approximation, adaptive hierarchical learning of compound concepts and skills, behavioral pattern identification, planning, conflict analysis and negotiations, and perception-based reasoning. The presented results seem to justify the following claim of Lotfi A. Zadeh: “In coming years, granular computing is likely to play an increasingly important role in scientific theories-especially in human-centric theories in which human judgement, perception and emotions are of pivotal importance”. The question of how ontologies of concepts can be discovered from sensory data remains as one of the greatest challenges for many interdisciplinary projects on learning of concepts.

The concept approximation problem is the basic problem investigated in machine learning, pattern recognition and data mining \cite{24}. It is necessary to induce approximations of concepts (models of concepts) consistent (or almost consistent) with some constraints. In the most typical case, constraints are defined by a training sample. For more compound concepts, we consider constraints defined by domain ontology consisting of vague concepts and dependencies between them. Information about the classified objects and concepts is partial. In the most general case, the adaptive approximation of concepts is performed under interaction with dynamically changing environment. In all these cases, searching for sub-optimal models relative to the minimal length principle (MLP) is...
performed. Notice that in adaptive concept approximation one of the components of the model should be the adaptation strategy. Components involved in construction of concept approximation which are tuned in searching for suboptimal models relative to MLP are called information granules. In rough granular computing (RGC), information granule calculi are used for construction of components of classifiers and classifiers themselves (see, e.g., [60]) satisfying given constraints. An important mechanism in RGC is related to generalization schemes making it possible to construct more compound patterns from less compound patterns. Generalization degrees of schemes are tuned using, e.g., some evolutionary strategies.

Rough set theory due to Zdzislaw Pawlak [43,44,45,46,17] is a mathematical approach to imperfect knowledge. The problem of imperfect knowledge has been tackled for a long time by philosophers, logicians and mathematicians. Recently it became also a crucial issue for computer scientists, particularly in the area of artificial intelligence. There are many approaches to the problem of how to understand and manipulate imperfect knowledge. The most successful one is, no doubt, the fuzzy set theory proposed by Lotfi A. Zadeh [69]. Rough set theory presents still another attempt to solve this problem. It is based on an assumption that objects and concepts are perceived by partial information about them. Due to this some objects can be indiscernible. From this fact it follows that some sets can not be exactly described by available information about objects; they are rough not crisp. Any rough set is characterized by its (lower and upper) approximations. The difference between the upper and lower approximation of a given set is called its boundary. Rough set theory expresses vagueness relative to the boundary region of a set. If the boundary region of a set is empty, it means that the set is crisp; otherwise, the set is rough (inexact). A nonempty boundary region of a set indicates that our knowledge about the set is not sufficient to define the set precisely. One can recognize that rough set theory is, in a sense, a formalization of the idea presented by Gotlob Frege [23].

One of the consequences of perceiving objects using only available information about them is that for some objects one cannot decide if they belong to a given set or not. However, one can estimate the degree to which objects belong to sets. This is another crucial observation in building the foundations for approximate reasoning. In dealing with imperfect knowledge, one can only characterize satisfiability of relations between objects to a degree, not precisely. Among relations on objects, the rough inclusion relation plays a special role in describing to what degree objects are parts of other objects. A rough mereological approach (see, e.g., [52,59,42]) is an extension of the Leśniewski mereology [31] and is based on the relation to be a part to a degree. It will be interesting to note here that Jan Łukasiewicz was the first who started to investigate the inclusion to a degree of concepts in his discussion on relationships between probability and logical calculi [35].

The very successful technique for rough set methods has been Boolean reasoning [12]. The idea of Boolean reasoning is based on construction for a given problem $P$ a corresponding Boolean function $f_P$ with the following property: