A Preference-Based Multi-Objective Evolutionary Algorithm for Semiautomatic Sensor Ontology Matching

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ABSTRACT

This article describes how with the advent of sensors for collecting environmental data, many sensor ontologies have been developed. However, the heterogeneity of sensor ontologies blocks semantic interoperability between them and limits their applications. Ontology matching is an effective technique to solve the problem of sensor ontology heterogeneity. To improve the quality of sensor ontology alignment, the authors propose a semiautomatic ontology matching technique based on a preference-based multi-objective evolutionary algorithm (PMMOEA), which can utilize the user’s knowledge of the solution’s quality to direct MOEA to effectively match the heterogeneous sensor ontologies. The authors specifically construct a new multi-objective optimal model for the sensor ontology matching problem, propose a user preference-based t-dominance rule, and design a PMMOEA to solve the sensor ontology matching problem. The experimental results show that their approach can significantly improve the sensor ontology alignment’s quality under different heterogeneous situations.

KEYWORDS

Preference-Based Multi-Objective Evolutionary Algorithm, Semantic Sensor Web, Semiautomatic Ontology Matching, T-Dominance Rule,

1. INTRODUCTION

With the advent of sensors for collecting environmental data, many sensor ontologies have been developed. A sensor ontology can be defined as 3-tuple \( (C, P, R) \), where \( C \), \( P \) and \( R \) are respectively the set of classes, properties and relationships, Which can describe the sensors’ capabilities, performance, and usage conditions that allow the discovery of different data depending on the purpose and context (Fernandez et al., 2013). Although sensor ontologies are thought to be a solution to data heterogeneity on the semantic sensor web, the subjectivity of ontology modeling results in the creation of heterogeneous ontologies, which might use different words to name the same concept, use the same word to name different concepts, create hierarchies for a specific domain region with different levels of detail and so on. The arising so-called sensor ontology heterogeneity problem blocks semantic interoperability between various sensor ontologies and limits their applications. Ontology matching is an effective technique to solve the sensor ontology heterogeneity problem by determining the semantically identical entities in heterogeneous sensor ontologies. The obtained sensor ontology alignment \( A \) is a correspondence set, and each correspondence inside is a 4-tuple \( (e, e', n, r) \), where \( e \) and \( e' \) are the entities of two sensor ontologies. \( n \in [0, 1] \) is a confidence value holding for the
correspondence between $e$ and $e'$, and $r$ is the relationship between $e$ and $e'$, which refers to equivalence in this work.

Due to the complex nature of the ontology matching process, evolutionary algorithm (EA) has emerged as a good methodology for computing optimal ontology alignments. However, there exist different aspects of solution that are partially or wholly in conflict, and the single-objective EA may lead to unwanted bias to one of them and reduce the solution’s quality. Multi-objective EA (MOEA) estimates different aspect of solutions simultaneously, and produces a set of solutions which contains a number of non-dominated solutions, none of which can be further improved on any one objective without degrading it in another. Ontology matching based on the MOEA is a recently introduced, innovative, and efficient methodology to address the ontology matching problem (Acampora et al., 2014). However, due to the complexity of the ontology matching process, ontology alignments generated by automatic matching tools should be checked by users (Shvaiko & Euzenat, 2013). The technique causes users and automatic tools to cooperate to create high-quality matching through a process called semiautomatic ontology matching (Falconer & Noy, 2011). To further improve the quality of sensor ontology alignment, it’s necessary to make use of the user’s knowledge of the solution’s quality to guide the automatic ontology matcher’s search direction, and based on this motivation, we propose a preference-based multi-objective evolutionary algorithm (PMOEA)-based semiautomatic ontology matching technique. In particular, our contributions are as follows:

1. A PMOEA-based semiautomatic ontology matching framework is proposed for matching heterogeneous sensor ontologies;
2. A multi-objective optimal model is constructed for the sensor ontology matching problem;
3. A user-preference-based $t$-dominance rule is proposed and a problem-specific PMOEA is designed to effectively solve the sensor ontology matching problem.

The rest of the paper is organized as follows. Section 2 describes related works. Section 3 defines the ontology matching problem. Section 4 provides the details of PMOEA. Section 5 shows the experimental results, and section 6 relates our conclusions.

2. RELATED WORK

2.1. Multi-Objective Evolutionary Algorithm Based Ontology-Matching

2.1.1. Techniques

Since a suitable computation of parameters could be better performed by evaluating the right compromise among different objectives involved in the matching process, approaches based on MOEAs are emerging as an innovative and efficient methodology to address the ontology matching problem.

Acampora et al. first proposed to use Non-dominated Sorting Genetic Algorithm II (NSGA-II) (Deb et al., 2002) to tune the appropriate values for an ontology matching system’s parameters. NSGA-II enables the determination of high-quality ontology alignments. Xue et al. also proposed the use of NSGA-II to determine various non-dominated ontology matching system parameters in terms of recall and precision (Xue et al., 2015). They further proposed new ontology alignment quality measures that do not require experts to provide a reference alignment (Xue et al., 2014), and on this basis, a novel optimal model was constructed for ontology matching. Xue et al. also tried to use the multi-objective evolutionary algorithm based on decomposition (MOEA/D) (Zhang & Li, 2007) to improve the performance of ontology-matching technique based on NSGA-II (Xue et al., 2014b). They presented the decomposition approach of the objective, the encoding mechanism, the problem-specific evolutionary operators and the principle of selecting the representative solutions for different decision-makers. A more recent study (Acampora et al., 2014) compared the performance of NSGA-II, SPEA2 (Zitzler et al., 2001), PESA-II (Corne et al., 2001), OMPPSO (Sierra & Coello,
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