Expert Systems with Applications xxx (2015) xxx–xxx

Contents lists available at ScienceDirect

Expert Systems with Applications

journal homepage: www.elsevier.com/locate/eswa

A novel case adaptation method based on an improved integrated genetic algorithm for power grid wind disaster emergencies

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A R T I C L E I N F O

Article history:
Available online xxxx

Keywords:
Case-Based Reasoning
Case adaptation
Grey relational analysis
Multi-objective genetic algorithms
D/S evidence theory
Wind disaster emergencies

A B S T R A C T

Case adaptation is a challenging and crucial process of Case-Based Reasoning (CBR) for power grid wind disaster emergencies. The statistical adaptation method is a traditional method that is independent of domain knowledge, is easy to implement, but is not proper for the complex system problem. Therefore, the aim of this paper is to propose a novel case adaptation method to address this problem by integrating the multi-objective genetic algorithm with gray relational analysis, called the grey relational analysis-multi-objective genetic algorithms method (GRAMOGA). Compared with the traditional method, GRAMOGA is performed in terms of corresponding relations between the case similarity and emergency plan, indicating a new idea for case adaptation. To improve adaptation accuracy, this paper improved the multi-objective genetic algorithm by using a selection method based on the fitness function. Furthermore, the frame theory is expanded by combining it with the D/S evidence theory, providing a novel method for case description and retrieval with incomplete information. A practical example from the south of Jiangsu demonstrates that GRAMOGA achieves better adaptation performance for power grid wind disaster emergencies. In addition to the practical applications in case adaptation, GRAMOGA can be used as a novel method for expanding the case base.

1. Introduction

In recent years, typhoons have hit the power grid of China many times, which not only greatly harms to economic development but also affects social stability. It has been critical subject for decision makers to make fast decisions according to scenario features and implement rescue and repair work. However, mathematics analysis and statistics methods cannot work perform perfectly during power grid wind disaster emergencies because the problem involves many complex factors and incomplete information. CBR is a type of intelligent decision-making method that features implicit reasoning according to the current state, which gives the method a very strong learning ability and can provide decision support for the problem. However, it is still a challenging task for CBR researchers to accomplish case adaptation. Therefore, the design of a scientific case adaptation method is an important issue for applying CBR to power grid wind disaster emergencies.

Case adaptation of wind disaster emergencies belongs to the typical calculation method of case adaptation methods because it needs to work out the types and numbers of emergency workers and resources. The calculation method for case adaptation can be divided into the indirect case adaptation method and indirect case adaptation method according to the calculation approach (Henrieta, Lenia, Laurenta, & Salomonb, 2014). The former obtains results through adjusted models or formulas (Hu, Qi, & Peng, 2015; Qi, Hu, & Peng, 2015); the latter makes case adaptation a reality with genetic algorithms (Liao, Hannam, Xia, & Zhao, 2012a) neural networks (Callow, Lee, Blumenstein, Guan, & Loo, 2013) and k-NN (Qi, Hu, & Peng, 2012). Among them, the k-NN adaptation method is independent of domain knowledge and easy to implement, but has low-accuracy adaptation results. Although the accuracy of the neural network adaptation method is high, the method needs to create a model in advance. Thus, this method is not suitable for power grid wind disaster emergencies that involve many complex models. Power grid wind disaster emergencies involve many scenario features, of which the comprehensive effect on decision results is calculated through formulas. Therefore, it is very hard to address this problem with simple genetic algorithms (SGA).

Motivated by these observations, in this paper, we propose GRAMOGA to accomplish case adaptation in the CBR for power grid wind disaster emergencies. In GRAMOGA, the multiple object functions include the case similarity function (CSF) and grey relational difference function (GRDF). Among them, CSF is used to ensure that the adapted case (which is the result of GRAMOGA) has a high

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http://dx.doi.org/10.1016/j.eswa.2015.05.042
0957-4174/© 2015 Published by Elsevier Ltd.

similarity with the object case (current emergency case); GRDF is designed to ensure that the grey relational coefficients of the scenario features and decision features in the adapted case are similar to those of similar cases (which have been retrieved from similar cases for adaptation from CBR cases). These two functions can ensure that the adaptation result is a satisfactory and is based on current scenario features. The main contributions of this paper are (see Figs. 1 and 2):

(1) We propose a novel and efficient case adaptation method based on GRAMOGA in CBR for power grid wind disaster emergencies.
(2) We improve multi-objective genetic algorithms by using selection method based on the fitness function and improve the adaptive genetic algorithm, which has been proven to be more effective.
(3) We combine D/S evidence theory with frame theory for more precise case descriptions and retrievals to decrease the disturbance of incomplete information.

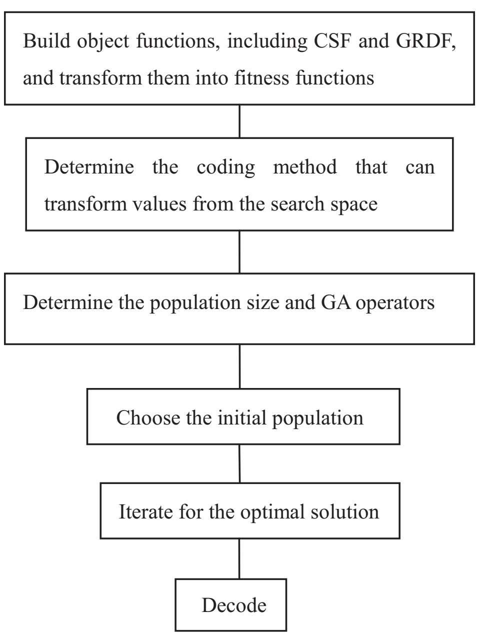

Fig. 1. The flow chart of GRAMOGA.

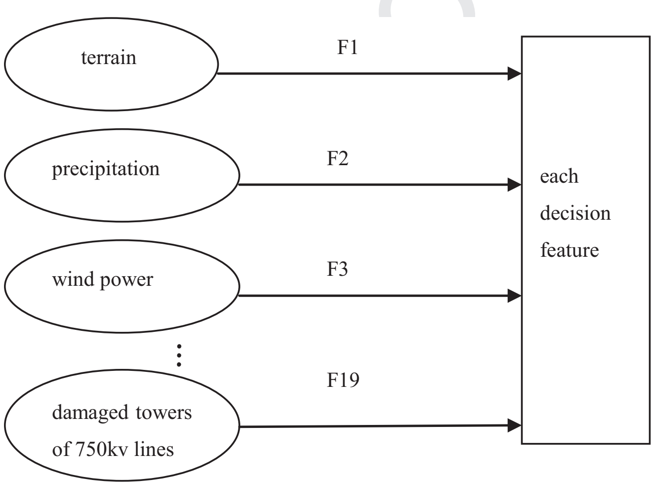

Fig. 2. Functions between scenario features and decision features.

(4) Because GRAMOGA is effective and efficient, it can be treated as another method for expanding the case base of CBR.

The rest of this paper is organized as follows. Section 2 reviews the related work. Section 3 details CBR for power grid wind disaster emergencies, including case representation, case retrieval and the case adaptation method that is based on the improved adaptive genetic algorithm. Section 4 describes extensive experiments to evaluate our proposed algorithm. Section 5 presents discussions and ideas for future improvements. Finally, Section 6 presents the conclusions.

2. Related work

2.1. Case adaptation of CBR

CBR, which was put forward by Schank, is a type of intelligent reasoning method that guides actions based on past experience. Compared with Rule-Based Reasoning and Model-Based Reasoning, CBR focuses more on the implicit reasoning of empirical knowledge and has more practicability (Schank, 1982). A complete CBR process includes case representation, case retrieval, case adaptation and case saves (Ping & et al., 2015; Pla, López, Gay, & Pous, 2013). Most of the papers on CBR focus on case representation (Teodorović, Šelmić, & Mijatović-Teodorović, 2013), case retrieval (Hong, Koo, & Park, 2012; Vukovic, Delibasic, Uzelac, & Suknovic, 2012) and feature-weights learning (Yeow, Mahmud, & Raj, 2014), because case adaptation is still a challenging process in CBR.

In recent years, few studies have focused on case adaptation. At present, there are three types of adaptation styles according to the problem presentation style, including pictures, words and data. Adaptation for pictures is usually applied during physician examinations, transportation and photo taking. An example is that of Esmat, Hossei and Saeid, who employed case adaptation for modifying retrieved images in relevance feedback (Esmat, Hossein, & Saeid, 2014). This type of adaptation involves color design and intelligent calculation. The second type of adaptation aims to address sematic words or processes presented by words. Reyes, Negny, Robles and Lann presented a new methodology for the process engineering domain. In their paper, constraint satisfaction problem algorithms were integrated for adaption, and the modification of the adaptation loop was used for improving performance. This method is appealing, although specific adaptation methods need to be built for the problem that is addressed.

The case adaptations for data are applied in more fields because many natural phenomena and societal problems can be presented though data that is helpful for predictions or judgments. The process of this adaptation style can be performed in two ways: classification and computation. The case adaptation based on classification is often applied to diagnoses, predictions and so on. It compares the object case with the base cases and distinguishes the sample, which belongs to one type or another, following the principle of taking a decision task as a classification task (Amailef, & Lu, 2013). Researchers often achieve case adaptation objects by integrating CBR with intelligent algorithms or technologies, especially data mining (Zhu, Hu, Qi, Ma, & Peng, 2014), supporting vector machines (Pinzón et al., 2013), neural networks (Planton, Dehkordi, & Martel, 2015) and GA (Koo & Hoo, 2015). Although there are many differences in the processes and methods for the classification of these smart technologies, one common characteristic of these processes and methods is determining which values of the object case fall into which category after conducting data analysis and then performing qualitative analysis (Chang, Lin, & Liu, 2012). Computation is another important way to achieve case adaptation. Case adaptations based on computation

Please cite this article in press as: Zhang, B., et al. A novel case adaptation method based on an improved integrated genetic algorithm for power grid wind disaster emergencies. *Expert Systems with Applications* (2015), http://dx.doi.org/10.1016/j.eswa.2015.05.042