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Mathematics and Computers in Simulation 78 (2008) 379–400
MATHEMATICS AND COMPUTERS IN SIMULATION
www.elsevier.com/locate/matcom

Artificial Intelligence techniques: An introduction to their use for modelling environmental systems

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Available online 20 January 2008

Abstract

Knowledge-based or Artificial Intelligence techniques are used increasingly as alternatives to more classical techniques to model environmental systems. We review some of them and their environmental applicability, with examples and a reference list. The techniques covered are case-based reasoning, rule-based systems, artificial neural networks, fuzzy models, genetic algorithms, cellular automata, multi-agent systems, swarm intelligence, reinforcement learning and hybrid systems.
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Keywords: Case-based reasoning; Cellular automata; Multi-agent; Environmental modelling

1. Introduction

Use of Artificial Intelligence (AI) in environmental modelling has increased with recognition of its potential. AI mimics human perception, learning and reasoning to solve complex problems. This paper describes a range of AI techniques: case-based reasoning, rule-based systems, artificial neural networks, genetic algorithms, cellular automata, fuzzy models, multi-agent systems, swarm intelligence, reinforcement learning and hybrid systems. Other arguably AI techniques such as Bayesian networks and data mining [21,148] are not discussed.

2. Case-based reasoning

2.1. Description

Case-based reasoning (CBR) solves a problem by recalling similar past problems [57] assumed to have similar solutions. Numerous past cases are needed to adapt their solutions or methods to the new problem. CBR recognises that problems are easier to solve by repeated attempts, accruing learning. It involves four steps [1] (Fig. 1):

(1) *retrieve* the most relevant past cases from the database;
(2) *use* the retrieved case to produce a solution of the new problem;
(3) *revise* the proposed solution by simulation or test execution; and
(4) *retain* the solution for future use after successful adaptation.

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doi:10.1016/j.matcom.2008.01.028

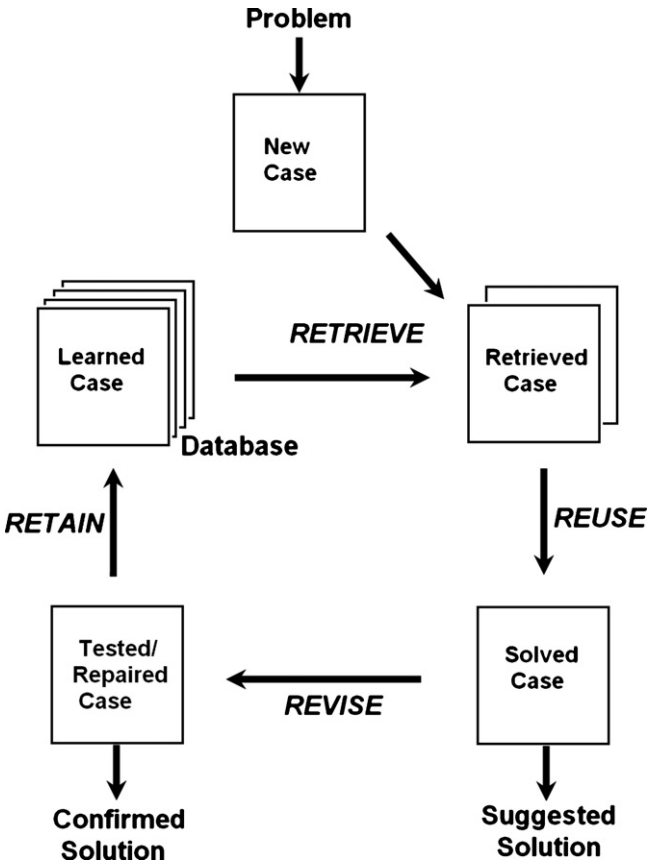

Fig. 1. The CBR four-step process (adapted from [1]).

Retrieval recognises either syntactical (grammatical structure) or semantic (meaning) similarity to the new case. Syntactic similarities tend to be superficial but readily applied. Semantic matching according to context is used by advanced CBR [1]. The main retrieval methods are nearest-neighbour, inductive and knowledge-guided [136].

Nearest-neighbour retrieval finds the cases sharing most features with the new one and weights them by importance. Determining the weight is the biggest difficulty [166]. The method overlooks the fact that any feature's importance, influenced by other features, is case-specific [12]. Retrieval time increases linearly with database size, so the method is time-consuming [166]. The inductive method decides which features discriminate cases best [166]. The cases are organised in a decision tree according to these features, reducing retrieval time. However, the method demands a case database of reasonable size and quality [136]. Knowledge-guided retrieval applies existing knowledge to identify the important features in each case, assessing all cases independently. It is expensive for large databases and thus often used with others [166].

After retrieval, CBR adapts past solutions to the new problem. Adaptation is structural or derivational [166]. Structural adaptation creates a solution to the new problem by modifying the solution of the past case; derivational adaptation applies the algorithms, methods or rules used in the past case to the new case. The proposed solution is then evaluated and revised if necessary. After it is confirmed, the solution is stored in the database. Redundant cases can be removed and existing cases combined [57].

2.2. Discussion

By updating the database, a CBR system continually improves its reasoning capability and accuracy and thus performance. CBR can handle large amounts of data and multiple variables. It organises experience efficiently. However,

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