

Efficient Incremental Algorithm for Building Swiftly Concepts Lattices

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ABSTRACT

Efficient tool and platform for several areas, concept lattice are widely used in many fields of research. Dynamic environment requires an incremental algorithm to build formal concepts. It plays an essential role in the application of concept lattice. This paper presents a fast, efficient, incremental algorithm to compute formal concepts. Algorithmic complexity is studied both theoretically (in the worst case) and experimentally. It presents a complexity of at most $(|M|.|G|.|L|)$ where M is set of attributes, G is set of objects and L is set of concepts of the lattice. Irrespective of the lattice, the algorithm computes incrementally all formal concepts without increasing time complexity. Algorithmic complexity of the most important incremental algorithms is compared theoretically, and an experimental study based on density/sparseness of underlying formal contexts is performed with Norris' algorithm classified the most one efficient incremental in practice.

Keywords: *Algorithm, Algorithmic Complexity, Concept Lattice, Dynamic Environment, Incremental Algorithm*

1. PRELIMINARY

Several approaches (Bendaoud *et al.*, 2008; Huchard *et al.*, 2007) showed how powerful is Formal Concept Analysis (FCA) for data analysis and information extraction (Changsheng *et al.*, 2013) and the lattice is usually considered as the knowledge model (Thao

Tang *et al.*, 2013). Introduced by Barbut and Monjardet (Barbut *et al.*, 1970) and defined as a mathematical classification, the approach was popularized by Wille who used the notion of Galois lattices as a basis for Formal Concept Analysis (Wille, 1982). This method allows the discovery of possible combinations of elements, organized hierarchically, with characteristics

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in common. It proved to be a useful tool in many applied domains: knowledge discovery (Chekol *et al.*, 2013), (Kumar, 2011), (Pfaltz *et al.*, 2002), data mining (Hamrouni *et al.*, 2011), information retrieval (Sakji *et al.*, 2008), web services (Aversano *et al.*, 2006; Azmeh, 2011; Chen, 2008), robotics (Zenou *et al.*, 2004), etc.

The construction of concept lattice of a given binary relation can be made by:

1. The list of formal concepts;
2. The search for partial order relation between concepts;
3. The graphical representation of the lattice (construction of the Hasse diagram corresponding to the lattice).

The first two points are the calculation problem of a lattice of concepts from a formal context and can be performed simultaneously or sequentially. The third point is a problem of graph visualization. Treated independently, these two problems gave rise to two complementary lines of research: The first is to propose algorithms more efficient (complexity, execution time, memory usage, scalability) for the construction of concept lattice and the second is to provide effective tools for the visualization of these lattices (Ben Tekaya *et al.*, 2005).

Depending on the strategy for acquiring data from a set of instances of objects and properties (the formal context), there are three families of lattice construction algorithms:

- The batch algorithms that consider the entire formal context from the start;
- The incremental algorithms that consider an instance (object or property) one at the time;
- The assembly algorithms that divide the context in two, calculate concepts corresponding to each part and then assemble.

The incremental algorithms allow management contexts where the number of objects and / or properties may change without having to recalculate the trellis from scratch follow-

ing a modification of the formal context. The problem of generating the set of all concepts and the concept lattice of a formal context is extensively studied in literature. It is known that the number of concepts can be exponential in the size of the input context.

In this paper we propose a simple and efficient algorithm for construction of concept lattices in dynamic environment such as the web services. The rest of the paper is organized as follows: Section 2 introduces some mathematical foundations of the concepts formal theory. Section 3 discusses in detail the proposed algorithm. Lemmas and rules governing this algorithm are outlined. The section ended with the study of complexity. Section 4 as a second part of this article presents a comparative study of the proposed algorithm with incremental algorithms. First, the algorithmic complexity of the main incremental algorithms that exist in the literature is compared with that of our algorithm. We then present the results of an experimental comparison of the proposed algorithm with the algorithm of Norris. The paper ends with a conclusion in section 5.

2. GENERAL GALOIS LATTICES

In this section we present some basic definitions from the theory of formal concepts:

Definition 1: (formal context) (Ganter *et al.*, 1999)

A formal context is a triple $K = (G, M, I)$ where G is a set of objects, M is a set of properties and I is a binary relation between G and M called incidence relation expressing that an object has a set of properties:

Definition 2: (Godin *et al.*, 2000)

Given a formal context $K = (G, M, I)$ it is possible to define two applications, f and g , by the following formulations:

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