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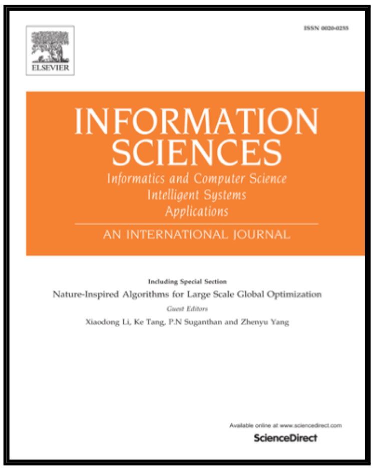

Determinization of fuzzy automata by factorizations of fuzzy states and right invariant fuzzy quasi-orders

Stefan Stanimirović, Miroslav Ćirić, Jelena Ignjatović

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Determinization of fuzzy automata by factorizations of fuzzy states and right invariant fuzzy quasi-orders☆

Stefan Stanimirović, Miroslav Ćirić*, Jelena Ignjatović

University of Niš, Faculty of Sciences and Mathematics, Višegradska 33, 18000 Niš, Serbia

Abstract

In this paper we provide improvements of determinization methods, based on factorization of fuzzy states, for fuzzy finite automata that accept fuzzy languages of infinite range. The improvements are based on the usage of the fuzzy relational calculus, namely, on the usage of the right invariant fuzzy quasi-orders. Our algorithms perform better in the sense that they produce smaller automata, while require the same computation time. In addition, they can produce finite deterministic automata in cases when previous algorithms result in infinite deterministic automata. We show that the weak representable-cycles property is necessary and sufficient condition for determinization of a fuzzy automaton via a maximal factorization of fuzzy states. This condition is more general than the representable-cycles property previously determined as the necessary and sufficient condition for determinization of a fuzzy automaton via a maximal factorization of fuzzy states.

Keywords: Fuzzy automaton; Fuzzy language; Infinite range; Complete deterministic fuzzy automaton; Determinization; Complete residuated lattice;

1. Introduction

Determinization of nondeterministic finite automata (NFAs, for short) is a fundamental problem in automata theory, dating back from [37]. Nondeterministic automata can be determinized by means of a simple, although exponential, subset construction [14], where a state in the determinized automaton is a set of states of the input automaton. Several determinization algorithms based on the subset construction, which are more memory efficient and produce smaller deterministic automata than the subset construction have been provided in [42, 43].

The basic model of NFA has been extended by various researchers, giving rise to automata-based frameworks for new settings. Such generalizations include weighted finite automata (WFAs) and fuzzy finite automata (FFAs), in which transitions, initial and final states take values from certain structures (cf. [12, 32]). For weighted automata these values are called weights, and are usually taken from semirings (such as tropical semirings [31] or hemirings [11]) or even more general structures (for example, strong bimonoids [6, 13]), and for fuzzy automata they are called truth values, and are taken from certain ordered structures, the most often from lattice-ordered structures (like lattice-ordered monoids [24], po-monoids [21], complete distributive lattices [2], general lattices [23] and complete residuated lattices [15, 16, 34–36]).

Unlike NFAs, which can always be determinized, not all WFAs, nor FFAs, can be determinized, and the determinization problem is of special interest in such settings. Over the years, various methods for

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*Corresponding author. Tel.: +38118224492; fax: +38118533014.

Email addresses: stefan.stanimirovic@pmf.edu.rs (Stefan Stanimirović), miroslav.ciric@pmf.edu.rs (Miroslav Ćirić), jelena.ignjatovic@pmf.edu.rs (Jelena Ignjatović)

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