

Hvordan referanser kan etablere
grunnlaget for en artikkel
(og en masteroppgave)

How references may establish a
sound foundation of an article
(and maybe a thesis)

On the Minimality of Finite Automata and Stream X-machines for Finite Languages

FLORENTIN IPATE

*Department of Computer Science and Mathematics, University of Pitesti, Str Targu din Vale 1,
0300 Pitesti, Romania
Email: fipate@ifsoft.ro*

A cover automaton of a finite language L is a finite automaton that accepts all words in L and possibly other words that are longer than any word in L . An algorithm for constructing a minimal cover automaton of a finite language L is given in a recent paper. This paper goes a step further by proposing a procedure for constructing all minimal cover automata of a given finite language L . The concept of cover automaton is then generalized to a form of extended finite automaton, the stream X-machine, and the procedure is extended to this more general model.

Received 8 January 2004; revised 30 September 2004

1. INTRODUCTION

Finite automata [1, 2, 3] are widely used in computing, ranging from lexical analysis to protocol testing. Finite automata are known to accept regular languages [4, 5]. However, in many applications, only finite languages are used. The number of states of a finite automaton (FA) that accepts a finite language is at least one more than the length of the longest word in the language and may be exponentially large. On the other hand, if we do not restrict the FA to accept only the given finite language but also extra words that are longer than the longest word in the language, then the number of its states may be reduced. In most applications the maximum length of words in the language is known and the system of the length of the words processed, so the number of states will usually be adequate. This is the motivation for finite automata for finite languages.

Informally, a cover automaton of a finite language L is an FA that accepts all words in L and possibly other words that are longer than any word in L . A minimal cover automaton of L is a cover automaton of L having the least number of states. In many cases, a minimal cover automaton of L has a much smaller size than the minimal automaton that accepts L .

The concept of minimal cover automaton of a finite language is introduced in [6] and it is shown that there may be several minimal cover automata of the same language that are not isomorphic. Furthermore, [6] provides an algorithm that, for a finite language L (given as an FA that accepts L or as a cover automaton of L), constructs a minimal cover automaton of the language. An improved algorithm (in terms of complexity) is also presented in [7].

This paper goes a step further by giving a procedure for constructing all minimal cover automata of a given finite language.

Finite automata [1, 2, 3]

REFERENCES

- [1] Hopcroft, J. E. and Ullman, J. D. (1979) *Introduction to Automata Theory, Languages and Computation*. Addison Wesley, Reading, MA.
- [2] Salomaa, A. (1969) *Theory of Automata*. Pergamon Press, Oxford.
- [3] Cohen, D. I. A. (1996) *Introduction to Computer Theory* (2nd edn). John Wiley & Sons, New York.

Investigated and techniques for forming given specifications into more complex, more detailed implementation-oriented versions have been developed [14, 15]. Furthermore, several models of communicating SXMs have been devised and used in real applications [16, 17, 18].

One of the strengths of using SXMs to specify a system is that it is possible to derive test sets from an SXM specification which, if satisfied, guarantee, under certain constraints, the correctness of the implementation with respect to the specification [10, 19, 20, 21]. Among these constraints are the so-called 'design for test conditions' that the SXM specification has to meet: input-completeness and output-distinguishability [10, 19]. The class of SXMs that meet these conditions is therefore of particular interest and has

1. INTRODUCTION

Finite automata [1, 2, 3] are widely used in the area of computing, ranging from lexical analysis to protocol testing. Finite automata are known to accept regular languages [4, 5]. However, in many applications of finite automata only finite languages are used. The number of states of a finite automaton (FA) that accepts a finite language is at least one more than the length of the longest word in the language and may be exponentially large in this length [6]. On the other hand, if we do not restrict the automaton to accept only the given finite language but also accept extra words that are longer than the longest word in the language, then the number of its states may be reduced. In most applications the maximum length of words in the language is known and the system will usually be adequate, so such an automaton will usually be adequate. This is the idea behind cover automata for finite languages.

Informally, a cover automaton of a finite language L is an FA that accepts all words in L and possibly other words that are longer than any word in L . A minimal cover automaton of L is a cover automaton of L having the least number of states. In many cases, a minimal cover automaton of L has a much smaller size than the minimal automaton that accepts L .

The concept of minimal cover automaton of a finite language is introduced in [6] and it is shown that there may be several minimal cover automata of the same language that are not isomorphic. Furthermore, [6] provides an algorithm that, for a finite language L (given as an FA that accepts L or as a cover automaton of L), constructs a minimal cover automaton of the language. An improved algorithm (in terms of complexity) is also presented in [7].

regular languages [4, 5].

A system is a type of a machine [8, 9] that describes a system as a finite set of states, each with an internal store called memory, and a number of transitions between the states. A transition is triggered by an input value, produces an output value and may alter the memory. An

[4] Salomaa, K., Yu, S. and Zhuang, Q. (1994) The state complexity of some basic operations on regular languages. *Theoretical Computer Science*, **125**, 315–328.

[5] Yu, S. (1995) *Regular Languages*, *Handbook of Formal Languages*. Springer Verlag.

a specification method, especially for interactive systems. A tool to support the creation of SXM specifications has been constructed [13]. The refinement of SXMs has been investigated and techniques for refining given specifications into more complex, more detailed implementation-oriented versions have been developed [14, 15]. Furthermore, several models of communicating SXMs have been devised and used in real applications [16, 17, 18].

One of the strengths of using SXMs to specify a system is that it is possible to derive test sets from an SXM specification which, if satisfied, guarantee, under certain constraints, the correctness of the implementation with respect to the specification [10, 19, 20, 21]. Among these constraints are the so-called ‘design for test conditions’ that the SXM specification has to meet: input-completeness and output-distinguishability [10, 19]. The class of SXMs that meet these conditions is therefore of particular interest and has

The concept of minimal cover automaton of a finite language is introduced in [6] and it is shown that there may be several minimal cover automata of the same language that are not isomorphic. Furthermore, [6] provides an algorithm that, for a finite language L (given as an FA that accepts L or as a cover automaton of L), constructs a minimal cover automaton of the language. An improved algorithm (in terms of complexity) is also presented in [7].

reduced. In most applications the maximum length of the words in the language of the length of the words will usually be adequate automata for finite languages.

Informally, a cover FA that accepts all words are longer than any word L is a cover automaton. In many cases, a minimal smaller size than the

The concept of minimal cover automaton of a finite language is introduced in [6] and it is shown that there may be several minimal cover automata of the same language that are not isomorphic. Furthermore, [6] provides an algorithm that, for a finite language L (given as an FA that accepts L or as a cover automaton of L), constructs a minimal cover automaton of the language. An improved algorithm (in terms of complexity) is also presented in [7].

by giving a procedure for automata of a given finite in generalized to a form of team X-machines (SXM). [8, 9, 10] that describes es, each with an internal per of transitions between gered by an input value, ay alter the memory. An A (the associated FA) in tion names (the processing bine the dynamic features a structures, thus sharing Various case studies

- [6] Campeanu, C., Santean, N. and Yu, S. (1999) Minimal cover automata for finite languages. *Theoretical Computer Science*, 267, 3–16.
- [7] Paun, A., Santean, N. and Yu, S. (2001) An $O(n^2)$ algorithm for constructing minimal cover automata for finite languages. *LNCS*, 2088, 243–251.

that it is possible to derive test sets from an SXM specification which, if satisfied, guarantee, under certain constraints, the correctness of the implementation with respect to the specification [10, 19, 20, 21]. Among these constraints are the so-called ‘design for test conditions’ that the SXM specification has to meet: input-completeness and output-distinguishability [10, 19]. The class of SXMs that meet these conditions is therefore of particular interest and has

1. INTRODUCTION

Finite automata [1, 2, 3] are widely used in many areas of computing, ranging from lexical analysis to circuit and protocol testing. Finite automata are known to compute regular languages [4, 5]. However, in many applications of finite automata only finite languages are used. The number of states of a finite automaton (FA) that accepts a finite language is at le

language
On the
accept
extra
language
reduce
words
of the
will u
autom
Info
FA tha
are lon

L is a cover automaton of *L* having the least number of states

In many
smaller
The
language
be sever
are not
that, fo
L or as
automat

of complexity) is also presented in [7].

This paper goes a step further by giving a procedure for constructing all minimal cover automata of a given finite language *L*. The procedure is then generalized to a form of extended finite automata, called stream X-machines (SXMs).

An SXM is a type of X-machine [8, 9, 10] that describes a system as a finite set of states, each with an internal store called memory, and a number of transitions between the states. A transition is triggered by an input value, enter the memory. An (the associated FA) in names (the processing the dynamic features pictures, thus sharing Various case studies value of the SXM as interactive systems. M specifications has t of SXMs has been g given specifications mentation-oriented Furthermore, several models of communicating SXMs have been devised and used

This paper goes a step further by giving a procedure for constructing all minimal cover automata of a given finite language *L*. The procedure is then generalized to a form of extended finite automata, called stream X-machines (SXMs).

An SXM is a type of X-machine [8, 9, 10] that describes a system as a finite set of states, each with an internal store called memory, and a number of transitions between the states. A transition is triggered by an input value,

- [8] Eilenberg, S. (1994) *Automata, Languages and Machines*, Vol. A. Academic Press, New York.
- [9] Holcombe, M. (1988) X-machines as a basis for dynamic system specification. *Software Engineering Journal*, 3, 69–76.
- [10] Holcombe, M. and Ipate, F. (1998) *Correct Systems: Building a Business Process Solution*. Springer Verlag, Berlin.

o specify a system is
n SXM specification
certain constraints,
with respect to the
g these constraints
tions' that the SXM
leteness and output-
of SXMs that meet
these conditions is therefore of particular interest and has