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Theory of Machines and Computations



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PREFACE

This volume consists of the papers presented at the International Symposium on the Theory of Machines and Computations, held at Technion-Israel Institute of Technology, Haifa, Israel in August 1971. They are representative of a wide variety of subjects in the areas of computability theory, formal languages, automata theory, and switching theory.

The papers were chosen by an international program committee from a large number of submitted contributions. Each author was responsible for the typing and preparation of his manuscript for the photocopying process by which this volume is printed.

The editors would like to thank the committees' members for their help in the organization of the symposium and the screening of the manuscripts.

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SECTION I
COMPUTABILITY THEORY

DECIDABLE PROPERTIES OF MONADIC FUNCTIONAL SCHEMAS

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Abstract

We define a class of (monadic) functional schemas which properly includes 'Ivanov' flowchart schemas. We show that the termination, divergence and freedom problems for functional schemas are decidable. Although it is possible to translate a large class of non-free functional schemas into equivalent free functional schemas, we show that this cannot be done in general. We show also that the equivalence problem for free functional schemas is decidable. Most of the results are obtained from well-known results in Formal Languages and Automata Theory.

I. Monadic Functional Schemas

An alphabet Σ_S of a (monadic) functional schema S consists of one individual variable x , a finite set of monadic function variables $\{F_i\}$ (with a designated initial function variable F_0), a finite set of monadic function constants $\{f_i\}$, and a finite set of monadic predicate constants $\{p_i\}$. Note that individual constants are not allowed.

The research reported here was supported in part by the Advanced Research Projects Agency of the Office of the Secretary of Defense (SD-183).

A term over Σ_S is any term in the normal sense constructed from the monadic function variables $\{F_i\}$, monadic function constants $\{f_i\}$ and the variable x , e.g., $f_1(F_0(f_2(x)))$. A conditional term over Σ_S is any finite expression of the form

$$\text{if } p_i(x) \text{ then } \tau_1 \text{ else } \tau_2,$$

where p_i is any predicate constant of Σ_S , and τ_1 and τ_2 are any terms or conditional terms over Σ_S . A definition of F_i over Σ_S is of the form

$$F_i(x) \leq \tau,$$

where τ is any term or conditional term over Σ_S . A (monadic) functional schema S (over an alphabet Σ_S) consists of a finite set of definitions over Σ_S , one for each function variable F_i in Σ_S . Whenever the special function variable F_∞ is used, its definition is considered to be $F_\infty(x) \leq F_\infty(x)$. This definition is usually omitted.

Example 1: Let us consider the functional schema S_1 :

$$F_0(x) \leq \text{if } p_1(x) \text{ then if } p_2(x) \text{ then } F_\infty(x) \text{ else } F_1(f_1(x)) \\ \text{else } x$$

$$F_1(x) \leq \text{if } p_3(x) \text{ then } F_0(f_2(x)) \text{ else } f_1(x).$$

Since we are using a very restricted alphabet, parentheses and the individual variable x may be omitted without causing any confusion. Therefore the functional schema S_1 can be rewritten as:

$$F_0 \leq \text{if } p_1 \text{ then if } p_2 \text{ then } F_\infty \text{ else } F_1 f_1 \\ \text{else } I$$

$$F_1 \leq \text{if } p \text{ then } F_0 f_2 \text{ else } f_1,$$

where I stands for the 'identity function'.*/

*/ It is worth noting that most of the results in this paper would be trivial if we did not allow the 'identity function'.

THEORY OF MACHINES AND COMPUTATIONS

An interpretation \mathcal{I} of a functional schema S consists of:

1. a non-empty set of elements D (called the domain),
2. an element f_0 of D used as the initial value of x , and
3. assignments to the constants of Σ_S :
 - (i) a total monadic function (from D into D) for each function constant f_i , and
 - (ii) a total monadic predicate (from D into $\{T, F\}$) for each predicate constant p_i .

For a given interpretation \mathcal{I} , the pair (S, \mathcal{I}) , called a functional program, can be computed by evaluating F_0 with input f_0 in the usual way (see McCarthy [1963]).

The computation either (i) terminates yielding an element of D denoted by $\text{val}(S, \mathcal{I})$, or (ii) diverges (i.e., does not terminate) in which case $\text{val}(S, \mathcal{I})$ is said to be undefined. The method of computation is described more fully later for special types of interpretations called 'Herbrand interpretations'.

A functional schema S is said to terminate/diverge if for every interpretation \mathcal{I} , $\text{val}(S, \mathcal{I})$ is defined/undefined. Two functional schemas S_1 and S_2 are said to be equivalent if for every interpretation \mathcal{I} either both $\text{val}(S_1, \mathcal{I})$ and $\text{val}(S_2, \mathcal{I})$ are undefined or both are defined and $\text{val}(S_1, \mathcal{I}) = \text{val}(S_2, \mathcal{I})$.

The same class of functional schemas has been discussed by DeBakker and Scott [1969].

It is straightforward to show that every functional schema in which any term contains at most one function variable, occurring on the left-hand side of the term (as in Example 1 above), can be translated to an equivalent 'Ivanov' flowchart schema (Ivanov [1960], see also Rutledge [1964]). However, such simple functional schemas as

$$F_0 \Leftarrow \text{if } p \text{ then } I \text{ else } f_1 F_0 f_2$$

have no equivalent Ivanov flowchart schema. Hence, the results in this paper generalize known results about Ivanov flowchart schemas.