

## THE ALGEBRA OF CONTROL MACHINES AND ITS APPLICATIONS TO CONTROL AUTOMATA AND GLUSHKOV'S SYSTEMS

*Andrzej Orlicki*

1-26

**Abstract.** The main result of this paper is the description of the external behaviours of control automata, developing an algebra of these behaviours and making use of these behaviours to obtain the fundamental theorem of programming for the Glushkov system.

**Keywords:** control machine, pushdown control automata, Glushkov's systems, fundamental programming theorem.

## PROGRAMMABLE REAL NUMBERS AND FUNCTIONS

*Kostas Skandalis*

27-56

**Abstract.** In this paper we study the notion of programmability of functions and relations in the sense of algorithmic logic. We introduce a notion of acceptable structure. In acceptable structures a programmable function is a function which is defined by an infinite recursive sequence of cases which happens to be the so called Friedman's schema. The last notion has been introduced as a generalization of a notion of a recursive function for structures which admit pairing system. We apply the technique of Friedman's schemata to study programmability in fields which as we shall prove do not admit pairing systems. We also study some notions of effectiveness of real numbers.

**Keywords:** programmable real function, algorithmic logic, Friedman's schema, recursive reals.

## A COMPARISON OF THE WORST-CASE COMPLEXITIES OF TWO ALGORITHMS FOR THE REACHING DEFINITIONS PROBLEM

*Zbigniew Czech*

57-76

**Abstract.** An algorithm to solve the "reaching definitions" problem on reducible flow graphs is presented. It is based on the concept of a region of a flow graph, and has the worst-case time bound of  $O(n^2)$  bit-vector operations. The algorithm is compared for time complexity with the well-known round-robin version of the iterative algorithm. The comparison shows that for every flow graph of  $n > 2$  nodes the region analysis algorithm for the "reaching definitions" problem requires in the worst case fewer bit-vector operations than the round-robin version of the iterative algorithm for the same problem.

**Keywords:** global program optimization, flow graph, reducibility, region analysis, depth-first spanning tree, data flow analysis, reaching definitions, time complexity.

## GENERALIZED POLYNOMIAL-TIME REDUCIBILITIES, DEGREES AND NP-COMPLETENESS

*Uwe Schöning*

77-82

**Abstract.** An infinite hierarchy of polynomial-time reducibilities is introduced which generalizes the notion of polynomial-time Turing reducibility and strong nondeterministic polynomial-time Turing reducibility.

**Keywords:** polynomial-time reducibility, NP-completeness, polynomial-time hierarchy

## REMARKS ON THE COMPLEXITY OF REGULATED REWRITING

*Jürgen Dassow*

83-103

**Abstract.** We compare the description of languages by context free, Indian parallel, Russian parallel, programmed, matrix, and random context grammars with respect to the number of non-terminals.

**Keywords:** formal language theory, complexity of languages, regulated rewriting

## ROUGH SETS AND INFORMATION SYSTEMS

*Wiktor Marek*

105-116

**Abstract:** We apply rough sets to characterize definable subsets of the universe of the information system.

**Keywords:** approximation space, fuzzy sets, information systems, tolerance theory.

## SOME PROPERTIES OF TRACE LANGUAGES

*Wojciech Rytter*

117-128

**Abstract.** In this paper we present an application of nondeterministic multihead automata to the membership problem for trace languages. Here our result shows that regular and context-free trace languages are not very complicated. On the other hand, we make two simple observations which are the evidence that regular trace languages are very complicated from the algebraic point of view.

**Keywords:** trace languages, time and space complexity, nondeterministic multihead automata

## EXTENDING THE RELATIONAL ALGEBRA FOR RELATIONS WITH MAYBE TUPLES AND EXISTENTIAL AND UNIVERSAL NULL VALUES

*Joachim Biskup*

129-150

**Abstract.** We study operations on generalized database relations which possibly contain maybe tuples and two types of null values. The existential null, value has the meaning "value at present unknown" whereas the universal null value has the meaning "value arbitrary". For extending a usual relational operation to generalized relations we develop three requirements: adequacy, restrictedness, and feasibility. As demonstrated for the natural join as an example, we can essentially meet these requirements although we are faced with a minor tradeoff between restrictedness and feasibility.

**Keywords:** relational algebra, null values, relational data bases.

**RESTRICTING THE IN-OUT STRUCTURE OF GRAPHS OF PETRI NETS.****A language theoretic point of view***Grzegorz Rozenberg, Raymond Verraedt*

151-190

**Abstract.** Petri nets are classified according to the restrictions on the possible in-out structure of nodes of the underlying graphs. Such a classification is investigated separately for the structure of transitions and the structure of places. The classification is done from the language theoretical point of view, i.e. behaviour of a net is expressed by the language it generates. Two approaches are used. Firstly, various classes of nets are compared with respect to the languages of firing sequences they generate. Secondly, the comparison results so obtained are sharpened (often quite drastically) by looking at nets as generators of the so-called subset languages.

**Keywords:** Petri nets, graphs, transition and place restrictions, string language, subset language.

**CLASSES OF TRANSFINITE SEQUENCES. ACCEPTED BY NONDETERMINISTIC FINITE AUTOMATA***Jerzy Wojciechowski*

191-224

**Abstract.** In this paper the notion of a nondeterministic finite automaton acting on arbitrary transfinite sequences is introduced. It is a generalization of the finite automaton on finite sequences and the finite automaton on  $\omega$ -sequences. The basic properties of the behaviour of such automata are proved. The methods are shown how to construct automata accepting classes  $A \cup B, A \cap B, A \circ B, A^*, A^\omega, A^\#$  we have automata accepting classes  $A$  and  $B$ . We prove that if a TF-automaton having  $k$  states accepts anything then it accepts an  $\alpha$ -sequence for a certain,  $\alpha \in \{\sum_{i=0}^m \omega^i \cdot a_i : \sum_{i=1}^m i \cdot a_i + a_0 \leq k\}$ . Using the foregoing fact, we show that the family of classes definable by TF-automata is not closed with respect to the complement operation, that nondeterministic automata are not equivalent to the deterministic ones and that the emptiness problem for TP-automata is decidable. In the last section we show the construction of TP-automata defining sets  $\{*\alpha\}$  for  $\alpha < \omega^\omega$  and having as few states as possible.

**ON THE CONNECTIVITY OF THE PRODUCT OF AUTOMATA***Zamir Bave, Jerzy Grzymala-Busse, Kwang Soo Hong*

225-266

**Abstract.** Our main results include: Sufficient conditions for two strongly connected automata to have a strongly connected product. Sufficient conditions for the product of two connected automata to be connected and sufficient conditions for it to be not connected. Necessary and sufficient conditions for the product of two strongly connected automata, one of which is total, to be strongly connected. Necessary and sufficient conditions that a singly-generated subautomaton of the product be strongly connected. Necessary and sufficient conditions for the existence of an isomorphic copy of an automaton in its product another.

**Keywords:** connected and strongly connected automata, directed product of automata, homomorphisms of automata.

**ON LOCAL CONTROL AND CONFLICT RESOLUTION IN PETRI NETS***Hans-Dieter Burkhard*

267-280

**Abstract.** A certain partition of Transitions in Petri Nets is characterized. This partition makes possible to construct local control which excludes global conflict.

**Keywords:** Petri nets, concurrency.

 **$\omega$ -RULE AND CONTINUITY ON CONNECTIONS BETWEEN ALGEBRAIC SEMANTICS, FIXPOINT SEMANTICS AND ALGORITHMIC LOGIC***Patrice Enjalbert*

281-300

**Abstract.** Some links between algorithmic logic AL and algebraic semantics are examined. We show that the axioms of AL force the functions associated with programs to be fixpoints of the usual functionals, the  $\omega$ -rule being indispensable for forcing the least one.

**Keywords:** order relation, continuity, fixpoint, formal computation trees.

**MODALITIES FOR TOTAL CORRECTNESS***Luis Farinas del Cerro*

301-310

**Abstract.** This paper is concerned with the relationship of termination problem for regular programs to the validity of certain formulas in modal logic.

**Keywords:** modal logic, termination of programs.

**A METHOD FOR SYNTHESIZING ALGEBRAS FROM THEIR SPECIFICATION***Klaus P. Jantke*

311-322

**Abstract.** This paper is concerned with automatic implementation of final algebras. The result states that it is possible under the condition that there is an effective procedure generating all mutually nonequivalent (in the specified algebra) terms.

**Keywords:** final algebras, automatic programming.

**A FORMAL DESCRIPTION OF LISP 1.5 DATA STRUCTURES BY MEANS OF ALGORITHMIC LOGIC***Grażyna Kubica*

323-336

**Abstract.** A formal description of LISP 1.5 data structures is proposed. Algorithmic theory of states, which included all the LISP 1.5 data structures, is defined. By means of operations of this theory we can define each operation of programming language LISA 1.5.

**Keywords:** LISP 1.5, algorithmic theories.

**REMARKS ON THE SHUFFLE OPERATION***Dariusz Leonarski*

337-342

**Abstract.** Shuffle of formal languages and its properties are considered. An application of some results of the shuffle theory to decidability of deadlock and fairness problem in parallel systems is shown.

**Keywords:** shuffle operation, deadlock, fairness, parallel systems.

## ON CERTAIN PROPERTY NOT EXPRESSIBLE IN PAL

*Grażyna Mirkowska*

343-348

**Abstract.** The property of finite degree of nondeterminism is not expressible by a formula and by any set of formulas in propositional algorithmic logic PAL.

**Keywords:** logic of programs, expressiveness, degree of nondeterminism.

## LOGIC FOR STRUCTURED STATES

*Ewa Orłowska*

349-356

**Abstract.** In the paper we suggest an approach to proving global properties of structured states by using languages with special modal operators reflecting an internal structure of these states.

**Keywords:** program logic, modal logic.

## ON SEQUENTIAL FORM OF FUNCTIONAL DYNAMIC LOGICS

*Regimentas Pliuškevičius*

357-358

**Abstract.** A Gentzen-style axiomatization of dynamic logics is proposed. It is compared to other axiom systems for dynamic logics. Some problems of relative decidability are considered.

**Keywords:** dynamic logics, Gentzen-style axiomatization.

## A FORMAL SYSTEM FOR PROVING SOME PROPERTIES OF PROGRAMS IN ITERATIVE COMBINATORY SPACES

*Dymiter Skordev*

359-366

**Abstract.** The paper presents an abstract tool for describing general properties of programs. Iterative combinatory space approach makes possible to transfer recursion - theoretical methods onto logical system which is constructed in this paper.

**Keywords:** iterative combinatory space, normal form theorem.

## ON P NORMAL FORM OF PARALLEL PROGRAM

*Lucjan Stapp*

367-376

**Abstract.** In the last few years parallel programs are intensively studied. But when parallel program is investigated, it is assumed, that only one "cobegin ... coend" ("fork ... join") operation is used (see e.g. [1,2]) in the program schemata. In the paper we introduce the notion of the equivalence relation between parallel programs and then it is proved that it is sufficient to study properties of parallel programs only with one "cobegin ... coend" program connective.

**Keywords:** equivalence of parallel programs, normal form of parallel programs.

## ON AN APPLICATION OF ALGORITHMIC THEORY OF STACKS

*Andrzej Szalas*

377-388

**Abstract.** The fact that for every formula describing properties of programs with recursive functions there exists an equivalent while-formula with stacks is proved in a constructive way. This implies the possibility of using the algorithmic theory of stacks to prove the properties of ALGOL-like programs. The normal forms for such programs are also defined.

**Keywords:** algorithmic logic, algorithmic theory, block-structured program, interpretation of theories, normal forms for programs, recursive functions, relational system, translation.

**ALGORITHMIC LOGIC WITH STACKS AND ITS MODEL-THEORETICAL PROPERTIES***Wiktor Dańko*

391-428

**Abstract.** In this paper we propose to transform the Algorithmic Theory of Stacks (cf. Salwicki [30]) into a logic for expressing and proving properties of programs with stacks. We compare this logic to the Weak Second Order Logic (cf. [11, 15]) and prove theorems concerning axiomatizability without quantifiers (an analogon of Łoś-Tarski theorem) and  $\aleph_0$ -categoricity (an analogon of Ryll-Nardzewski's theorem).

**Keywords:** logics of programs, infinitary logics, categoricity in power, data structures.

**A NOTE ON THE IMPACT OF CONFLICT RESOLUTION TO LIVENESS AND DEAD-LOCK IN PETRI NETS***Hans-Dieter Burkhard, Peter H. Starke*

429-446

**Abstract.** In this paper systems are investigated which consist of a Petri net and a control device. In any situation of the systems the control device selects one (or some) of the (concurrently) enabled transitions of the net and orders them to fire - this way solving conflicts, avoiding deadlocks etc. The results concern the corresponding decidability problems and the question whether it is possible to carry over such properties as deadlock avoidance and liveness from the uncontrolled net to a controlled net and vice versa.

**Key words:** Petri net, conflict resolution, deadlock, liveness, controlled nets, counter machine.

**PROPOSITIONAL LOGICS OF FORMAL LANGUAGES***Slavian Radev*

447-482

**Abstract.** A family of propositional logics of programs with Kripke-style semantics is introduced. A global deductive system is given and the completeness of the logics from that family is proved.

**Keywords:** abstract languages, propositional logics of programs, modal theories, completeness theorem, propositional dynamic logics.

**ON SOME SUBSET OF THE PARTITION SET***Jerzy W. Grzymała-Busse, Zdzisław Pawlak*

483-488

**Abstract.** This paper contains a simple algorithm for minimal partition of a set, which is the departure point to study attribute dependencies in information system (see [3], [6], [7], [9]). Theoretical properties of such partitions have been studied by Log (see [5]) and the proposed algorithm has been implemented by Stevens (see [8]). The implementation shows many practical advantages of the proposed method.

**Keywords:** partition, block, minimal nontrivial partition, minimal number of partitions.

**ON ITERATION IN ROBOT PLANNING***Olga Štěpánková*

489-501

**Abstract.** The paper discusses the role of iteration in robot plans constructed in the framework of predicate logic. It is shown that, unless some special axioms are added, the class of solvable tasks is not enlarged by admitting iteration in plans.

**Keywords:** robot planning, dynamic logic, situation calculus, iteration.