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Abstract

This is a collection of one-page abstracts of recent results of interest to the Complexity community. The purpose of this document is to spread this information, not to judge the truth or interest of the results therein.

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The Directed Planar Reachability Problem

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Abstract Number 05-1

The s-t-connectivity problem for directed graphs is the standard complete problem for nondeterministic logspace (NL). We consider the restriction of this problem to planar graphs. This problem is known to be hard for L under AC^0 reductions, but nothing is known about its complexity beyond the upper bound of NL and the lower bound of L.
We consider the class of problems logspace-reducible to the planar directed s-t-connectivity problem. We show that this class is closed under complement, and contains the s-t-connectivity problems for graphs of genus k for any constant k.
A full paper will be available soon at http://www.cs.rutgers.edu/~allender

Making the Polynomial-Time Hierarchy Look Like the Arithmetic Hierarchy

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Abstract Number 05-2

We give the first relativized world where the polynomial-time hierarchy acts like the arithmetic hierarchy, i.e., for all k, $\Sigma_k^p \neq \Pi_k^p$ and $\Sigma_k^p \cap \Pi_k^p = \Delta_k^p$.

In addition our oracle makes $\mathbf{P} \neq \mathbf{UP}$ and for every **NP** machine M that accepts Σ^*, there is a polynomial-time function f such that $f(x)$ is an accepting path in the computation $M(x)$.

This is also the first relativized world where the latter condition holds and the polynomial-time hierarchy is infinite answering an open question of Fenner, Fortnow, Naik and Rogers.

To create the oracle, we introduce Kolmogorov-generic oracles where the strings placed in the oracle are derived from an exponentially long Kolmogorov-random string.

A full paper will be available soon.

On the Query Complexity of Quantum Learners

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Abstract Number 05-3

This paper introduces a framework for quantum exact learning via queries, the so-called quantum protocol. It is shown that usual protocols in the classical learning setting have quantum counterparts. A combinatorial notion, the general halving dimension, is also introduced. Given a quantum protocol and a target concept class, the general halving dimension provides a lower bound on the number of queries that a quantum algorithm needs to learn. For usual protocols, this lower bound is also valid even if only involution oracle teachers are considered. The general halving dimension also approximates the query complexity of ordinary randomized learners. From these bounds we conclude that any quantum polynomially query learnable concept class must be also polynomially learnable in the classical setting.

A preliminary version is available by email to castro@lsi.upc.edu

Separating the Notions of Self- and Autoreducibility[a]

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Abstract Number 05-4

Recently it was shown that all PSPACE-complete languages (as well as all complete languages for many other classes, including NP) are autoreducible. However, it remains open whether all PSPACE-complete (NP-complete) languages are Turing self-reducible.

This paper considers a simpler version of this question—whether all PSPACE-complete (NP-complete) languages are length-decreasing self-reducible. We show that if all PSPACE-complete languages are length-decreasing self-reducible then PSPACE = P and that the same kind of implication holds for many other natural complexity classes. In particular, if all NP-complete sets are length-decreasing self-reducible then NP = P. We also show that our technique can be applied to L and NL to show that unless L = NL, not all NL-complete sets are logspace length-decreasing self-reducible.

Using the same technique, we show that some PSPACE-complete languages are not logspace length-decreasing self-reducible and that some EXP-complete languages are not polynomial-time length-decreasing self-reducible.

A full paper is available by email to pfali@cs.rochester.edu

[a] This work is supported in part by NSF Grants EIA-0080124, EIA-0205061, and CCF-0426761.

Autoreducibility, Mitoticity, and Immunity

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Abstract Number 05-5

A set L is *many-one autoreducible* if L many-one reduces to L via a reduction f such that $f(x) \neq x$. A set L is *weakly many-one mitotic* if there exists S such that L, $L \cap S$, and $L \cap \overline{S}$ are many-one equivalent. If additionally $S \in$ P, then L is called *many-one mitotic*. The notion of *weak Turing mitoticity* is defined analogously.

We show the following results regarding complete sets.

- NP-complete sets and PSPACE-complete sets are many-one autoreducible.
- Complete sets of any level of PH, MODPH, or the Boolean hierarchy over NP are many-one autoreducible.
- EXP-complete sets are many-one mitotic.
- NEXP-complete sets are weakly many-one mitotic.
- PSPACE-complete sets are weakly Turing-mitotic.
- If one-way permutations and quick pseudo-random generators exist, then NP-complete languages are many-one mitotic.
- If there is a tally language in NP $\cap$ coNP $-$ P, then, for every $\epsilon > 0$, NP-complete sets are not $2^{n(1+\epsilon)}$-immune.

These results solve several of the open questions raised by Buhrman and Torenvliet in their 1994 survey paper on the structure of complete sets.

A full paper is available at ECCC. The report number is TR05-011.

Redundancy in Complete Sets

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Abstract Number 05-6

A set L is *many-one autoreducible* if L many-one reduces to L via a reduction f such that $f(x) \neq x$. A set L is *weakly many-one mitotic* if there exists S such that L, $L \cap S$, and $L \cap \overline{S}$ are many-one equivalent. If additionally $S \in \mathrm{P}$, then L is called *many-one mitotic.* Ambos-Spies, 1984, showed that every many-one mitotic set is many-one autoreducible, and asked whether the converse holds.
We show that every many-one autoreducible set is many-one mitotic. As a corollary we obtain that many-one complete sets for classes such as NP, PSPACE, EXP, NEXP are many-one mitotic.
We show that the equivalence of autoreducibility and mitoticity cannot be extended to more general reductions: We exhibit a sparse set in EXP that is 3-truth-table autoreducible but not weak Turing mitotic.
A complete version of the paper is not yet avialable.

Canonical Disjoint NP-Pairs of Propositional Proof Systems

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Abstract Number 05-7

Razborov, 1994, associated a canonical disjoint NP-pair with every propositional proof system. In this paper, we prove that every disjoint NP-pair is polynomial-time, many-one equivalent to the canonical disjoint NP-pair of some propositional proof system. Therefore, the degree structure of the class of disjoint NP-pairs and of all canonical pairs is identical. Secondly, we show that this degree structure is not superficial: Assuming there exist P-inseparable disjoint pairs, there exist intermediate disjoint NP-pairs. That is, if (A, B) is a P-separable disjoint NP-pair and (C, D) is a P-inseparable disjoint NP-pair, then there exist P-inseparable, incomparable NP-pairs (E, F) and (G, H) whose degrees lie strictly between (A, B) and (C, D). Furthermore, between any two disjoint NP-pairs that are comparable and inequivalent, such a diamond exists. These results are reminiscent of Ladner's result for NP, 1975, and our proof is based on Schöning's formulation, 1982, together with techniques of Regan, 1983 and 1988.

A full paper is available at ECCC. The report number is TR04-106.

The Complexity of the Inertia and some Closure Properties of GapL

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Abstract Number 05-8

The *inertia* of an $n \times n$ matrix A is defined as the triple $(i_+(A), i_-(A), i_0(A))$, where $i_+(A)$, $i_-(A)$, and $i_0(A)$ are the number of eigenvalues of A, counting multiplicities, with positive, negative, and zero real part, respectively. It is known that the inertia of a large class of matrices can be determined in **PL** (*probabilistic logspace*). However, the general problem, whether the inertia of an *arbitrary* integer matrix is computable in **PL**, was an open question. In this paper we give a positive answer to this question and show that the problem is complete for **PL**.
As consequences of this result we show necessary and sufficient conditions that certain algebraic functions like the rank or the inertia of an integer matrix can be computed in **GapL**.

A full paper is available by email to thanh.hoang@uni-ulm.de

Kolmogorov Complexity Leads to a Representation Theorem for Idempotent Probabilities (σ-Maxitive Measures)

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Abstract Number 05-9

In many application areas, it is important to consider σ-maxitive measures (idempotent probabilities), i.e., measures m for which $m(A \cup B) = \max(m(A), m(B))$. Such measure are used in science and engineering to describe rare events, in AI to describe degree of possibility, etc. In his 2003 paper [1], J. H. Lutz has used Kolmogorov complexity to show that for constructively defined sets A, one σ-maxitive measure – fractal dimension – can be represented as $m(A) = \sup\limits_{x \in A} f(x)$. We show that a similar representation is possible for an arbitrary σ-maxitive measure.

Let us start by describing what we mean by a *constructive* set. Intuitively, a set is constructive if there exists a constructive procedure for producing elements of this set. Every procedure has to be described by a finite sequence of instructions, i.e., by a finite sequence of symbols in some alphabet used to describe these instructions. Since there are countably many such sequences, there can only be countably many constructive sets. We thus arrive at the following definition:

Definition 1. *Let X be a set, and let $\mathcal{F} \subseteq 2^X$ be a countable family of subsets of X. Elements of $\mathcal{F}$ will be called* constructive sets.

Definition 2. *By a σ-*maxitive measure *on X, we mean a mapping $m : \mathcal{A} \to R$, where $\mathcal{A} \subseteq 2^X$ is a σ-algebra that contains all constructive sets, and for every sequence of sets $A_i \in \mathcal{A}$, $m\left(\bigcup\limits_{i=1}^{\infty} A_i\right) = \sup\limits_i m(A_i)$.*

Representation theorem. *For every σ-maxitive measure on X, there exists a function $f : X \to R$ such that for every constructive set A, we have $m(A) = \sup\limits_{x \in A} f(x)$.*

The above representation holds also for countable unions of constructive sets. For example, let X be a separable metric space, and let $\mathcal{F}$ be a family of all the open balls of rational radii with centers in x_i. Then, the above representation theorem holds for all open sets.

[1] J. H. Lutz, "The dimensions of individual strings and sequences", *Information and Computation*, 2003, Vol. 187, pp. 49–79.

A full paper is available at http://www.cs.utep.edu/vladik/2005/tr05-20.pdf

If an Exact Interval Computation Problem Is NP-Hard, then the Approximate Problem Is Also NP-Hard: A Meta-Result

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Abstract Number 05-10

One of the main problems of interval computations is, given a function $f(x_1, \ldots, x_n)$ and n intervals $\mathbf{x}_i$, to compute the range $f(\mathbf{x}_1, \ldots, \mathbf{x}_n)$ of possible values of f when $x_i \in \mathbf{x}_i$.

In interval computations, many subclasses of this general problem are NP-hard: e.g., the problem of computing the range of a quadratic function. Usually, once we prove that a problem of computing the exact range is NP-hard, then it later turns out that the problem of computing this range with a given accuracy is also NP-hard.

In theory of computing in general, it is possible that a problem is NP-hard but its approximation is easy to solve. We provide a general explanation why in interval computations, the introduction of approximations does not make the problem much easier.

In general, most proofs of NP-hardness reduce a known discrete NP-complete problem – given a discrete object g, find a discrete object o such that $P(g, o)$ is true (where P can be checked in polynomial time) – to the problem in question. A reduction means that for each g, we form an instance P_g of the corresponding interval computation problem.

In most interval computation proofs, this reduction is usually set up in such a way that:

• the original instance of the discrete problem has a solution if and only if the range $[\underline{r}, \overline{r}]$ of the corresponding interval problem satisfies the inequality $\underline{r} \le a(g)$ (or, alternatively, $\overline{r} \ge a(g)$), where $\underline{r}$ is a rational number, and $a(g)$ is a feasibly computable rational-valued function of g;
• based on a solution o of the discrete problem, we can feasibly compute the values $x_1, \ldots, x_n$ for which $f_g(x_1, \ldots, x_n) \le a(g)$;
• vice versa, if we know the values x_i for which $f_g(x_1, \ldots, x_n) \le a(g)$, then we can feasibly compute a solution o to the original discrete problem.

Also, we usually know that the value $\underline{r}$ is attained at one of the discretely many points $x(d)$, where d is a discrete string of length n, and $x(d)$ is a feasible function of d.

We prove that in this case, the approximate interval computations problem is also NP-hard. Formal definitions are given in the full paper, which is available at http://www.cs.utep.edu/vladik/2005/tr05-21.pdf

2-Local Random Reductions to 3-Valued Functions

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Abstract Number 05-11

Yao (in a lecture at DIMACS Workshop on structural complexity and cryptography) showed that if a language L is 2-locally-random reducible to a *Boolean function*, then $L \in$ PSPACE/poly. Fortnow and Szegedy quantitatively improved Yao's result to show that such languages are in fact in NP/poly (*Information Processing Letters*, 1992).
In this paper we extend Yao's result to show that if a language L is 2-locally-random reducible to a target function which takes values in $\{0, 1, 2\}$, then $L \in$ PSPACE/poly.
A full paper is available by email to the authors.