

On closer inspection - understanding complexity

Or: algorithms, complexity and Peter

Jan van Leeuwen

**Information and Computing
Sciences
Utrecht University**







A special message for Peter ...



First of all, I would like to congratulate Peter van Emde Boas on his very successful career as a computer scientist and thank him for his friendship and our interactions which have enriched my life.

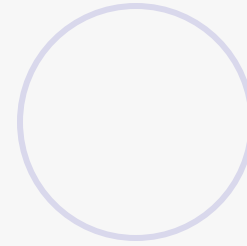
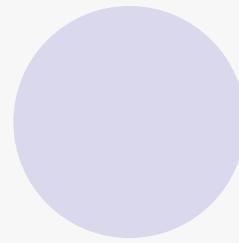
I first met Peter in the early nineteen seventies in Bonn and later at Cornell. These were intellectually exciting days as we explored the foundations of computational complexity.

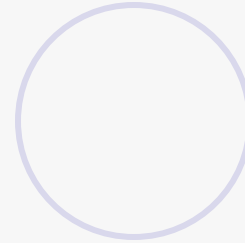
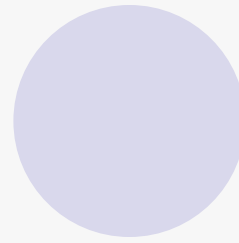
Peter wrote a beautiful dissertation on Abstract Resource-Bounded Classes and I have the honor of being listed as a co-referent and given credit for introducing him to the field of abstract computational complexity theory.

His dissertation had a surprise for me which I did not notice right away. As you may know, Peter is an awed photographer and has enriched many a publication with his photographs. As his thesis lay on my desk, after I had studied it for several days, I looked more carefully at its cover, which originally looked to me like a gray, not very sharp abstract design. To my great surprised and some embarrassment, I recognized that it is a view of the Cornell campus photographed from a low flying airplane. I believe that the airplane was piloted by Bob Constable.

From Cornell, I wish Peter and everyone a great symposium.

Cheers, juris





⑩ Oase:

Friday 16 October 2009 om 15:54 Ah Van Emde Boas, ik heb nog Logische Complexiteit van hem gehad in 1996 of zo. Ik word nu nog wel eens zwetend wakker van het pumping lemma. Jammer dat hij zijn Egghead t-shirt niet aan heeft op de foto op zijn site!

Informatics around 1970 (just a taste):

- Computing, numerical algorithms - software, data processing, process control
- IBM, Bell Labs, UNIX (1969), C (1970), microcomputers (Intel 1968), ARPANET (1969), ...
- *NB*: Microsoft only in 1975, Apple in 1976, *MS Windows* in ..1985, etc
- *Systems*: mainframe architecture (Blaauw 1964), operating systems (Coffman-Denning 1973), communication nets (Kleinrock 1964-1975),...
- *Algorithms and Data structures*: Quicksort (Hoare 1962), Knuth (vol I 1969), Tarjan (DFS 1972), Bron-Kerbosch (1973), Aho-Hopcroft-Ullman (1973),
- *Programming languages*: Algol 68 (two-level grammars), Pascal (Wirth 1971), axiomatic basis and proof rules (Hoare 1969), structured programming (Dijkstra), systematic programming (Wirth 1973) ...
- *Mathematical semantics*: Scott (1970), De Bakker (recursive procedures 1971), ..
- *Automata theory, formal languages, parsing*: Hopcroft-Ullman 1967, L-systems, Aho-Ullman 1972, ..
- *Computability, recursion theory*: Minsky 1967, Rogers 1967, ...
- *Algebraic complexity*: Winograd, Schönhage, Strassen (1969), ..
- *Networks and graph algorithms*: Ford-Fulkerson (1962), Deo (1974), Christofides (1975), Bondy-Murty (1976), ...
- *Operations research, discrete opt.* Dantzig (1963) etc, Klee-Minty (1972), ...
- *Computational complexity*: Rabin-Hartmanis-Stearns (complexity 1965), Blum (abstract compl theory 1966-7), Meyer-Fischer (1972), Cook (P vs NP 1971), Karp (1972), ...
- *NB*: Garey and Johnson published only in 1979, ...

Now it is:

- About designing and creating processes and systems and their interactions with the world.
- Centered around networks, embedded systems and intelligent (agent-based/software) environments.
- *Algorithmic game theory, natural computing (quantum computing), computing by ad hoc networks, etc etc etc.....*

Some Elementary Proofs of Lower Bounds in Complexity Theory

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Submitted by Hans Schneider

ABSTRACT

We introduce a new and easily applicable criterion called rank immunity for estimating the minimal number of multiplications needed to compute a set of bilinear forms in commuting variables. The result is obtained by an elimination argument after canonically embedding computations in a quotient ring R/I , where I is an appropriately chosen ideal that is left invariant under the eliminations. The criterion combines the well-known arguments based on elimination and on row rank, but in contrast to (for instance) column- and mixed-rank arguments it normally leads to better elementary estimates than were derivable in a uniform manner before.

1. INTRODUCTION

Let k be a field, and let x_1, \dots, x_n and y_1, \dots, y_m be distinct and independent commuting indeterminates.

Winograd [25] proved that even in a more general setting, lower bounds on the number of multiplications needed to compute a finite set of bilinear forms $\sum \alpha_i x_i y_i$ over $k \cup \{x_1, \dots, x_n\} \cup \{y_1, \dots, y_m\}$ may be obtained using criteria of linear independence. Fiduccia [11] was probably among the first to notice that fast algorithms for bilinear forms relate to an appropriate matrix decomposition, and in an interesting argument Strassen [24] proved that indeed the minimal number of multiplications needed to compute such forms is exactly equal to the minimal rank of an associated tensor.

Although the tensor rank is certainly an exact bound, it has long been known that in nearly all practical cases it is very hard to compute. Thus Brockett and Dobkin [2, 6] had to go through involved arguments to obtain (for instance) a lower bound of $3n^2 - 3n + 1$ multiplications to form the

MOVE RULES AND TRADE-OFFS IN THE PEBBLE GAME

Peter van Emde Boas and Jan van Leeuwen

NUU-CB-78-4

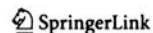
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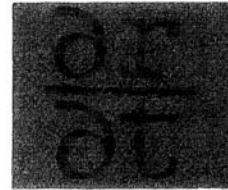
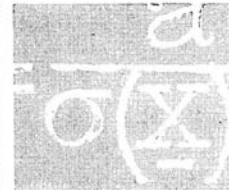
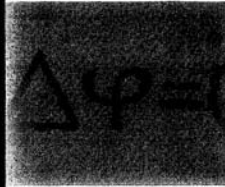
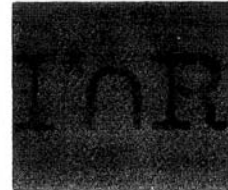
COLLOQUIUM COMPLEXITEIT EN ALGORITMEN

DEEL 2

P.M.B. VITÁNYI (red.)

J. van LEEUWEN (red.)

P. van EMDE BOAS (red.)



MC SYLLABUS



48.2

Colloquium series 1980/81
2 Volumes, published 1982

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Committee PhD defense G.
Tel, Utrecht, Febr 6, 1989



Chairing PhD committee of V. Hollink
University of Amsterdam, Jan 31, 2008,
Photo: J. Liem

A current theme - Information flow in (wireless) networks

- Sensor networks, nodes embedded in the plane
- Edges determined by proximity
- Question: information gathering, sink node t
- Limiting constraint: not 'edge capacity' but energy and sending capacity (range) at nodes
- Batteries small, energy is used, not replenished (limited lifetime)
- Information not held back at the nodes
- Variants: minimize (average) flow time etc.

A current theme - Information flow in (wireless) networks

- Geometric graph vs relaxation to arbitrary graph model, sending range vs arbitrary edge
- Node i : battery energy E_i , transmission to (neighboring or any) node j costs $e_{i,j}$ per unit of flow (all integers)
- Transmission means: receiving and passing on, measured in one cost unit
- **Problem: Maximize (integer) data flow from set of source nodes to t , *subject to the energy constraint.***
- Just another network flow problem?: *NO*

Integer Max-SN Flow

Objective: Max $F = \sum_j f_{j,t}$

Subject to

- $f_{i,j}$ integer
- $f_{i,j} \geq 0$
- $\sum_j f_{i,j} = \sum_j f_{j,i}$ for all non-source nodes i
- $\sum_j f_{i,j} \cdot e_{i,j} \leq E_i$ for all i

Relaxations: arbitrary edges, directed, costs not geometrically induced unless stated, *later.* $f_{i,j}$ arbitrary (i.e. real).

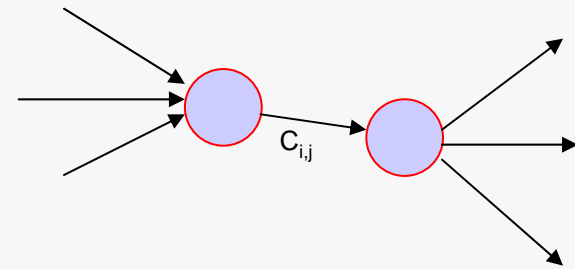
Integer Max-SN Flow

- *Theorem*: The (decision variant of the) Integer Max-SN Flow problem is strongly NP-complete.
(Reduce from 3-Partition)
- Thus: the Integer Max-SN Flow problem has no Fully Polynomial-Time Approximation Scheme (no FPTAS, unless $P = NP$)
- *Theorem*: *Even in the geometric case, with costs $e_{i,j}$ proportional to common Euclidean distance squared: $(loc_i - loc_j)^2$.*
- In the latter case: *even when all E_i equal.*

Integer Max-SN Flow

- **Fact:** if only one 'power setting' at every node, i.e. $e_{i,j} = e_{i,j'}$, then reducible to integer flow and thus polynomial.

Capacity at i : $c_{i,j} = \lfloor E_i / e_{i,j} \rfloor$



- **Theorem:** If (at least) *two* power settings are allowed at every sensor node, then the Integer Max-SN Flow problem has no Polynomial-Time Approximation Scheme (PTAS, unless $P = NP$)

Integer Max-SN Flow

- *Approximability?*
- **Fact:** In polynomial time a solution f_{approx} to the Integer Max-SN Flow problem can be computed with: $f_{approx} \geq f_{Opt} - m$, where $m = \#edges$.
- **Fact:** There is a ρ -approximation algorithm for the Integer Max-SN problem with $\rho = \max_i \{ \max_{i,j} e_{i,j} / \min_{i,j} e_{i,j} \}$.

(Convert the sensor network into a flow network, with unlimited capacity at the edges and capacity $E_i / \max e_{i,j}$ at the nodes i .)
- Constant factor?

Max flow – min ?? cut

- (When a flow is maximum, there is a cutset of nodes that use up all their energy. Not enough.)
- *Fact:* `Maximum flow – min energized nodes theorem`.
- *Approximability?*
- *Theorem:* Let $g_{i,k}$ be the unit transmission cost at i over flow path k . If $\sum_{\text{flow paths } k \text{ through } i} g_{i,k} \leq (1-\alpha)E_i$ for all nodes i , then an integer flow exists (and can be efficiently computed) that has value $\geq \alpha \cdot \text{Opt}$.



STELLINGEN
BEHORENDE BIJ HET PROEFSCHRIFT
ABSTRACT RESOURCE-BOUND CLASSES

VAN
PETER VAN EMDE BOAS

18 SEPTEMBER 1974

18

Het uit de kelder van het Stedelijk Museum afkomstige, niet convexe kunstwerk van C. KORTLANG, dat de Universiteit van Amsterdam heeft opgehangen in de voormalige consistoriekamer, die zij tijdelijk in gebruik heeft als receptieruimte bij oraties en promoties, is noch qua oppervlakte, noch qua uitwerking op diegenen die in deze ruimte vertoeven, in staat het hiaat op te vullen dat ontstaan is na de verwijdering van het voorheen aldaar aanwezige Meesterwerk van A. VAN PELT (1815-1895), voorstellende MAARTEN LUTHER voor de Rijksdag te Worms (1521). De voor het weghalen verantwoordelijke Lutherse gemeente, die handelde op grond van een gerechtvaardigde vrees voor het immer oproerige studentenvolkje, treft in dezen geen blaam.

19

De Weg tot de Wetenschap voert langs een militair complex.

