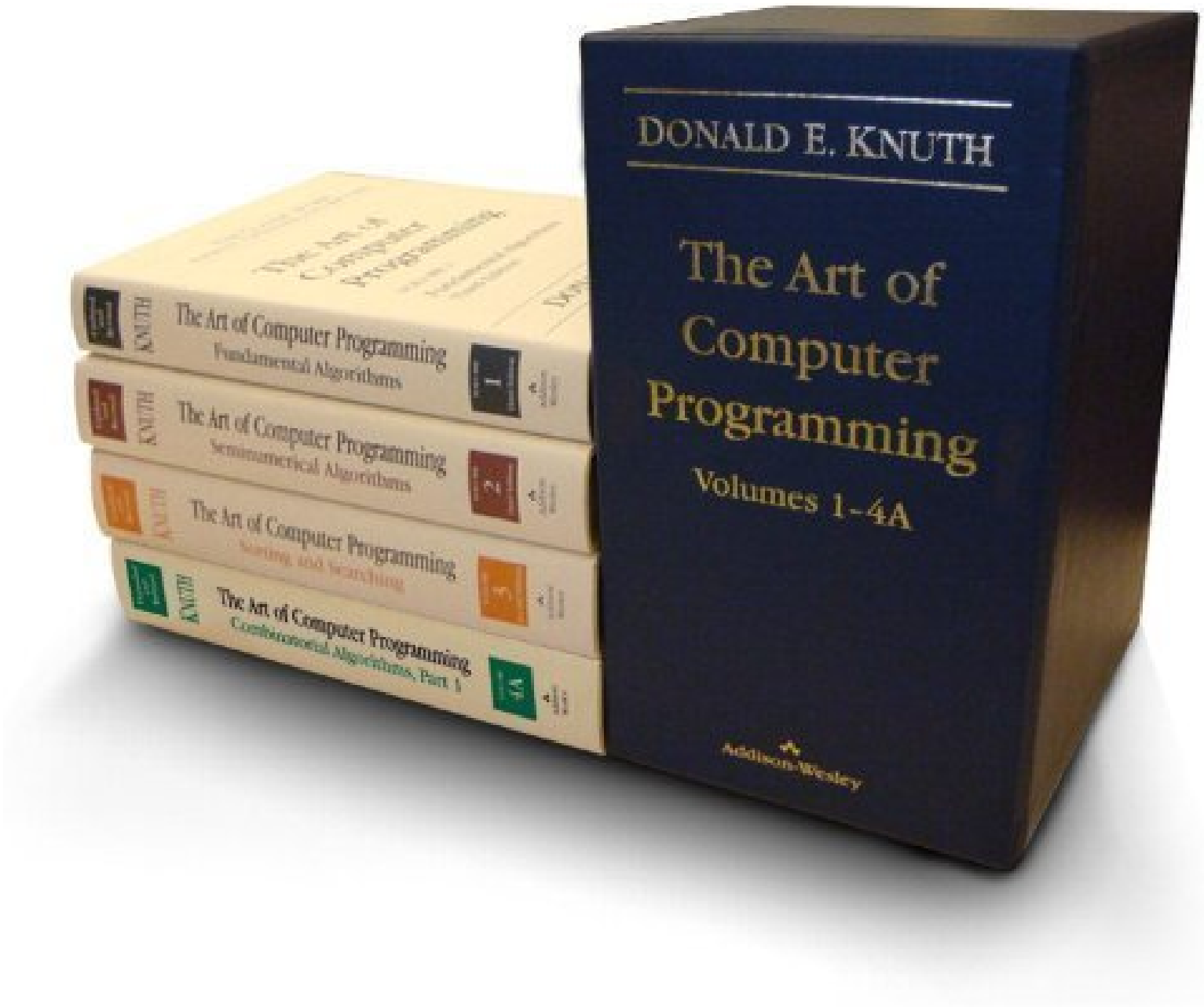
ACM Turing Award Winner 1974: Donald Ervin Knuth

Venkatesh Raman
The Institute of Mathematical Sciences, Chennai

Talk at ACM Chennai Chapter
September 21, 2017

The Turing Award Citation 1974

..... for a number of major contributions to analysis of algorithms and the design of programming languages, and in particular for his most signification contributions to the "art of computer programming" through his series of well-known books. The collection of techniques, algorithms, and relevant theory in these books have served as a focal point for developing curricula and as an organizing influence on computer science.


DONALD E. KNUTH
The Art of Computer Programming
Volumes 1-4A
Addison-Wesley
The Art of Computer Programming
Fundamental Algorithms
The Art of Computer Programming
Seminumerical Algorithms
The Art of Computer Programming
Sorting and Searching
The Art of Computer Programming
Combinatorial Algorithms, Part 1

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  - is part of bible study every Sunday, written a book on Chapter 3, Verse 16 on bible books

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- Left Caltech for a brief stint at the Institute for Defense Analyses' Communications Research Division (NSA/Crypto).

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The TAOCP

- Volume 1 – Fundamental Algorithms, published in 1968, 1969, second edition in 1973, 1974 and third in 1997
- Volume 2 – Seminumerical Algorithms, published in 1969, 1971, second edition in 1981 and third in 1997
- Volume 3 – Sorting and Searching, published in 1973, 1975, second edition in 1998.
- Volume 4A – Combinatorial Algorithms, Part I, 2011.
- Volume 4, Fascicle 6 – Satisfiability, 2015

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- Exercises and Gradings for the problems became important component of the books
- Open problems from the first edition of Volume 3 triggered several PhD theses.
- "Go to" place for most of the material in these volumes.
- In the second edition of Volume 3, in the index, had the names of every author in their native language.

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From: Venkatesh Raman <vraman@imsc.ernet.in>
Message-Id: <199802240654.MAA23860@imsc3.imsc.ernet.in>
To: taocp@CS.Stanford.EDU
Subject: A possible unreported error

Dear Prof Knuth,

I haven't seen the following (possible) error
in Volume 3, reported in your home page. Maybe
it is not an error or already someone has reported
which I couldn't locate.

In section 5.2.3, exercise 35 (Page 159) gives a procedure for
deleting an element (node P) from a leftist heap:

        replace P by merger of left(P) and right(P) and fix the
        distance field of its ancestors.

I don't think it is enough. The tree obtained after replacing
P by merger of left(P) and right(P) need not even be a leftist
tree (not hard to constuct such examples). So, one has to check
the "right distance bigger" condition also and swap "left-right"
subtrees if necessary in the path where we change the distance field,
as you'd do for merge operation. One could do everything in O(log n)
time, of course.

Venkatesh

Thank goodness you reported this on the very day
I was finishing the new Vol 3 ... 24 hours later
would probably have been too late!

I agree that the exercise is badly worded,
although the answer does have this in mind
in the case $d_1 > d_0$.

I have J of Alg and BIT, TCS and Algorithmica

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About your papers: I have J of Alg and BIT, TCS and Algorithmica
but would appreciate reprints from
because they will help me decide what to put in the
3rd edition I had little time for major changes and I cited
edition about 15 years from now. In the 2nd
only your WADS 91 paper where it refers to
heapsort with equal keys. I am now on my way
to the library to see if the WADS 91 paper has a
journal version, in which case I will change the
citation from LNCS to the appropriate j

Cordially don knuth

Research Highlights

Robinson-Schensted-Knuth or RSK correspondence between the set of involutions on n elements and the set of young tableaux on n cells.

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- Permutation – a bijection from S to S (e.g. 34152 is a permutation on 5 elements where 1 is mapped to 3, 2 to 4 etc).

Robinson-Schensted-Knuth or RSK correspondence between the set of involutions on n elements and the set of young tableaux on n cells.

- Let $S = \{1, 2, \ldots n\}$.
- Permutation – a bijection from S to S (e.g. 34152 is a permutation on 5 elements where 1 is mapped to 3, 2 to 4 etc).
- Involution – a permutation π such that $\pi = \pi^{-1}$. (Example: 21345)

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- Knuth gave an algorithmic proof and extended this for permutations on multisets in a 1971 paper.

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- For example $\delta(m, 1) = 1$ and $\delta(m, m) = (1 + 2 + 3 + \ldots m - 1)/m = (m - 1)/2$.
- Computing $\delta(m, n)$ for intermediate values of n is quite non-trivial.

Linear probing analysis – Continued

- For example $\delta(m, 1) = 1$ and $\delta(m, m) = (1 + 2 + 3 + \ldots m - 1)/m = (m - 1)/2$.
- Knuth showed that

$$\begin{aligned} \delta(m, n) &= 1 + (n - 1)/2m + (n - 1)(n - 2)/2m^2 \\ &+ (n - 1)(n - 2)(n - 3)/2m^3 + \ldots \end{aligned}$$

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  which he managed to find a close form to derive the value for $\delta(m,n)$.
- Gave him the idea of "Concrete Mathematics" (a course at Stanford, and he later wrote a book on the subject) where such finite sums are dealt with.

in Problem 1. Replacing r by $-k-2$ gives the desired expansion,

$$S_m = \sum_{k\geq 0}\binom{n+k}{k}\binom{n}{k}\frac{(-1)^k}{k+1}\sum_{j\geq 0}\binom{m}{j}\binom{-k-2}{j}^{-1}.$$

Now the $(k+1)^{-1}$ can be absorbed into $\binom{n}{k}$, as planned. In fact, it could also be absorbed into $\binom{-k-2}{j}^{-1}$. Double absorption suggests that even more cancellation might be possible behind the scenes. Yes — expanding everything in our new summand into factorials and going back to binomial coefficients gives a formula that we can sum on k:

They expect us to check this on a sheet of scratch paper.

$$\begin{aligned} S_m &= \frac{m!\,n!}{(m+n+1)!}\sum_{j\geq 0}(-1)^j\binom{m+n+1}{n+1+j}\sum_k\binom{n+1+j}{k+j+1}\binom{-n-1}{k} \\ &= \frac{m!\,n!}{(m+n+1)!}\sum_{j\geq 0}(-1)^j\binom{m+n+1}{n+1+j}\binom{j}{n}. \end{aligned}$$

The sum over all integers j is zero, by (5.24). Hence $-S_m$ is the sum for $j<0$.

To evaluate $-S_m$ for $j<0$, let's replace j by $-k-1$ and sum for $k\geq 0$:

$$\begin{aligned} S_m &= \frac{m!\,n!}{(m+n+1)!}\sum_{k\geq 0}(-1)^k\binom{m+n+1}{n-k}\binom{-k-1}{n} \\ &= \frac{m!\,n!}{(m+n+1)!}\sum_{k\leq n}(-1)^{n-k}\binom{m+n+1}{k}\binom{k-n-1}{n} \\ &= \frac{m!\,n!}{(m+n+1)!}\sum_{k\leq n}(-1)^k\binom{m+n+1}{k}\binom{2n-k}{n} \\ &= \frac{m!\,n!}{(m+n+1)!}\sum_{k\leq 2n}(-1)^k\binom{m+n+1}{k}\binom{2n-k}{n}. \end{aligned}$$

Finally (5.25) applies, and we have our answer:

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- Build an automata for accepting strings containing x, and then run y on the automata and see if it is accepted.
- Building the automata takes $O(m^3|\Sigma|)$. Knuth, Morris and Pratt came up with a way to compute it in $O(m)$ time. (Running y on the automata takes $O(n)$ time.)

Other highlights

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- $LR(k)$ Grammars (languages accepted by deterministic push down automaton). Practical applications for compiler constructions.

Books

- The Art of Computer Programming Volume 1-3, 4A, 4 fasciciles
- Concrete Mathematics (with Graham and Patashnik)
- Marriages Stables
- Axioms and Hulls

- Surreal Numbers
- Mathematical Analysis of Algorithms
- Mathematical Writing (with Paul Roberts)
- Mathematics for the Analysis of Algorithms

- Stanford GraphBase
- The METAFONTbook
- Computers and Typesetting

- MMIXware
- The CWEB System of Structured Documentation
- Literate Programming
- Digital Typography

- 3:16 Bible Texts Illuminated
- Things a Computer Scientist Rarely Talks About

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- Resulted in
  - the entire board quitting JAlgs and starting an ACM Transactions on Algorithms, and
  - creation of more open access journals

Knuth Prize

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- Awarded since 1996 and includes an award of $ 5000
- Awarded to individuals for their overall impact in the field.
- Awarded in alternation at the ACM STOC and at the IEEE Symposium on FOCS conferences

Yao (1996) Valiant (1997) Lovasz (1999) Ullman (2000) Papadimitriou (2002) Ajtai (2003) Yannakakis (2005) Lynch (2007) Strassen (2008) Johnson (2010) Kannan (2011) Levin (2012) Miller (2013) Lipton (2014) Babai (2015) Nisan (2016) Goldreich (2017)

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- Knuth's co-author on his (last?) paper, Fan Chung says "I thought that I was a perfectionist until I met Don Knuth" (http://www.math.ucsd.edu/ fan/paint/math.html)

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  'The fact that I have to translate my knowledge of this method into something that the machine is going to understand forces me to make that knowledge crystal-clear in my head. Then I can explain it to somebody else infinitely better. The exposition is always better if I have implemented it, ... I wake up in the morning with an idea, and it makes my day to think of adding a couple of lines to my program. It gives me a real high. It must be the way poets feel, or musicians, or painters. Programming does that for me.'

Respect for Software Enginners

‘I used to think there were different kinds of tasks: writing a paper, writing a book, teaching a class, things like that. I could juggle all of those simultaneously. But software was an order of magnitude harder. I could not do that and still teach a good Stanford class.’

Theory and Practice

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(Secret motivation ...)

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... We should make use of the idea of limited resources in our own education. We can all benefit by doing occasional "toy" programs, when artificial restrictions are set up, so that we are forced to push our abilities to the limit. We shouldn't live in the lap of luxury all the time, since that tends to make us lethargic. The art of tackling miniproblems with all our energy will sharpen our talents for the real problems, and the experience will help us to get more pleasure from our accomplishments on less restricted equipment.

About rigor in computer science

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My work on Metafont introduced me to applications where "correctness" cannot be defined. How do I know, for example, that my program for the letter A produces a correct image? I never will; and I've learned to live with that uncertainty. On the other hand, when I implemented the routines that interpret Metafont specifications and draw the associated bitmaps, there was plenty of room for rigor. The algorithms that go into font rendering are among the most interesting I've ever seen.

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Advice for researchers ...

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- 'When my books came out, they were not copies of any other books. They always were something that had not been fashionable to do, but they corresponded to my own perception of what ought to be done. Do not just do trendy stuff. If something is really popular, I tend to think: back off. I tell myself and my students to go with their own aesthetics, what they think is important. Dont do what you think other people think you want to do, but what you really want to do yourself. That has been a guiding heuristic for me all the way through.'

Thank You


I am here.