

Correspondence

Dear Sir,

I read the article by Hannu Erkiö (the Worst Case Permutation for Median-of-Three Quicksort) in the August issue with interest. You may like to receive some further comments on the matter.

While the true worst case is extremely unlikely to occur by chance, some approximations to it are much more plausible and still make the algorithm $O(N^2)$. One example of this is any sequence of the general shape: 1, 2, 3, ..., 999, 1000, 0, 501, 0, 502, 0, 503, ..., 0, 999, 0, 1000. While this is still not likely to occur as a single series, it is quite possible as the concatenation of two sets of data.

There is a very simple modification of this algorithm that effectively eliminates the problem. This may be described as follows:

(1) Whenever a sequence splits into two very unbalanced parts, flag the larger as needing special attention on the next pass. The exact definition of very unbalanced does not matter much, but the following has suitable properties:

length of longer part $> 5 \times (5 + \text{length of shorter part})$;

(2) Before splitting a flagged sequence, swap the two end points with two random points from the middle of the sequence.

This requires a source of random numbers that is essentially independent of the data to be sorted. In practice, very few random numbers are needed, so that their speed is not very important. For example, the above criterion gave the following counts of random numbers used when sorting an array of length 10000:

5 different sets of random values – 26, 32, 33, 23, 35

1 set of random values repeated 5 times – 34, 32, 49, 31, 29

A bad distribution (as described above) – 48, 38, 17, 16, 37

As the amount of extra code obeyed for balanced splits is negligible, this modification is almost exactly the same speed as Singleton's method on well-behaved data, whether random or partially ordered. Timing tests confirm this. The only difference is that the speed of this method is very unlikely to be significantly degraded by difficult distributions.

Asymptotically, this makes the sorting algorithm $O(N \log(N))$ with probability one (in the statistical sense). Even for quite small amounts of data, very poor cases are extremely unlikely. The use of random numbers in Quicksort was originally suggested by Hoare; the present algorithm is different only in that it preserves the good behaviour of Singleton's algorithm on nearly sorted data, and that it uses very few random numbers.

Such a routine has been written and tested. It has been submitted to the NAG library as part of an upgrade to the sorting chapter, and should be available in due course.

Yours sincerely

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Announcements

24–26 MARCH 1986

OAC '86. OAC '86 will be held in Houston, Texas at the newly renovated Astrohall. OAC '86, 'Integrated Systems: Merging Islands of Technology', will present the latest developments in business automation and communications – a complete exhibition covering over 100,000 square feet of exhibit space and featuring the industry's top companies. A full range of technical sessions and Professional Development Seminars are planned to provide a unique business education opportunity to the OAC '86 attendee. A variety of special activities will complete the year's most valuable conference experience for every participant.

Further information may be obtained from:

Catherine Shippert, OAC '86 A.F.I.P.S., 1899 Preston White Drive, Reston, VA 22091, USA.

20–23 MAY 1986

SOCOCO 86, IFAC/IFIP Symposium on Software for Computer Control, Graz, Austria.

For further information contact: Mrs R. Hammer, SOCOCO 86, IIG, Schießstattgasse 4a, A-8010 Graz, Austria.

Call for Papers

17–19 MARCH 1986

ESOP 86, European Symposium on Programming, Saarbrücken. Sponsored by AFCET, AICA, BCS, and GI. Several European computer science organisations have decided to cooperate in establishing an international conference series devoted to all aspects of programming. The first such conference will be held on the campus of the Universität des Saarlandes in Saarbrücken, Federal Republic of Germany.

The following is a (non-exclusive) list of topics to be covered by the conference:

- programming methodology and its linguistic support,
- programming styles, e.g. imperative, functional and predicate programming,
- language implementation issues, e.g. compilers and interpreters,
- foundations, i.e. programming language theory, semantics, concurrency, verification, abstract data types.

Conference Chairmen: Bernard Robinet (Paris) and Reinhard Wilhelm (Saarbrücken). Program Committee: J. Arsac (Paris), G. Ausiello (Roma), D. Björner (Lyngby), H. Ganzinger (Dortmund), C. Girault (Paris), K. Indermark (Aachen), C. H. A. Koster (Nijmegen), R. Milner (Edinburgh), U. Montanari (Pisa), M. Nivat (Paris), M. Paul (München), B. Robinet (Paris), M. Sintzoff (Louvain), R. Wilhelm (Saarbrücken).

Authors are invited to submit 10 copies of a résumé of a paper (between 8 and 12 pages) to

Bernard Robinet, Laboratoire Informatique Théorique et Programmation, Université Paris

VI, 4 Place Jussieu, F-75230 Paris Cedex 05, France.

Deadline for the submission is 15 October 1985; authors will be notified of acceptance or rejection by 1 December 1985; final papers are due 6 January 1986.

14–16 APRIL 1986

International Conference on Text Processing and Document Manipulation, University of Nottingham, England, organised by the Electronic Publishing Specialist Group of the British Computer Society in association with a number of sponsors. The conference is intended primarily for people actively working in the field, but will also provide a number of state-of-the-art surveys for those who wish to find out what is available. An associated exhibition will provide an opportunity for participants to see systems in action.

The conference will cover all aspects of computer document preparation, text processing, and printing. It will include considerations of document design, digital typography, authoring systems, videotex, and electronic publishing. Papers – which should either present original research work or give a comprehensive survey of a particular area – are invited on any topic related to document processing, including the following: Markup languages; Document compilers or interactive document editors; The integration of text, graphics, and images; End-user interfaces; Mathematical text; Document structures; The creation, retrieval, and delivery of documents; Electronic publishing – applications and techniques; Document and type design; Structured editors.

Three copies of papers should be submitted to the Program Committee Chairman (Mrs Heather Brown, Computing Laboratory, The University, Canterbury, Kent CT2 7NF, England) not later than 1 September 1985. All papers will be read by two members of the Program Committee and authors will be notified of acceptance by 15 November 1985. Final copies of accepted papers will be due by 15 January 1986. The Conference Proceedings will be published by the Cambridge University Press, and will be available at the Conference.

Forthcoming Events

12–13 SEPTEMBER 1985

Workshop on Medical Microcomputing Applications, University of Liverpool, covering details of clinical practice and research. *Registration forms for attendance from:* Mr W. A. Corbett, Department of Surgery, University of Liverpool, P.O. Box 147, Liverpool L69 3BX.

25–27 SEPTEMBER 1985

British Pattern Recognition Association, Third International Conference, University of St Andrews, Scotland. Topics: image analysis, computer vision, speech recognition, pattern recognition. Proceedings will be published as a special issue of *Pattern Recognition Letters*, appearing early in 1986.

Further information may be obtained from: British Pattern Recognition Association, Third International Conference, Pattern Re-