

GREAT PAPERS IN COMPUTER SCIENCE: A RETROSPECTIVE

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Abstract:

In 1994 a survey of over a thousand professors of Computer Science was conducted to obtain a list of scholarly papers considered to be the most important in terms of contributions to the field. The resulting 36 still qualify as the greatest papers in Computer Science ever. In this retrospective, the list of papers is revisited.

1. Introduction

In 1994 as a young Assistant Professor of Computer Science at Fairleigh Dickinson University, it was my desire to create a list of important papers in the field. Every one of my colleagues had their favorite papers (and I had my own too), but these lists were inconsistent. Therefore, I resolved to compile a consensus list from as many other professors of Computer Science as I could find.

With a grant from West Publishing Company, and a list of names from their database, I mailed a set of questions to Computer Science professors at various universities in the United States (email was not ubiquitous at this time). I compiled the results and eliminated papers that were cited less than a threshold number of times. I then organized those papers into groups corresponding to the areas listed in the Denning report on the Computer Science Curriculum [Denning, 1989]. The resultant list represented what I believed to be a set of “Great Papers” in Computer Science.

My next step was to obtain copies of these papers (if I did not already have one), a task that proved to be daunting. Many of these papers were hard to find, and at the time, digital libraries were very new and very incomplete, so Internet searching was virtually useless. Instead, I had to scour libraries, or ask colleagues to send papers from their own personal libraries to complete the collections.

2. The Paper List

The list of papers with some annotations was published in 1994 [Laplante, 1994]. In addition to the list of papers further information that was included in the report showed how easy the paper was to obtain at the time (many of these papers are much easier to find today, thanks to comprehensive digital libraries), the appropriate level of the paper (graduate, upper division or lower division undergraduate) and a recommendation as to

how to use the paper in a classroom (either as a summary presentation, classroom discussion, or written summary). The list of papers from the survey is as follows.

1. Algorithms and Data Structures

- (a) Stephen A. Cook, "Complexity of Theorem Proving," *Proceedings of the 3rd Annual ACM Symposium on Theory of Computing*, 1971. pp. 151-158.
- (b) J. Hartmanis and R. E. Stearns, "On The Computational Complexity of Algorithms," *Transaction of the American Mathematical Society*, vol. 117, 1965, pp. 285-306.
- (c) C. A. R. Hoare, "QUICKSORT," *Journal of the British Computer Society*, vol. 5, no. 1, 1962, pp. 10-15, Elliot Brothers, LTD, London.
- (d) M. O. Rabin and D. Scott, "Finite Automata and Their Decision Problems," *IBM Systems Journal*, April 1959, pp. 114-125.

2. Programming Languages

- (a) J. W. Backus, R.J. Beebar, S. Best, R. Goldberg, L. M. Haibt, H. L. Herrick, R. A. Nelson, D. Sayre, P. B. Sheriden, H. Stern, I. Ziller, R. A. Hughes, R. Nutt, "The FORTRAN Automatic Coding System," *Proceedings of the Western Joint Computer Conference*, Los Angeles, 1957, pp. 188-198.
- (b) C. A. R. Hoare, "Axiomatic Basis for Computer Programming," *Communications of the ACM*, vol. 12, no. 10, Oct. 1969, pp. 576-580, 583.
- (c) C. A. R. Hoare and N. Wirth, "An Axiomatic Definition of the Programming Language PASCAL," *Acta Informatica*, vol. 2, no. 4, 1973, Springer-Verlag, pp. 335-355.
- (d) John B. Johnston, "The Contour Model of Block Structured Languages," *ACM SIGPLAN Notices*, vol. 6, no. 2, 1971, pp. 55-82.
- (e) Donald E. Knuth, "On the Translation of Languages from Left to Right," *Information and Control*, vol. 8, no. 6, 1965, pp. 607-639.
- (f) Peter Naur, J. W. Backus, F. L. Bauer, J. Green, C. Katz, J. McCarthy, A. J. Perlis, H. Rutishauser, K. Samelson, B. Vauquouis, J. H. Wegstein, A. van Wijngaarden, and M. Woodger, "Revised Report on the Algorithmic Language ALGOL 60," *Communications of the ACM*, vol. 6, no. 1, 1963, pp. 1-17.

3. Architecture

- (a) John von Neumann, "First Draft of a Report on the EDVAC," Contract W-670-ORD-4926, Moore School of Electrical Engineering, University of Pennsylvania, 1945.
- (b) C. E. Shannon, "Symbolic Analysis of Relay and Switching Circuits," *Transactions of the AIEEE*, vol. 57, 1938, pp. 713-723.
- (c) C. P. Thacker, E. M. McCreight, B. W. Lampson, R. F. Sproull, and D. R. Boggs, "Alto: A Personal Computer," reprinted in Siewiorek, Bell, and Newell, *Computer Structures: Principles and Examples*, pp. 549-572.
- (d) M. V. Wilkes, "The Best Way to Design an Automatic Calculating Machine," Manchester University Computer Inaugural Conference published by Ferranti, Ltd., 1951; reprinted in *Annals of the History of Computers*, vol. 8, no. 2, pp. 118-121.

4. Numerical and Scientific Computing

- (a) A. M. Turing, "On Computable Numbers With An Application To The Entscheidungsproblem, *Proceedings of the London Mathematical Society*, 1936, pp. 230-265, Cambridge University Press.

5. Operating Systems

- (a) E. W. Dijkstra, "Cooperating Sequential Processes," in F. Genuys (ed.), *Programming Languages*, Academic Press, Orlando, Florida, 1968, pp. 43-112.
- (b) E. W. Dijkstra, "Solution of a Problem in Concurrent Programming Control," *Communications of the ACM*, vol. 8, no. 9, Sept. 1965, page 569.
- (c) David Hsiao and Frank Harary, "A Formal System for Retrieval from Files", *Communications of the ACM*, vol. 13, no. 12, Feb. 1970, pp. 67-73.

6. Software Methodology and Engineering

- (a) Frederick P. Brooks, "No Silver Bullet: Essence and Accidents of Software Engineering," *Information Processing '86 (IFIP 86)*, H.-J. Kugler (ed.), North Holland.
- (b) Edsger W. Dijkstra, "Guarded Commands, Nondeterminacy and Formal Derivation of Programs," *Communications of the ACM*, vol. 18, no. 8, Aug. 1975, pp. 453-457.
- (c) Edsger, W. Dijkstra, "Go To Statement Considered Harmful," *Communications of the ACM*, vol. 11, no. 3, March 1968, pp. 147-148.
- (d) C. A. R. Hoare, "Proof of Correctness of Data Representations," *Acta Informatica*, vol. 1, no. 4, 1972, Springer-Verlag, pp. 271-281.
- (e) D. L. Parnas, "On The Criteria To Be Used In Decomposing Systems Into Modules," *Communications of the ACM*, vol. 15, no. 12, Dec. 1972, pp. 1053-1058.
- (f) David L. Parnas and Paul C. Clements, "A Rational Design Process – How and Why to Fake it," *IEEE Transactions on Software Engineering*, vol. 12, no. 2, Feb. 1986, pp. 251-257.
- (g) W. Wulf and Mary Shaw, "Global Variables Considered Harmful," *ACM SIGPLAN Notices*, vol. 8, no. 2, 1973, pp. 28-34.

7. Databases

- (a) A. V. Aho, C. Beeri and J. D. Ullman, "The Theory of Joins in Relational Databases", *ACM Transactions of Database Systems*, vol. 4, no. 3, Sept. 1979, pp. 279-314.
- (b) Peter Pin-Shan Chen, "The Entity Relationship Model – Toward a Unified View of Data", *ACM Transactions of Database Systems*, vol. 1, no. 1, March 1976, pp. 9-36.
- (c) E. F. Codd, "A Relational Model of Data for Large Shared Data Banks," *Communications of the ACM*, vol. 13, no. 6, June 1970, pp. 377-387.

8. Artificial Intelligence and Robotics

- (a) Marvin Minsky, "Steps Toward Artificial Intelligence," *Proceedings of the IRE*, vol. 49, Jan. 1961, pp. 8-30.
- (b) Marvin L. Minsky, "Matter Mind Models", in *Semantic Information Processing*, MIT Press, 1968, pp. 425-432.
- (c) Judea Pearl, "Fusion, Propagation, and Structuring in Belief Networks", *Artificial Intelligence, Elsevier Science Publishing Co. Inc.*, vol. 29, 1986, pp. 241-288.
- (d) A. M. Turing, "Computing Machinery and Intelligence," *Mind*, vol. 59, no. 236, Oct. 1950, pp. 433-460.

9. Human-Computer Communications

- (a) Edsger, W. Dijkstra, Programming considered as a human activity, Proc. IFIP Congress 65, North Holland, 1965, pp. 213-217.

10. History of Computer Science

- (a) John Backus, "Programming in the Nineteen Fifties – some Personal Impressions.", Turing Lecture, IBM.
- (b) James P. Fry and Edgar H. Sibley, "Evolution of Data-Base Management Systems", *ACM Computing Surveys*, vol. 8, no. 1, March 1976, pp. 7-42.
- (c) Dennis M. Ritchie, "The Evolution of the Unix Time-Sharing System," *Proceedings of the Symposium on Language Design and Programming Methodology*, Sydney, Sept., 1979, pp. 23-35.

3. The Great Papers Book

West Publishing was so pleased with the survey results that they asked me to organize a book that included the papers along with retrospective notes from any of the original authors who were still living [Laplante, 1996]. In the case where the authors were not living, or chose not to write the introduction to their papers, an appropriate expert was recruited to do so. The reflection notes of the available original authors are fascinating, and are worth the price of the book and I was honored to be connected to these luminary Computer Scientists in this way.

The Great Papers book, however, was fatally flawed. The Publisher desired to re-typeset each and every paper (rather than use photocopying technology) to achieve a uniform look for the book. The idea had merit, but due to the complexities of rekeying the text and especially several unique special symbols that were employed by some of the authors, many typographical errors were introduced. Inadequate proofreading and a rush to publish caused these errors to remain in the final copy. I was heartbroken by these errors and so were some of the original authors – I received a few notes of disappointment from them, including a courteous but firm reproach from Edsger Dijkstra, apparently written with his famous Mont Blanc pen. Sales of the book suffered, and it was never reprinted. It can be obtained now only through resellers.

Still, the value of the book is not completely diminished, and I am reminded that many antiques do not lose value even though they rust or become tattered. In fact, because the book contains several papers that are still hard to find in original form, these are often cited by other authors as "found in *Great Papers In Computer Science*, Laplante, West Publishing, 1994," and not from their original sources.

4. Conclusion

I am sometimes asked if there are new papers that should be added to the list, or if some of the papers from the old list should be removed. To the latter point, my answer is always "no". The papers that were selected in 1994 are still important today, even if only for historical value. As for new papers to add to the list, I would add the following three papers:

- (a) Zadeh, L., Fuzzy Sets, *Information Control* 8, 1965, pp. 338-353.

- (b) T. McCabe, "A Complexity Measure," *IEEE Trans. Software Engineering*, December 1976, pp. 308–320.
- (c) S.R. Chidamber, and C.F. Kemerer, "A Metrics Suite for Object Oriented Design," *IEEE Trans. Software Engineering*, June 1994, pp. 476–493.

Zadeh's paper is in the list because it laid the foundation for the entire field of fuzzy logic, which has immense theoretical and practical implications to many computing paradigms. McCabe's paper is included because it is one of the oldest papers on the quantitative measure of computer programs that is still regularly cited today. Finally, Chidamber and Kemerer's paper is included because it has spawned entire industries of tools and methodologies surrounding best practices in object-oriented programming, and this paper is cited frequently today too.

Of course, these additions are based on my opinion only and I am sure there are several other worthy papers. But a new survey should probably be conducted to get the list right. But I'll leave that task to another young Assistant Professor somewhere else.

References

1. Peter Denning, et al, "Computing as a Discipline," *IEEE Computer Journal*, vol. 22, Feb. 1989, pp. 63-70.
2. Phillip A. Laplante, "A Reading List of Classic Papers for Computer Science Majors," *Mathematics and Computer Science Education*, vol. 28, no. 2, Spring 1994, pp. 198-204.
3. Phillip A. Laplante (editor), *Great Papers in Computer Science*, West Publishing, 1996.