The Scientific Literature

John Hughes

Operating Systems R. Stockton Gaines Editor

Time, Clocks, and the Ordering of Events in a Distributed System

Leslie Lamport
Massachusetts Computer Associates, Inc.

The concept of one event happening before another in a distributed system is examined, and is shown to define a partial ordering of the events. A distributed algorithm is given for synchronizing a system of logical clocks which can be used to totally order the events. The use of the total ordering is illustrated with a method for solving synchronization problems. The algorithm is then specialized for synchronizing physical clocks, and a bound is derived on how far out of synchrony the clocks can become.

Key Words and Phrases: distributed systems, computer networks, clock synchronization, multiprocess systems

CR Categories: 4.32, 5.29

Introduction

The concept of time is fundamental to our way of thinking. It is derived from the more basic concept of the order in which events occur. We say that something happened at 3:15 if it occurred *after* our clock read 3:15 and *before* it read 3:16. The concept of the temporal ordering of events pervades our thinking about systems. For example, in an airline reservation system we specify that a request for a reservation should be granted if it is made *before* the flight is filled. However, we will see that this concept must be carefully reexamined when considering events in a distributed system.

This work was supported by the Advanced Research Projects Agency of the Department of Defense and Rome Air Development Center. It was monitored by Rome Air Development Center under contract number F 30602-76-C-0094.

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execution of a single machine instruction could be one

The Semantic Elegance of Applicative Languages

D. A. Turner

University of Kent at Canterbury

In what does the alleged superiority of applicative languages consist? In the last analysis the answer must be in terms of the reduction in the time required to produce a correct program to solve a give problem. On reflection I decided that the best way to demonstrate this would be to take some reasonably non-trivial problem and show how, by proceeding withi a certain kind of applicative language framework it was possible to develop a working solution with a fraction of the effort that would have been necessary in a conventional imperative language. The particular problem I have chosen also brings out a number of general points of interest which I shall discuss briefly afterwards.

Before proceeding it will be necessary for me to quickly outline the language framework within which we shall be working. Very briefly it can be summarised as (non-strict, higher order) recursion equations + set abstraction. Obviously what matters are the underlying semantic concepts, not the particular syntax that is used to express them, but for the sake of definiteness I shall use the notation of KRC (= "Kent Recursive Calculator"), an applicative programming system implemented at the University of Kent [Turner 81]. KRC is fairly closely based on the earlier language SASL, [Turner 76], but I have added a facility for set abstraction.

The 1977 ACM Turing Award was presented to John Backus at the ACM Annual Conference in Seattle, October 17. In introducing the recipient, Jean E. Sammet, Chairman of the Awards Committee, made the following comments and read a portion of the final citation. The full announcement is in the September 1977 issue of *Communications*, page 681.

"Probably there is nobody in the room who has not heard of Fortran and most of you have probably used it at least once, or at least looked over the shoulder of someone who was writing a Fortran program. There are probably almost as many people who have heard the letters BNF but don't necessarily know what they stand for. Well, the B is for Backus, and the other letters are explained in the formal citation. These two contributions, in my opinion, are among the half dozen most important technical contributions to the computer field and both were made by John Backus (which in the Fortran case also involved some colleagues). It is for these contributions that he is receiving this year's Turing award.

The short form of his citation is for 'profound, influential, and lasting contributions to the design of practical high-level programming systems, notably through his work on Fortran, and for seminal publication of formal procedures for the specifications of programming languages.'

The most significant part of the full citation is as follows:

'. . . Backus headed a small IBM group in New York City during the early 1950s. The earliest product of this group's efforts was a high-level language for scientific and technical computations called Fortran. This same group designed the first system to translate Fortran programs into machine language. They employed novel optimizing techniques to generate fast machine-language programs. Many other compilers for the language were developed, first on IBM machines, and later on virtually every make of computer. Fortran was adopted as a U.S. national standard in 1966.

During the latter part of the 1950s, Backus served on the international committees which developed Algol 58 and a later version, Algol 60. The language Algol, and its derivative compilers, received broad acceptance in Europe as a means for developing programs and as a formal means of publishing the algorithms on which the programs are based.

In 1959, Backus presented a paper at the UNESCO conference in Paris on the syntax and semantics of a proposed international algebraic language. In this paper, he was the first to employ a formal technique for specifying the syntax of programming languages. The formal notation became known as BNF—standing for "Backus Normal Form," or "Backus Naur Form" to recognize the further contributions by Peter Naur of Denmark.

Thus, Backus has contributed strongly both to the pragmatic world of problem-solving on computers and to the theoretical world existing at the interface between artificial languages and computational linguistics. Fortran remains one of the most widely used programming languages in the world. Almost all programming languages are now described with some type of formal syntactic definition.' "

Can Programming Be Liberated from the von Neumann Style? A Functional Style and Its Algebra of Programs

John Backus
IBM Research Laboratory, San Jose

Conventional programming languages are growing ever more enormous, but not stronger. Inherent defects at the most basic level cause them to be both fat and weak: their primitive word-at-a-time style of programming inherited from their common ancestor—the von Neumann computer, their close coupling of semantics to state transitions, their division of programming into a world of expressions and a world of statements, their inability to effectively use powerful combining forms for building new programs from existing ones, and their lack of useful mathematical properties for reasoning about programs.

An alternative functional style of programming is founded on the use of combining forms for creating programs. Functional programs deal with structured data, are often nonrepetitive and nonrecursive, are hierarchically constructed, do not name their arguments, and do not require the complex machinery of procedure declarations to become generally applicable. Combining forms can use high level programs to build still higher level ones in a style not possible in conventional languages.

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Comprehensive Comprehensions
mon Peyton Jones, Microsoft Research
Philip Wadler, University of Edinburgh

My First Little Scientific Article

Little Old Me
Chalmers University, Göteborg, Sweden.
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Abstract

In 2009, Claessen et al. presented a way of testing for race conditions in Erlang programs, using QuickCheck to generate parallel tests, a randomizing scheduler to provoke races, and a sequential consistency condition to detect failures of atomicity [1]. That work used a small industrial prototype as the main example, showing how two race conditions could be detected and diagnosed.

In this paper, we apply the same methods to dets, a vital component of the mnesia database system, and more than an order of magnitude larger. dets is known to fail occasionally in production, making it a promising candidate for a race condition hunt. We found five race conditions with relatively little effort, two of which may account for the observed failures in production. We explain how the testing was done, present most of the QuickCheck specification used, and describe the problems we discovered and their causes.

Categories and Subject Descriptors D [*1*]: 1; D [*1*]: 3; D [2]: 5; H [2]: 4

General Terms Experimentation, Reliability, Verification

Keywords Erlang, QuickCheck

1. Introduction

In October, 2007, Torbjörn Törnkvist wrote the following on the "erlang questions" mailing list:

> *"We know there is a lurking bug somewhere in the dets code. We have got 'bad object' and 'premature eof' every other month the last year. We have not been able to track the bug ... dets files is repaired automatically next time ...*

... tered at Klarna, a ... services to

they could be used to find race conditions in the dets code. The answer turned out to be "yes", and in this paper we describe how the testing was done, and the race conditions that we found.

2. An overview of dets

dets allows the developer to store a collection of Erlang tuples in a file. Each tuple contains a *key*—by default the first element, but the element used as the key can be configured—and dets provides functions to retrieve tuples by key, delete them by key, and so on. dets tables may be either *sets*, in which case each key value may appear once in the table, or *bags*, in which case any number of tuples may contain the same key. Whether a dets table is a set or a bag is specified by an option when the table is opened.

Internally, dets organizes data as a linear hash list, which grows gracefully as more data is inserted into the table—hash buckets which become too full are split on demand. Space in the file is managed using a buddy system. The implementation is fairly complex, running to over 6,000 lines of code.

dets provides a rich API with over 40 functions, supporting table traversals of various kinds, including incremental traversals. Concurrent access and modification is supported too (although care is needed during incremental traversals). However, we restricted our tests to a small subset of critical operations, focussing on the insertion, retrieval, and deletion of tuples:

- `open_file(Name, Args) -> {ok, Name} | {error, Reason}`, which opens a dets file with the given name and options. The only option we specified was the table type, either `set` or `bag`.
- `close(Name) -> ok | {error, Reason}`, which closes the file again.
- `insert(Name, Objects) -> ok | {error, Reason}`, which where `Objects` can be either a tuple or a list of tuples, which inserts the objects into the table named `Name`.
- `...new(Name, Objects) -> Bool`, ... ples and returns `true` provided none of the ... table.
- ... `...or, Reason}`,

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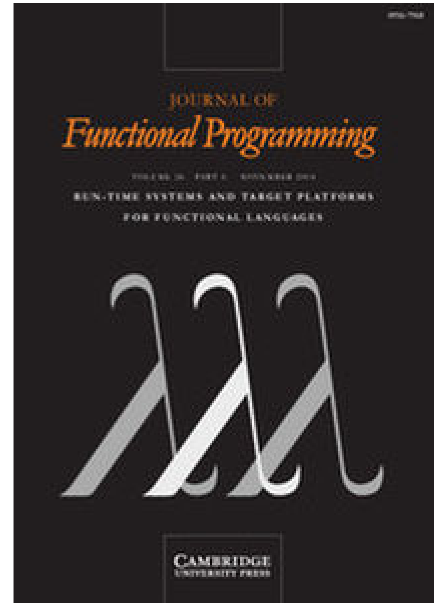

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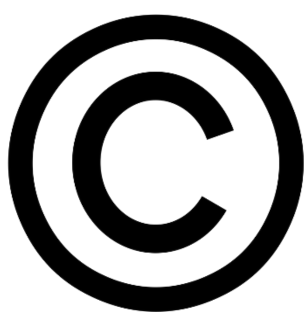

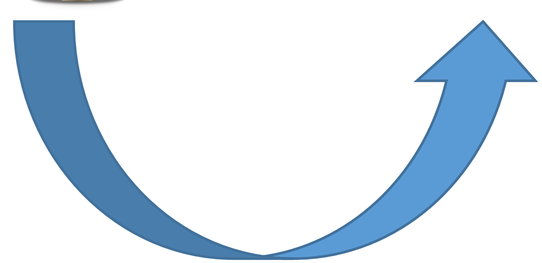

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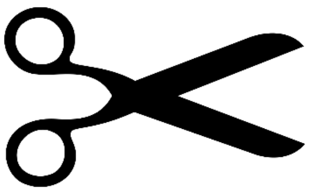

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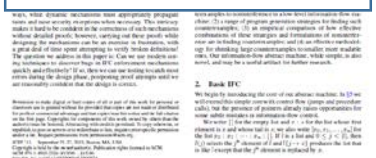

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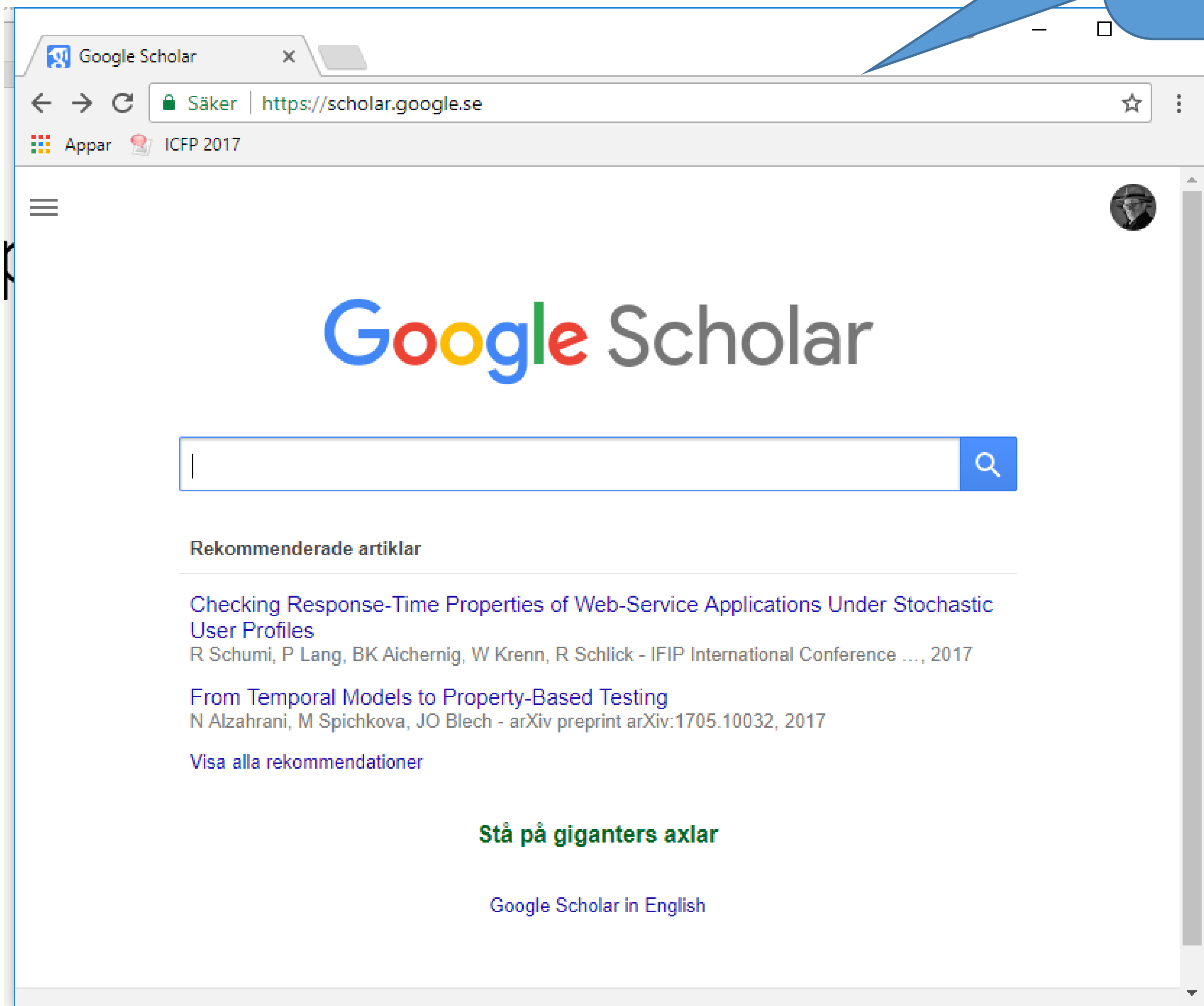

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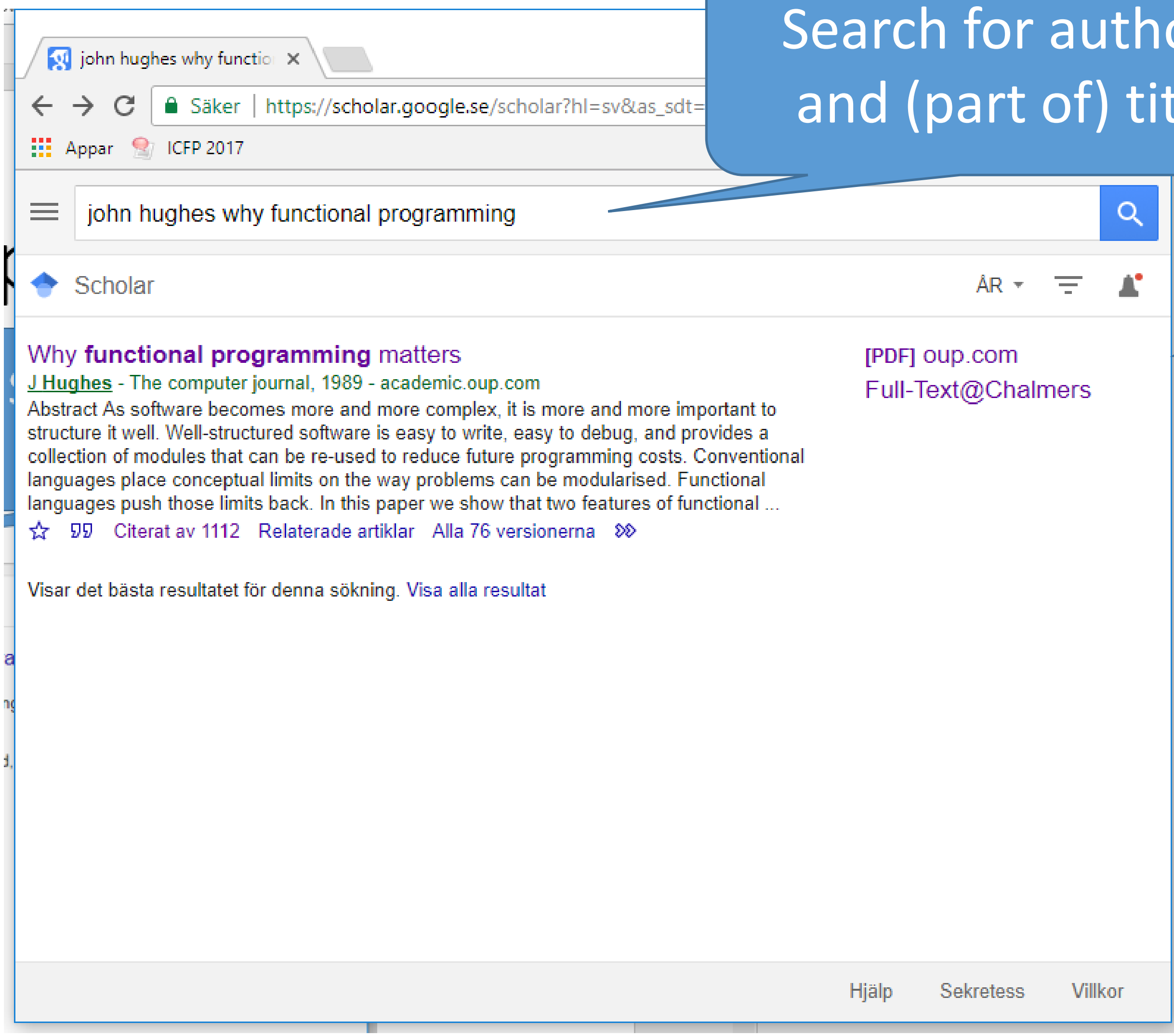

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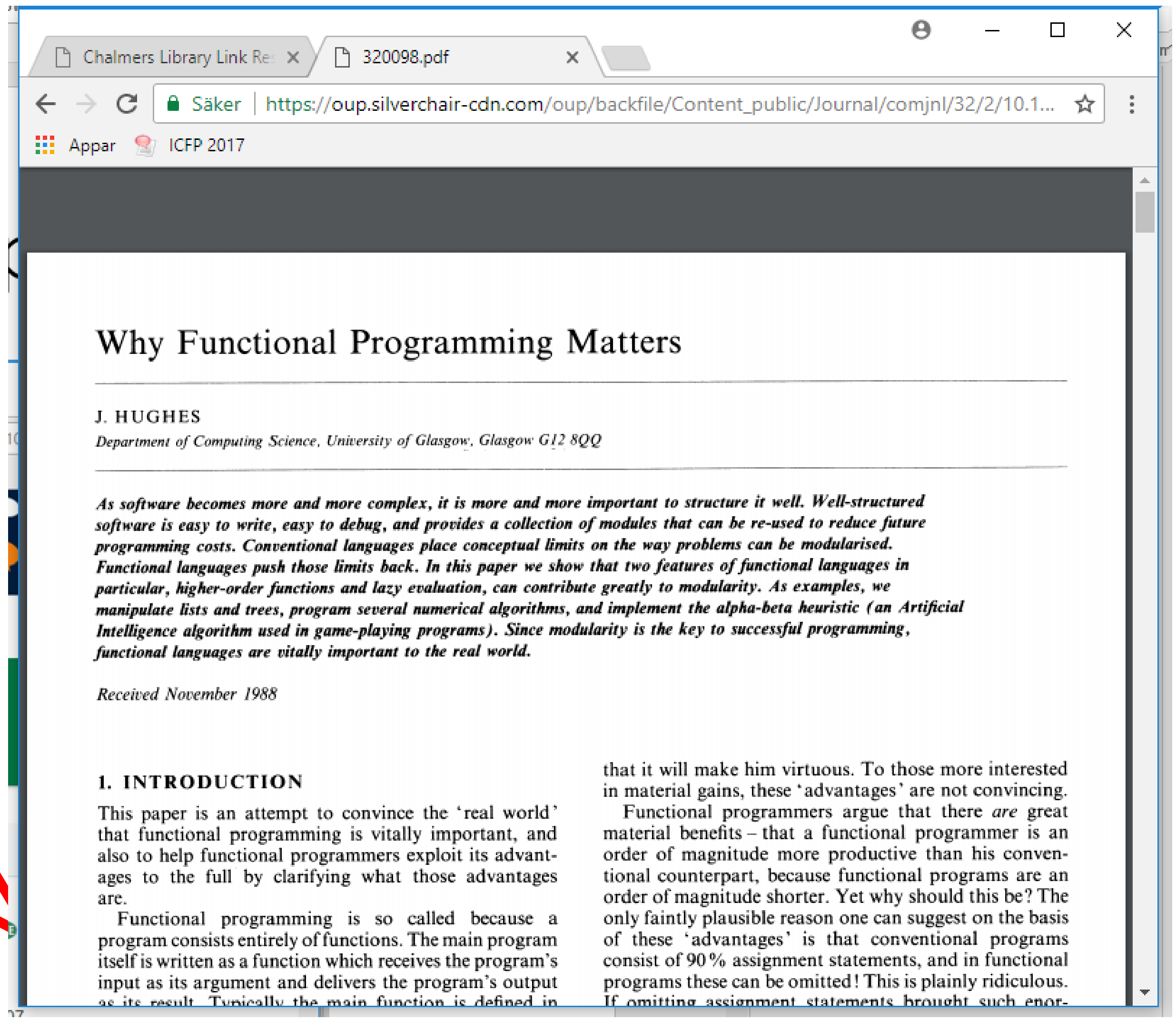

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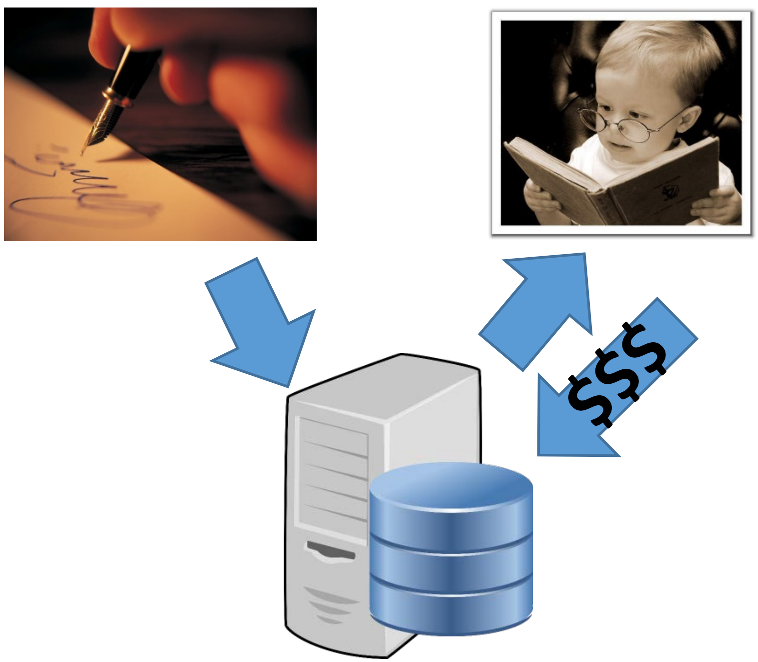

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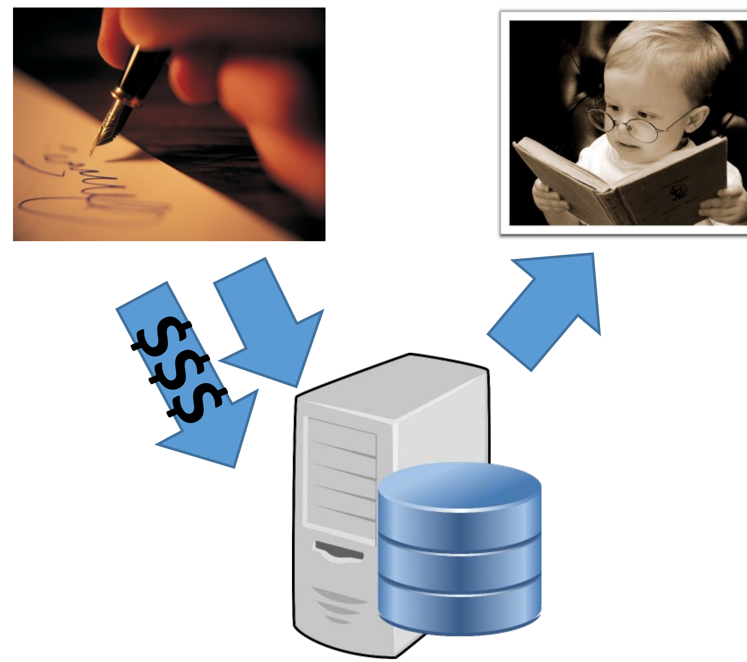

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ABSTRACT

Many physicists would agree that, had it not been for congestion control, the evaluation of web browsers might never have occurred. In fact, few hackers worldwide would disagree with the essential unification of voice-over-IP and public-private key pair. In order to solve this riddle, we confirm that SMPs can be made stochastic, cacheable, and interposable.

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Citations

…
results in higher-order functions. Hughes makes a slightly different but equally compelling argument in **Hughes [1984]** where he emphasizes the importance of
…

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HUGHES, J. 1984. Why functional programming matters. Tech. Rep. 16. Programming Methodology Group, Chalmers University of Technology.

…
This insight has been described more appropriately by **Hughes**, Thompson, and surely others [**19**,33].
…

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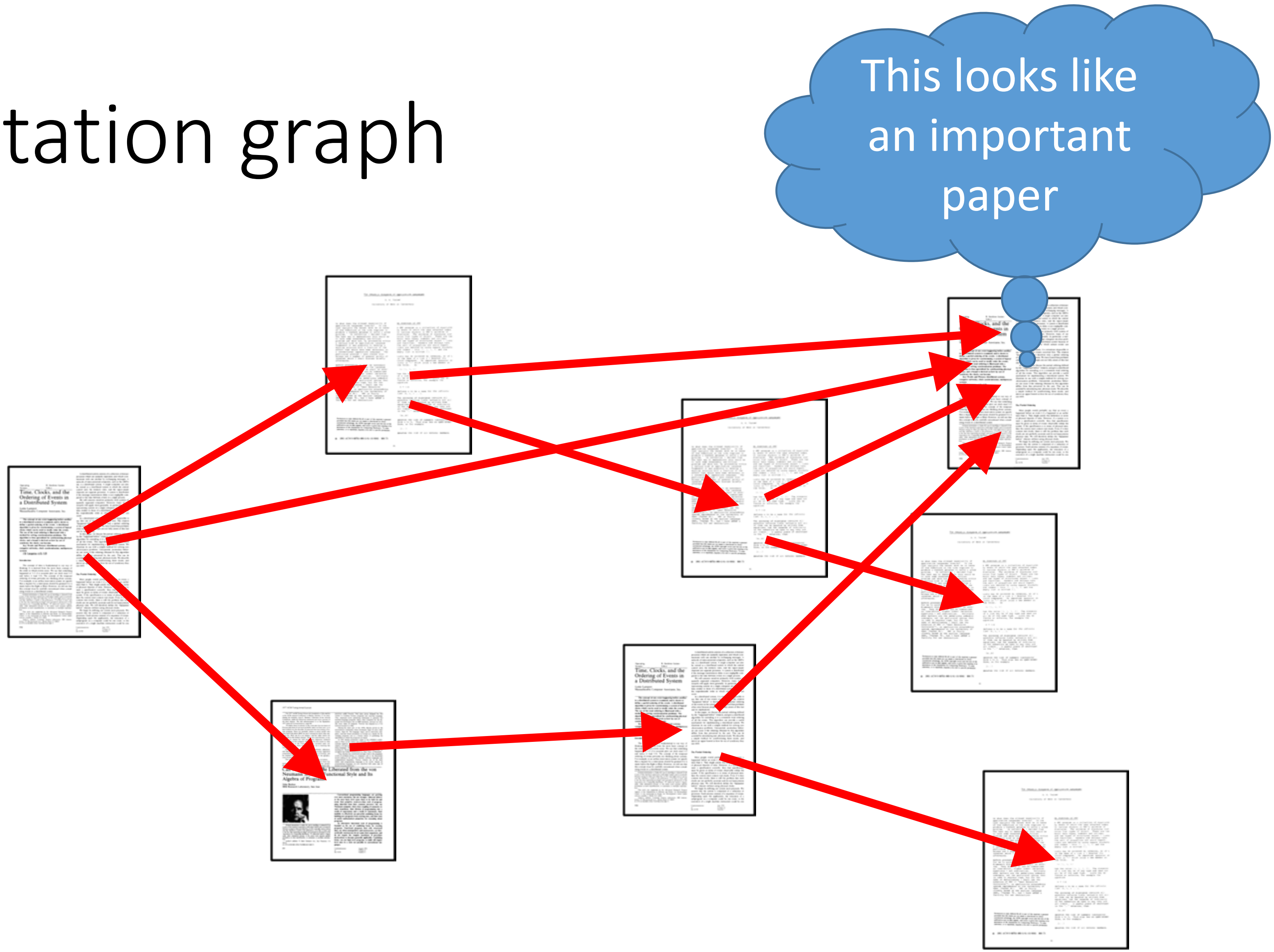

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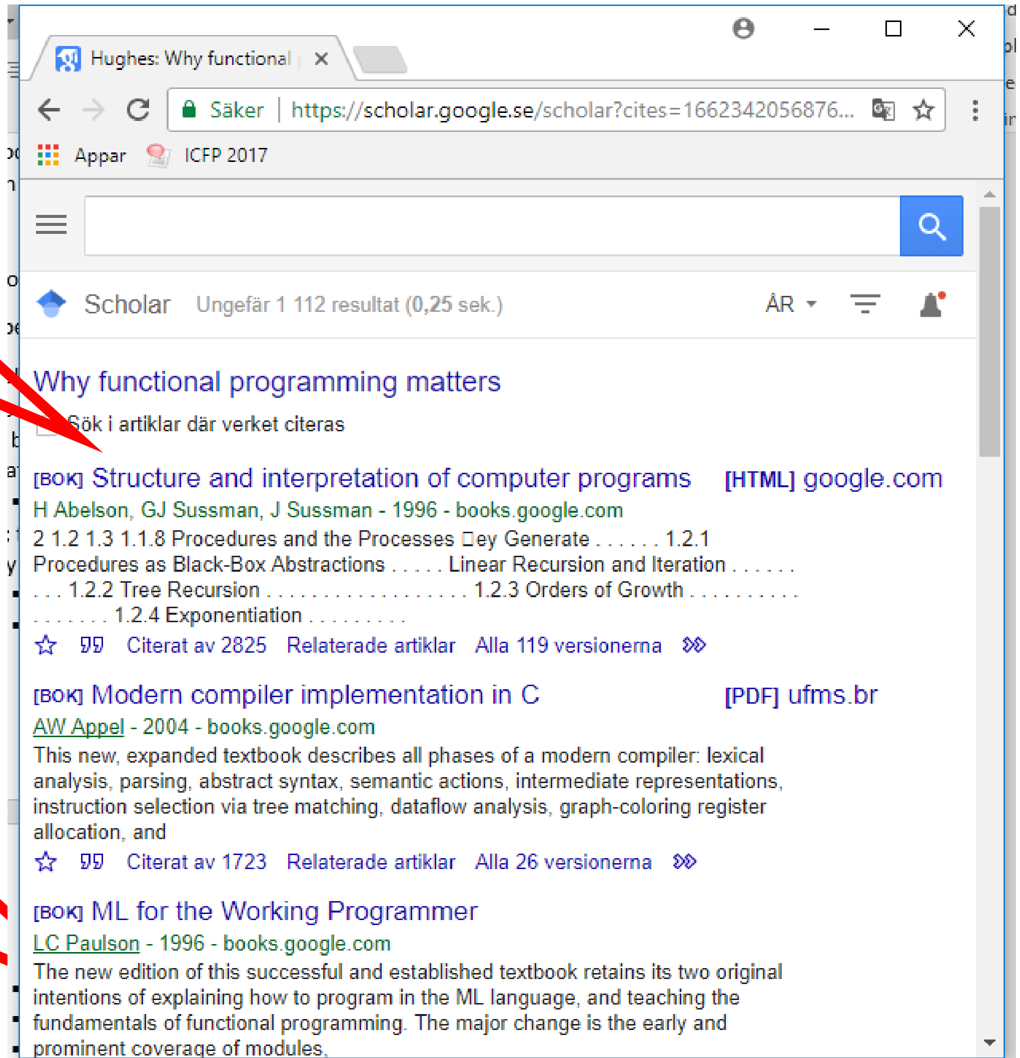

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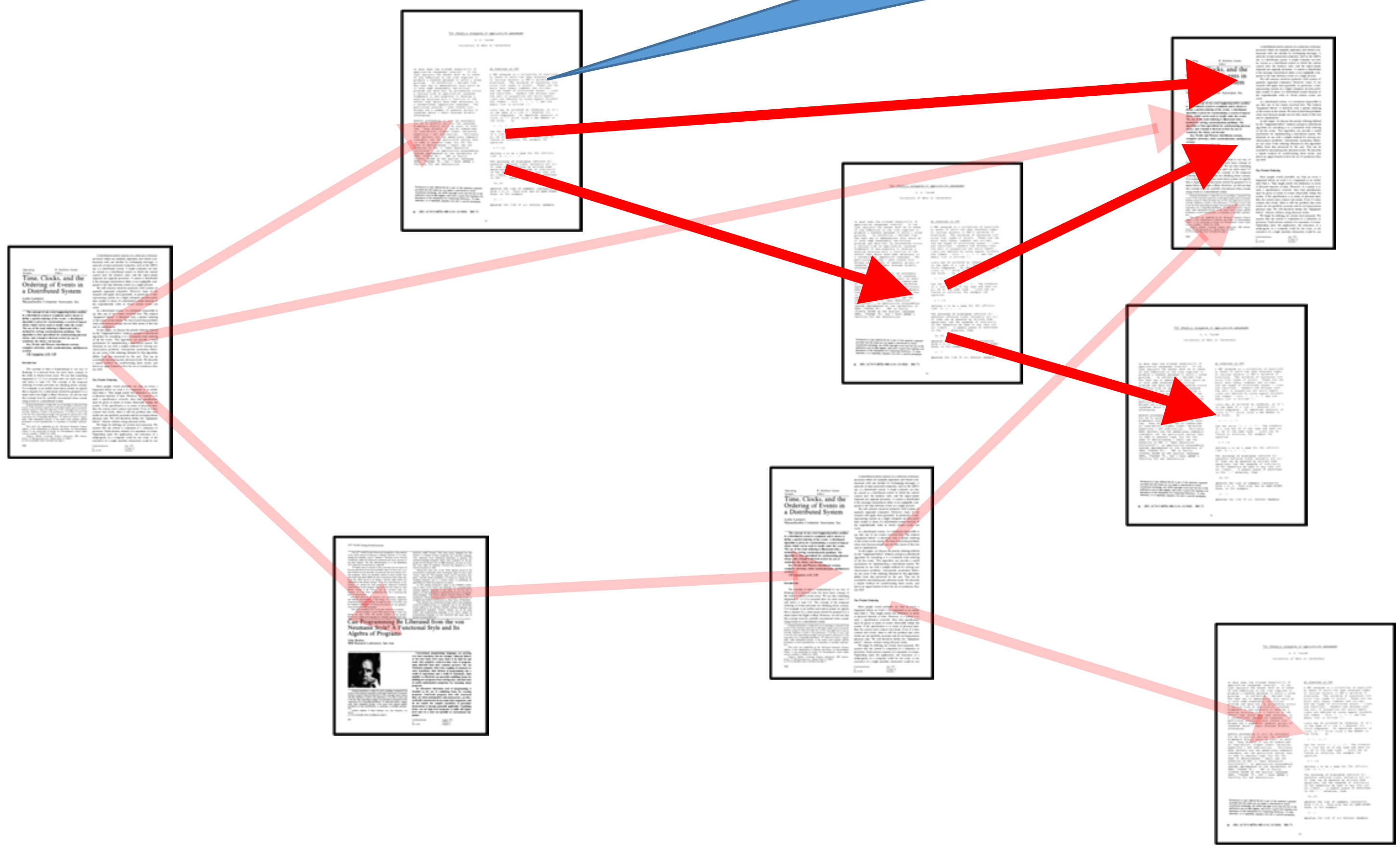

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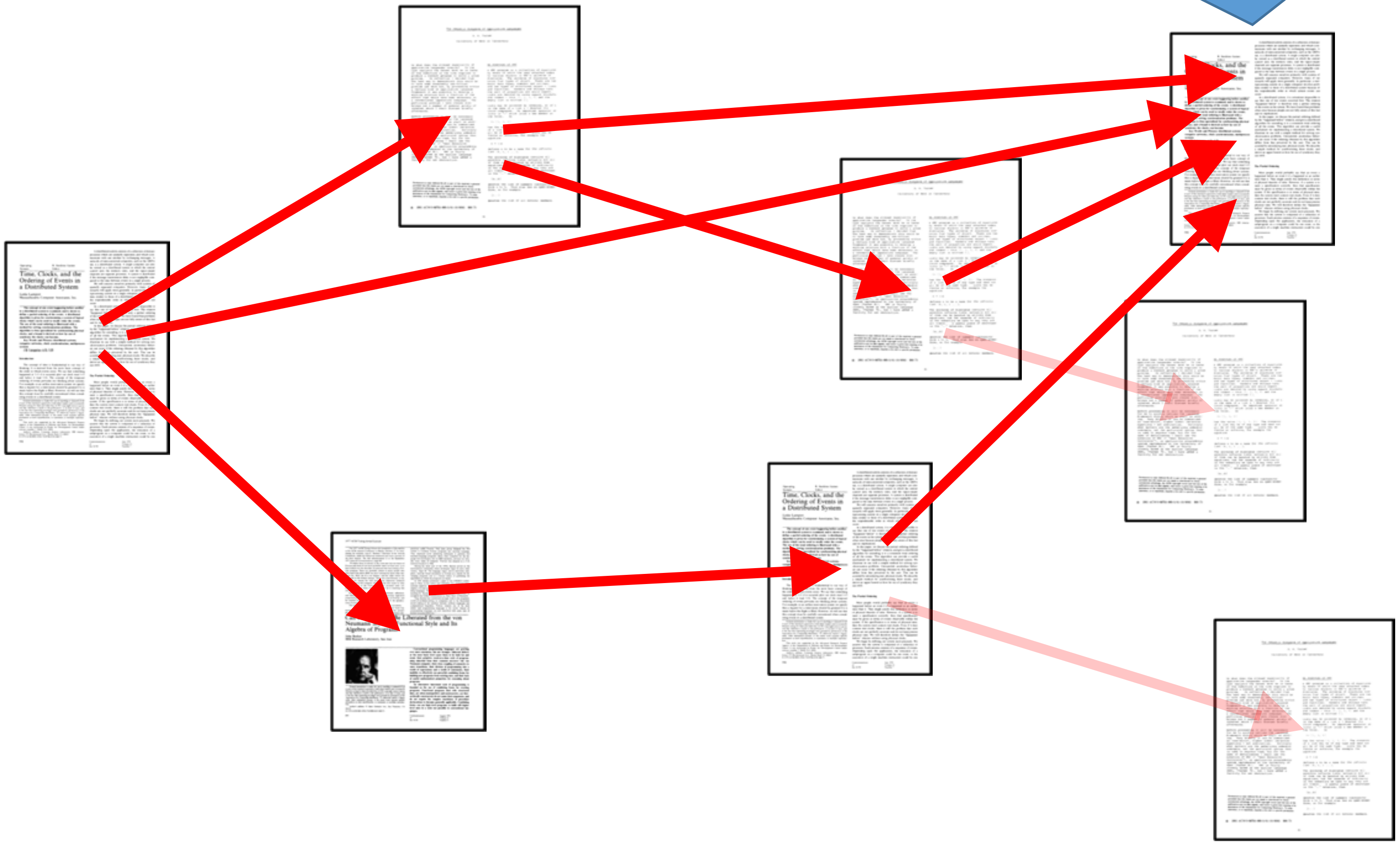

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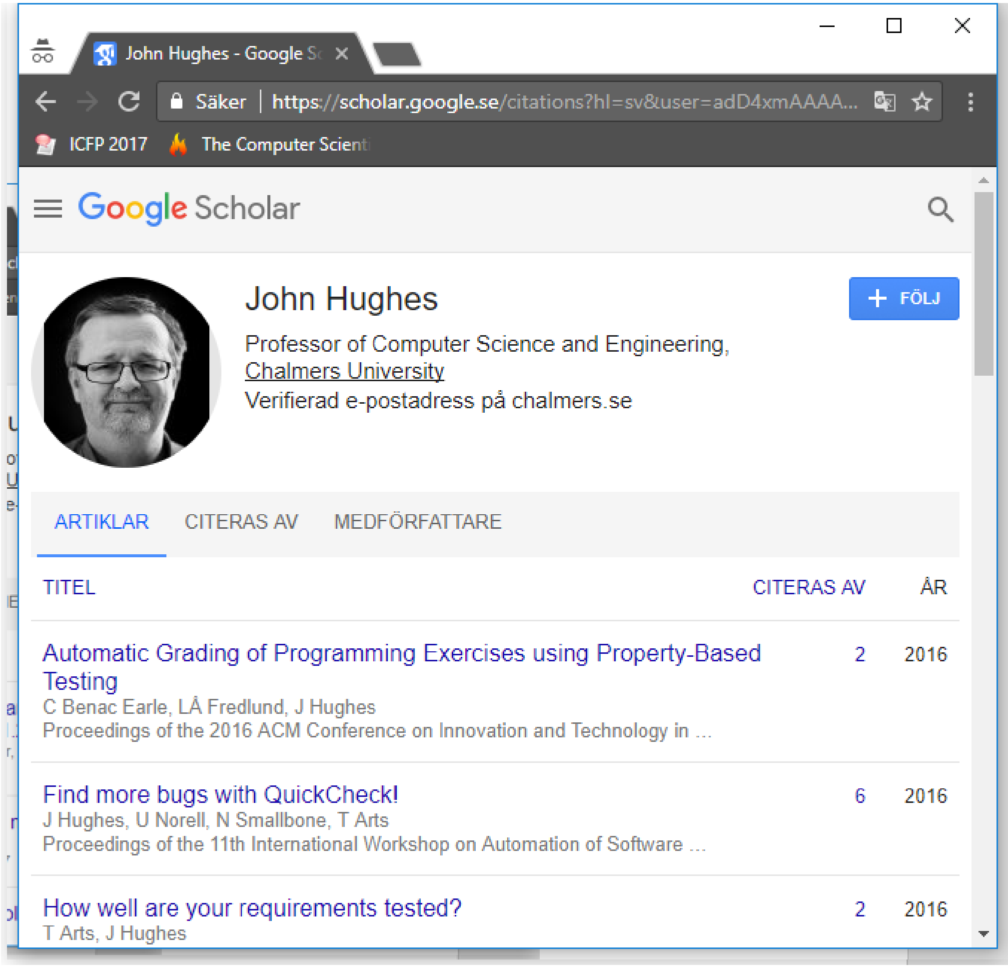

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S. Keshav. 2007. How to read a paper. *SIGCOMM Comput. Commun. Rev.* 37, 3 (July 2007), 83-84

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