01 Jan 2000

A Schooling on Their Implications for Software Engineering [Trends]

Ann K. Miller
Missouri University of Science and Technology

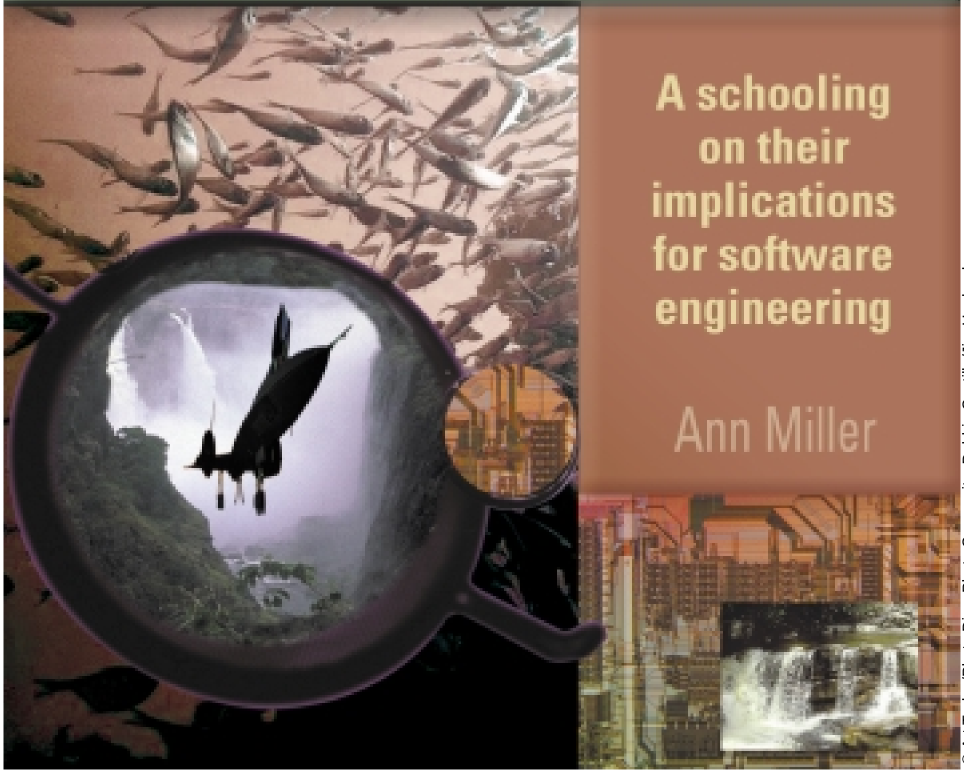
Recommended Citation

A. K. Miller, "A Schooling on Their Implications for Software Engineering [Trends]," *IEEE Potentials*, Institute of Electrical and Electronics Engineers (IEEE), Jan 2000.
The definitive version is available at https://doi.org/10.1109/45.890083

Trends in software systems

A schooling on their implications for software engineering

Ann Miller



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Some say the most accurate weather forecast, when averaged over an entire year, is to predict that tomorrow's weather will be just like today's. So when writing on trends in software engineering, it is tempting simply to extrapolate some of the popular, current trends. And, in fact, we will examine a few of these obvious indicators. But, weather also can exhibit a radical change from one day to the next. So, too, software engineering has had new approaches that are more revolutionary than evolutionary.

In particular, we will try to discern trends in software engineering based on trends in delivered software systems. Read them, think about them, disagree with them, create your own opinions, but, consider the various possibilities—because it is your future, too.

What follows are the opinions of someone who is more a practitioner than a theoretician and admittedly not much of a forecaster. If you had asked me when I first got out of graduate school and started teaching at a university if I would ever work in industry, I would have said "no." If you had asked me on my 10th anniversary of working in industry if I would leave to work in senior government service, I would have replied "definitely not." And yet I did just that. Now I have returned full circle to academic life. These varied opportunities provide the insights on which these forecasts are made.

System trend 1: more, bigger, better

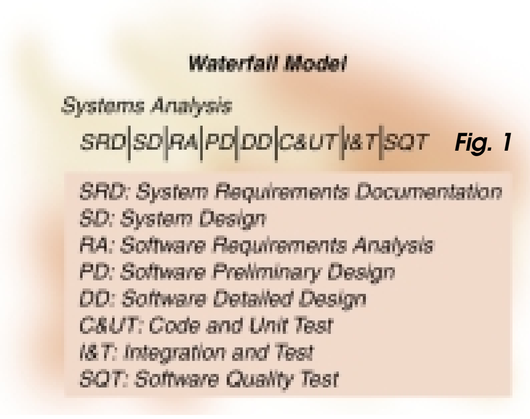
This trend, obviously, is based on an extrapolation of many years of historical data. Application programs as well as operating systems have been and likely will continue to grow. This phenomenon has been aided by the incredible growth in density and speed of integrated circuits that Gordon Moore accurately forecast in 1965. Thus, software products, whether measured by thousands of lines of code (KLOC) or by bytes of program memory, have exhibited a software version of Moore's Law. But what does this continued growth in sheer size imply for changes in software engineering? Several things.

Basically, there will be new and better methodologies for developing large-scale systems. Why is that? This is a "tomorrow's weather will be like today's weather" prediction. If we look at the history of large systems, they grew initially in an ad hoc, rather chaotic, fashion. Since some of the largest early programs were for military applications, it became imperative that there be some rigor in the development process. Winston Royce was the first to use the term "waterfall model" in 1970. His paper became the basis for the U.S. Department of Defense (DoD) standard 2167A for the development of software systems. The classical waterfall model of systems analysis, software requirements specification, analysis, preliminary design, detailed code and unit test, integration and test, and software quality test with on-going maintenance (Fig. 1) was an important first step in establishing rigor and repeatability in large-scale system development. However, the waterfall model quickly became impractical to use; this was due to various reasons, most notably changing requirements, new requirements and increased customer expectations.

As a result, methodologies such as the incremental model (Fig. 2), the evolutionary model (Fig. 3) and the backbone model (Fig. 4) have been adopted. These are all variations of the waterfall model. But they improve the way changes and growth of requirements can be managed.

So what new improvements will occur? Improvements will occur in automated tracing of requirements and in life-cycle support of changes, including better configuration management tools for multiple releases of a product in various stages of development. This may not sound like a big deal if you have only written short software programs required for courses and labs. However, Lehman and Belady studied the history of successive releases of a large operating system and found that the total number of modules increased linearly with the release number. More significantly, the total number of modules affected by changes increased *exponentially* with the release number.

One reason systems are getting larger is that they include whole programs inside the newer systems. In many cases, the smaller components are com-


Waterfall Model
Systems Analysis
SRD | SD | RA | PD | DD | C&UT | I&T | SQT
SRD: System Requirements Documentation
SD: System Design
RA: Software Requirements Analysis
PD: Software Preliminary Design
DD: Software Detailed Design
C&UT: Code and Unit Test
I&T: Integration and Test
SQT: Software Quality Test
Fig. 1

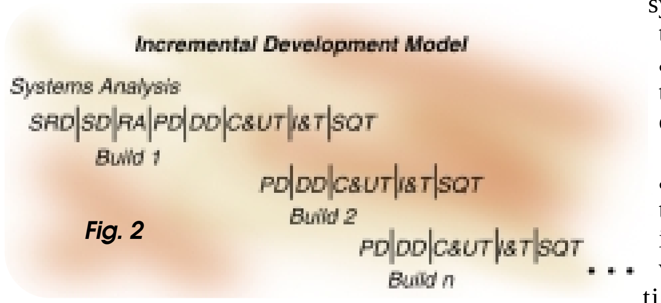
mercial-off-the-shelf (COTS) products such as a database system or a computational package. The advantage to this approach is that the overall larger system can be developed more quickly. This, in turn, lets the company bring the product to market sooner.

A disadvantage to this approach is that rarely is the COTS component a perfect match for what is needed. That is, it may not perform all the needed functions. Just as seriously, it may perform more functions than what is needed. This is a potential problem. The incorporated component may cause the entire system to behave unexpectedly due to an "extra" function being invoked. Thus, we will see better black-box testing techniques to verify that the functions that should be performed are performed correctly and, equally important, extraneous functions cannot be performed.

A second type of incorporated software is a "legacy system." This is a program that has been fielded for years but may have been written in a different language than a newer system; or it may have been developed in a non-object-oriented approach but will be part of an upgraded object-oriented system. We will have improved wrapper techniques for encapsulating such legacy code into updated systems.

Not only will the program size be large, but the amount of data manipulated by the programs will continue to grow. Thus, there need to be improved techniques for managing large datasets, including visualization techniques. Common mechanisms are the use of graphics, color and animation. Much work has been done using three-dimensional graphics and animation. However, there remains a dire need for better visualization techniques for massive datasets. And while visual techniques will predominate, there may be excellent applications where other senses such as sound or touch can provide additional assistance to the user in either a virtual reality setting or in a multimedia environment.

Lastly, a forecast that is a bit more of a stretch. We will see the emergence of true visual programming languages. Not just a graphical user interface (GUI), but a high level language that lets the developer point and click to various components (not just small routines) from multiple libraries/multiple sources and to specify the type of connection between these components. The final integration of these components will actually be completed by the language's compiler/assembler.


Incremental Development Model
Systems Analysis
SRD | SD | RA | PD | DD | C&UT | I&T | SQT
Build 1
PD | DD | C&UT | I&T | SQT
Build 2
PD | DD | C&UT | I&T | SQT
Build n
• • •
Fig. 2

System trend 2: faster, faster

As computers become embedded in more and more systems, the need for real-time and hard real-time processing increases. By real-time, we mean that the system must acquire data and/or process it within specified time intervals. Real-time systems range from programmable logic controllers that manage valves in a manufacturing plant to microprocessors that manage fuel-injection engines to banks of microprocessors that provide avionics flight control for aircraft.

These systems are difficult to construct because of timing. We've all seen our word processor or our web browser exhibit markedly different times to execute a function depending on size of a file or number of users on the network or a myriad of other factors. In a real-time system, certain functions must finish within a specified time limit. Otherwise, data will be lost or a switch will not close in time or some critical operation will not be performed.

To better design these systems, we will see advanced simulators emerge that can better describe and characterize the run-time operation of the system under development. These will include microprocessor models linked with simulators that also provide an extensive suite of test tools for timing and for fault detection. Fault detection tools will be included. For while speed is essential for embedded systems, there is another factor for real-time systems that is increasingly important: safety.

System trend 3: safer

Embedded computers control more and more systems, whether launching a satellite, managing oil flow in pipelines or controlling flight of aircraft. Thus, there is a growing need to assure the proper functioning of these systems. This is due to the significant cost of the system and/or the cost of the resource being managed and/or to the fact that human life depends on that system.

For such life-critical and safety-critical systems, there will be an increased emphasis on validation and verification (V&V). Validation ensures that the system features can be traced back to the stated requirements. (So there should not be flight simulators embedded in future spreadsheet programs.) Verification ensures that each function works correctly.

The classic phrases for these two activities are: (i) are we building the correct product and (ii) are we building the product correctly? There are standards by various organizations such as IEEE and the International Standards Organization (ISO) that are necessary but no longer sufficient. A trend for the future is not only V&V but a further step to certification.

For example, the Radio Technical Commission for Aeronautics standard DO-178B, entitled "Software Considerations in Airborne Systems and Equipment Certification," is a standard developed by the commercial air transport industry for software used in commercial aircraft. Essentially, all developers of aircraft systems adhere to this standard. The standard defines various criticality levels for software and prescribes different techniques for each level. I envision this type of standard spreading to other application areas, first perhaps to medical applications but eventually to a much wider arena. With these standards, there will need to be a *precise and testable* means to determine if the standard has been fulfilled or not.

As more and more software systems are safety-critical and life-critical applications, there will need to be a mechanism to guarantee system performance. The National Research Council sponsored a committee of information technology experts who published their findings in the 1998 report: “Trust in Cyberspace.” Among their comments:

“The absence of standard metrics and a recognized organization to conduct assessments of trustworthiness is an important contributing factor to the problem of imperfect information.

“A consumer may not be able to assess accurately whether a particular drug is safe but can be reasonably confident that drugs obtained from approved sources have the endorsement of the US Food and Drug Administration (FDA) which confers important safety information. Computer system trustworthiness has nothing comparable to the FDA.

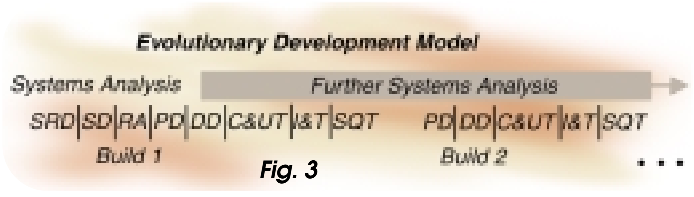


Fig. 3

The problem is both the absence of standard metrics and a generally accepted organization that could conduct such assessments. There is no Consumer Reports for [software and information] Trustworthiness.’’

The absence of a certifying organization such as Software Consumer Reports or an Underwriter’s Laboratory is a key problem. But, so, too, is the lack of sound metrics for quantifying the trustworthiness of information systems.

The frequency and sophistication of intrusions and attacks on commercial systems as well as government and military systems have led many agencies to be concerned about trustworthiness. This includes more than the traditional notion of security. Information and system survivability in the face of intrusions and attacks is recognized as a difficult but critical goal. So, while there may eventually be a national software certification office, a first step on the way to certification will be more emphasis on trustworthiness and survivability.

System trend 4: survivable

We have all seen the increase in intrusions to networks and viruses spread via e-mail. Not only will computer networks need better intrusion detection mechanisms, so too will application software. Web-based software will continue to increase. It will provide enormous advantages from increased distance learning capabilities to more secure electronic commerce applications.

However, there also will be increased concern about the fail-safe modes of operation in systems. Buffer overruns and other typical flaws will need to be examined before systems are fielded. Thus, we will see improved testing tools utilizing fault injection and other techniques. We will see more use of cryptography and better authentication techniques, including digital signatures. We will also see a greater investment by private industry in trustworthy computing.

System trend 5: smarter, synchronizing, collaborating

By this trend, I am not referring to the traditional notions of artificial intelligence but to a collection of interacting software modules. A lot of progress has been made in robotics; this trend will continue and we will begin to see “teams” of robots working together to perform a task. To do this effectively, they will need to collaborate and share information just as a human team would. Thus, they need to be able to update each other.

However, when problems occur, they will need to synchronize and return to some agreed-upon state from which to continue forward together. This provides all sorts of new areas of research in computational intelligence and robotics.

Discussing robots is a natural lead-in to the last trend—and that is people. Because people will continue to be central in software specification, development, and test. And so the last prediction will be:

People trend 1: certification re-visited. Certification at the software or system level is only a first step. We will see certification of software engineering programs and eventually certification of software engineers. A recent issue of *IEEE Software* discussed these topics in great detail. These included accreditation for university software engineering programs to the certification of individual software engineers similar to the Professional Engineer certification that the State of Texas has begun.

Summary

So there are a few thoughts. I will close with a quote from one of my favorite philosophers, Walt Disney. He said “Change is inevitable; growth is optional.” We will see some continuations and some change—here’s to growth!

Read more about it

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About the author

Ann Miller is the Cynthia Tang Missouri Distinguished Professor of Computer Engineering at the University of Missouri-Rolla. Prior to this, she was the Deputy Assistant Secretary of the Navy for Command, Control, Communications, Computing, Intelligence, Electronic Warfare, and Space. She has also held senior engineering positions in industry.

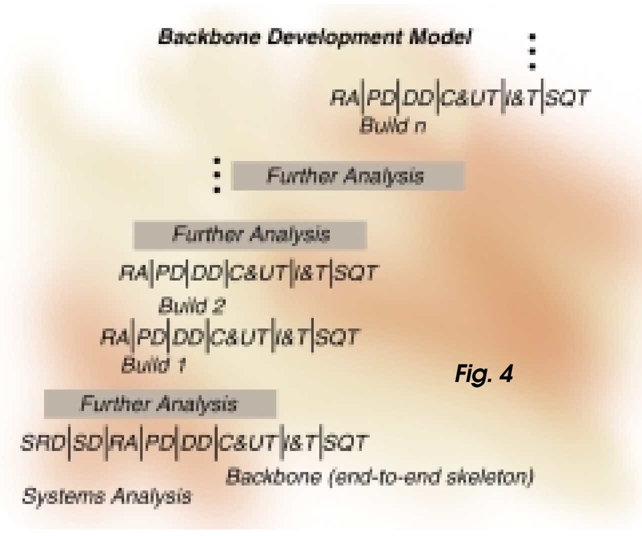

Fig. 4