INVITED CONTENT

Editor: **Giuliano Antoniol**
Polytechnique Montréal
antoniol@ieee.org

Editor: **Phillip Laplante**
Pennsylvania State University
pal11@psu.edu

Editor: **Steve Counsell**
Brunel University
steve.counsell@brunel.ac.uk

Recent Progress in Software Security

Edward Amoroso

EXACTLY 50 YEARS ago, Edsger Dijkstra sent the article "A Case against the GOTO Statement" to the *Communications of the ACM*, explaining why GOTO introduced too much complexity and should thus be avoided. Given the urgency of Dijkstra's message, Pascal inventor Niklaus Wirth made the prescient decision to recast the article as a letter to the editor with the now-iconic title, "Go To Statement Considered Harmful."[1]

In the years since, our community has, sadly, lost Dijkstra, but the debate he sparked has remained active. The cybersecurity community in particular has been vocal about finding ways to improve software, because most vulnerabilities involve exploitable weaknesses introduced through badly written code. Unfortunately, the rush to modern DevOps coding and the demands of software marketing have tended to overshadow most correctness concerns.

Instead, the cybersecurity community has widely adopted an approach to reduce cybersecurity risk in software that involves a collage of techniques, tools, and methods, each addressing some aspect of the threat implications of bad code. Here, I briefly survey recent progress in each element of this combined approach, including the pros and cons for reducing cybersecurity risk.

Advanced Malware Detection

Although improved programming methodology continues to influence software security, the cybersecurity software community has focused mostly on malware detection. This situation is curious, because while it's in everyone's interest in cybersecurity to prevent exploitable bugs, agreement exists that this is basically impossible for nontrivial code. Vendors have thus built small empires based on this (so far) correct assumption.

Whereas the original methods of malware detection were built on matching application code (or operating systems) to signatures, more-modern methods review behaviors for evidence of unacceptable runtime activity. Behavioral investigation is enabled by dynamic provision of virtual machines for safe detonation of executables. Without such virtual contained environments, behavioral analysis would be too dangerous for production systems.

Modern research in malware detection employs machine learning to help train security tools to identify bad code on the basis of samples. So, just as AI-powered systems are fed pictures of cats for learned recognition, comparable systems are fed "pictures" of files containing malware. Deep-learning techniques use massive parallelism to improve such algorithms' efficiency.

Perhaps the unifying aspect of this evolving space is that malware detection tools presume the continued existence of problems, which helps justify business investment by start-ups and other security vendors. The likelihood is thus low that software professionals will advance our art to the point at which no malware exists. So, the antimalware industry should expect to see continued vibrancy of its collective offerings in terms of sales, revenue, and growth.

Software Process Maturity

Another focus in modern software security involves inferring code security through its associated software process. That is, many security experts have suggested that, rather than directly inspecting software for evidence of malware or vulnerabilities, you examine that software's development process. This is like determining patients' health by asking them about their behaviors rather than testing their blood.

The theory supporting this approach is largely empirical—namely, that good code has tended to come from well-trained developers working with world-class tools in modern, well-organized development environments. In contrast, exploitable vulnerabilities frequently have been found in code written by poorly trained developers using makeshift tools in ad hoc development environments.

So, maturity models have emerged that let you link the degree of software security to the quality of the process. This has the useful side effect of driving improved security for all code that emerges from a given vendor's or team's software process. Common methods demanded in such processes include automation, periodic penetration testing, and proper software updating and maintenance procedures.

One excellent benefit of process maturity approaches is that little downside exists in any effort to improve the steps taken to create code. If the underlying rubric is sound, the associated effort to bring the software process in line with accepted best practices will have benefits far beyond just improved protection. Code reduction, time-to-market improvements, and quality increases will all result from improved software processes.

Software Review and Scanning

The most traditional means for improving software security involve direct inspection of code, sometimes using code-scanning tools. The tools' earliest use seems to have been at Bell Labs in the 1970s, with the introduction of the lint preprocessing program, which scanned C code and recommended improvements. All subsequent code-scanning tools trace their lineage to this early concept.

The ongoing use of manual code reviews is much debated in the software community, with traditionalists insisting that human inspection remains essential to high-quality, secure products. The challenge is that with the rapid cycle times in a DevOps environment, little time exists for human review of source code. Automated scans thus have become the norm in such environments; this has its pros and cons.

Software security will always include some degree of review and scans, presumably done properly once for reusable components, thus precluding the need for repeat security analysis. Critics claim that reusable componentry has been an elusive goal for decades. However, few would argue that modern DevOps and cloud-based software process environments are fertile ground for standard, well-reviewed components.

Runtime Software Controls

Perhaps the most promising advance in software security involves using runtime controls that are embedded in the execution environment. This technique is sometimes called *runtime application self-protection* (RASP). Through the integration of behavioral and even machine-learning controls into and around an executable, a programmed protection environment emerges—one that can compensate for code weaknesses.

RASP controls, cloud development, and DevOps are all tightly woven in most software development organizations. All three aim to increase delivered code's speed and flexibility. However, a somewhat open question is whether these three initiatives result in more secure code. Certainly, RASP will reduce the risk of any application good or bad, but it's unclear whether programmers write better code in the presence of RASP.

Nevertheless, runtime software controls will continue to influence software security, especially in the context of new self-learning methods. Machine-learning techniques have advanced to the point at which observed behaviors can serve as training data to label new variants of software exploits. This is an exciting new way to drive improved, autonomous software control using platform automation.

Deep-learning advances are especially promising for software security. This is because the improved efficiency and massive parallelism that characterize the approach are perfectly suited to the large number of combinations that must be examined in typical software execution. We might hope that deep-learning algorithms would be a superior way to review code for unused execution paths, dead code, logic errors, race conditions, and the like.

Our industry's early focus on methodology, as evidenced by Edsger Dijkstra's teachings on software, remains an important consideration in the assurance of secure software. However, the community has taken many practical steps to improve code quality and security in the absence of any real correctness progress by programmers. Bugs still abound in nontrivial software, and security teams must be practical in their risk reduction efforts.

We can hope that in the coming years, these methods will synthesize with improved programming languages and ever-improving programming techniques into an ecosystem that reduces risk by improving software. Given modern infrastructure's dependency on well-designed code with a minimum of exploitable flaws, this is certainly a welcome goal.

Reference

1. E. Dijkstra, "Go To Statement Considered Harmful," *Comm. ACM*, vol. 11, no. 3, 1968, pp. 147–148.

This article originally appeared in IEEE Software, *vol. 35, no. 2, 2018.*

ABOUT THE AUTHOR

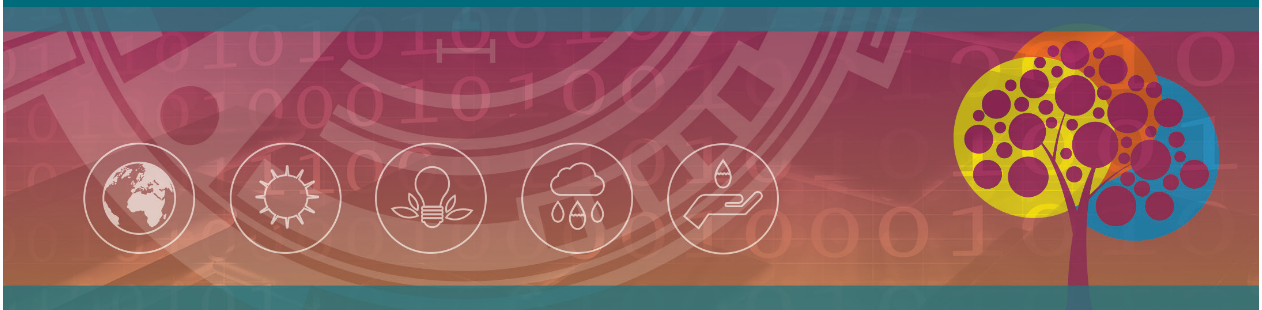
EDWARD AMOROSO is the founder and chief executive officer of TAG Cyber. He's also a Distinguished Research Professor in the New York University Tandon School of Engineering's Computer Science Department, an adjunct professor of computer science at the Stevens Institute of Technology, and a senior advisor at Johns Hopkins University's Applied Physics Laboratory. Contact him at eamoroso@tag-cyber.com.

SUBMIT TODAY

IEEE TRANSACTIONS ON
SUSTAINABLE COMPUTING

SUBSCRIBE AND SUBMIT

For more information on paper submission, featured articles, calls for papers, and subscription links visit: www.computer.org/tsusc



IEEE computer society
IEEE COMMUNICATIONS SOCIETY
CEDA IEEE Council on Electronic Design Automation
IEEE