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Software security, secure programming

Conclusion

Master M2 Cybersecurity

Academic Year 2024 - 2025

Software vulnerabilities

A multi-level issue ...

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. . . enhanced by the (incorrect) use of insecure languages

- importance of **type safety** and **memory safety**
- trade-off between safety/security and run-time efficiency
  (execution time, resource consumption)

$\hookrightarrow$ things may move slowly (JavaScript $\rightarrow$ TypeScript; C $\rightarrow$ Rust?)

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  - (lightweight) runtime error detection tools
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$\hookrightarrow$ widely deployed on main stream execution platforms . . .
but take care with more specific ones (IoT, Scada, etc.)!

Code analysis techniques & tools

Goals

- vulnerability detection
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- reverse-engineering and/or forensic analysis assistance
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And still a challenging issue to analyse binary code . . .

Outline

- What have been seen?
- Future trends?
- A few words on CodeQL
- A few words on machine-learning techniques

Software vulnerabilities

Probably **not over** in a near future . . .
(endless cat and mouse games between attackers & defenders)

but:

- “basic” vulnerabilities (BoF, arithmetic overflows, etc) should become less proeminent . . .
- more HW/SW security issues?

Vulnerability **exploitation** should become more and more difficult on **recent** execution plateforms . . .

but still a huge panel of **legacy/unprotected** hardware and software (e.g., in industrial systems)

Vulnerability detection & analysis tools

For the code developers

From DevOps to DevSecOps, with a potential increase of:

- fuzzing
- pattern-based detection tool (like CodeQL)
- machine-learning techniques (?)

For the code auditors &security experts

Towards (smarter) combinations of:

- fuzzing, dynamic-symbolic execution and static analysis
- machine-learning techniques . . .

Possibly with an emphasis on quantitative analysis
(**how much** dangerous is a vulnerability?)

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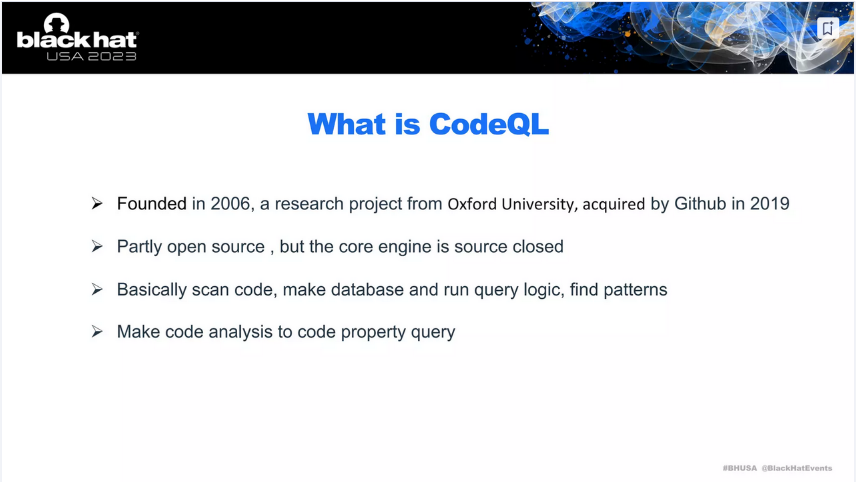
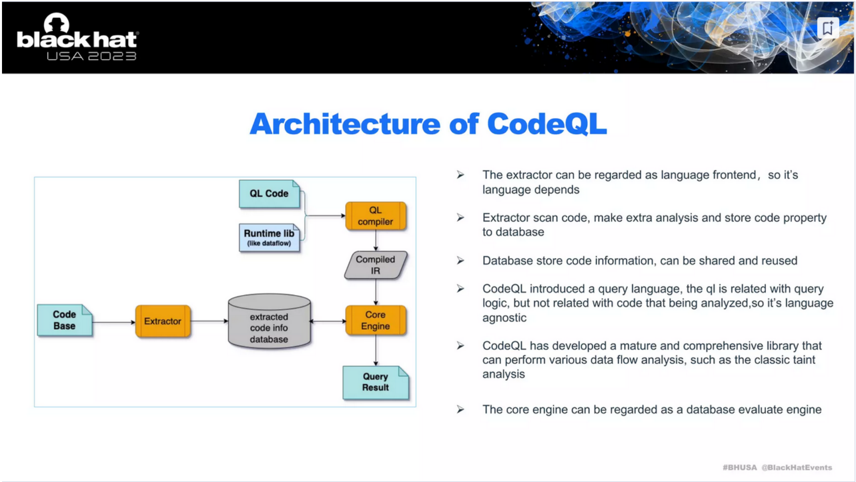
CodeQL: an example of pattern-detection tool

- static analysis (no code execution!)
- allows to find “arbitrary” **patterns** on (large) code bases
  ↪ e.g., to look for existing CWEs
- offer a powerful **query language** for pattern description allowing to mix syntactic and semantic features, including:
  - data-flow analysis
  - range analyis
  - alias analysis
  - etc.
- easy to integrate within a CD/CI pipeline . . .



[Credits: H. Zhang, **CodeQL: also a powerful binary analysis engine** - BlackHat 2023]



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Query examples and demo

Example of C/C++ publicly available queries

Demo of a use-after-free query . . .

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Examples of ML applications for cybersecurity

ML techniques

- **supervised ML:**
  Use **labeled dataset** to train algorithms and define the variables to be assessed for correlations (input/outputs being specified). Model weights can be adjusted to avoid overfitting or underfitting.
- **reinforcment ML:**
  Train the algorithm by **trial and error** rather than using sample data.
- **unsupervised ML** (used for deep-learning):
  Analyze and cluster **unlabeled datasets** to identify hidden patterns or data clustering.

Application to Cybersecurity

- Intrusion detection (computer, network)
- Malware/ransomware detection & recognition
- Anomaly detection
- Log aggregation/corelation & alert analysis (e.g. in SIEM systems)
- **vulnerability** detection and analysis . . .

ML for vulnerability analysis

Main challenges

- get a rather **balanced** sets of (labeled?) vulnerable & non vulnerable code examples
- relevant code features include **data-flow** and **control-flow** information, to be properly extracted & processed to feed the models

Main applications

- vulnerability **detection** (or simply “vulnerable code” detection . . .)
- reverse engineering: function detection, type identification, binary diffing, etc.
- enhanced code analysis techniques (fuzzing, pattern recognition)
- side-channel & information leakage detection
- etc.

examples of recent papers

A typical Vulnerability detection tool

VulDeePecker: A Deep Learning-Based System for Vulnerability Detection (NDDS Conference, 2018)

So, what about ML for Software Security?

Not yet the “definite solution” for vulnerability detection/analysis:

- hard to evaluate and compare with other existing techniques
- lack of result explainability
  (e.g., correctly locating vulnerable statements?)
- what about new vulnerability patterns?

But clearly a promising and essential research direction . . .
in conjunction with classical techniques

A possible next challenging (and more practical) step:
using generative IA to produce secure-by-construction software?

Credits

A Survey on Machine Learning Techniques for Cyber Security in the Last Decade - K. Shaukat et al- IEEE Access 2020

Machine learning (ML) in cybersec2yyurity - SailPoint

ML4Sec papers

Software Security Analysis in 2030 and Beyond: A Research Roadmap