Last Lecture

Testing, Quality Assurance, and Maintenance
Winter 2019

Prof. Arie Gurfinkel

Syntax versus Semantics

TESTING AND VERIFICATION

Testing and Verification / Quality Assurance

Testing: Software validation the “old-fashioned” way

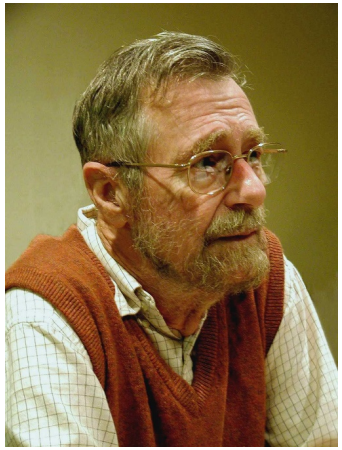
- create a test suite (a set of test cases)
- run and identify failures
- fix to address failures and repeat
- done when the test suite passes and achieves a desired criteria

Verification: formally prove that a computing system satisfies its specifications

- Rigor: well established mathematical foundations
- Exhaustiveness: considers all possible behaviors of the system, i.e., finds all errors
- Automation: uses computers to build reliable computers

“Program testing can be a very effective way to show the presence of bugs, but is hopelessly inadequate for showing their absence.”

Edsger W. Dijkstra



Very hard to test the portion inside the “if" statement!

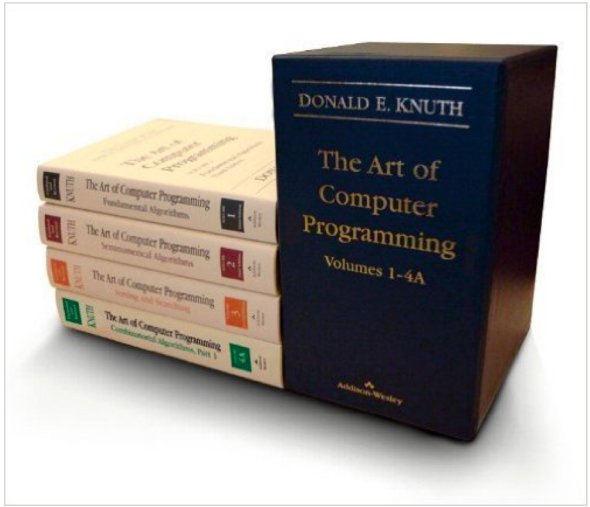
```
input x
if (hash(x) == 10) {
    ...
}
```

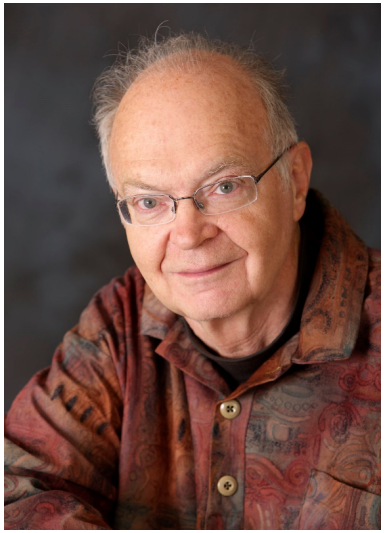
“Beware of bugs in the above code; I have only proved it correct, not tried it.”

Donald Knuth

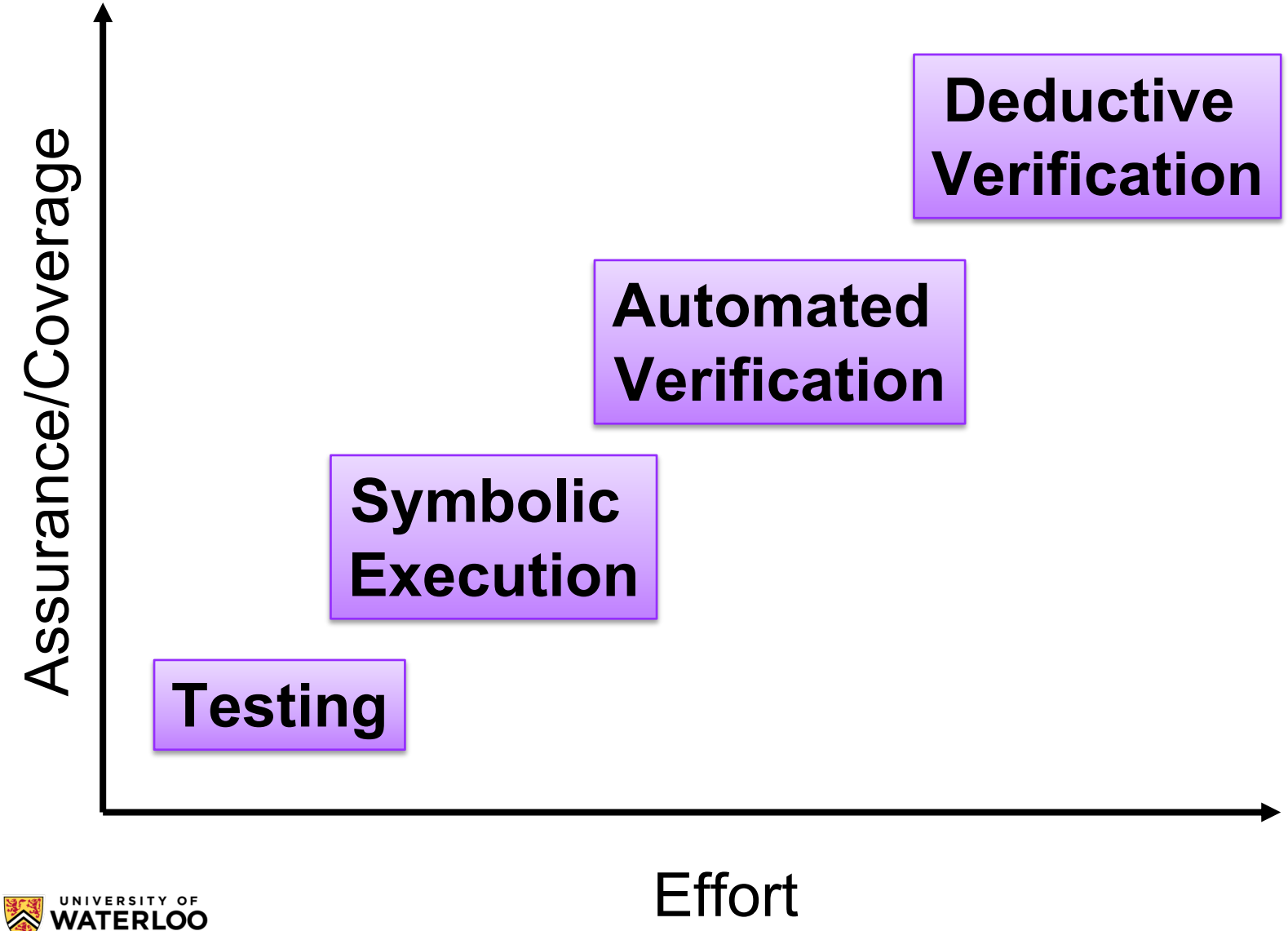
You can only verify what you have specified.

Testing is still important, but can we make it less impromptu?





(User) Effort vs (Verification) Assurance



Undecidability

A problem is undecidable if there does not exists a Turing machine that can solve it

- i.e., not solvable by a computer program

The halting problem

- does a program P terminates on input I
- proved undecidable by Alan Turing in 1936
- https://en.wikipedia.org/wiki/Halting_problem

Rice's Theorem

- for any non-trivial property of partial functions, no general and effective method can decide whether an algorithm computes a partial function with that property
- in practice, this means that there is no machine that can always decide whether the language of a given Turing machine has a particular nontrivial property
- https://en.wikipedia.org/wiki/Rice%27s_theorem

Topics Covered in the Course

Foundations

- syntax, semantics, abstract syntax trees, visitors, control flow graphs

Testing

- coverage: structural, dataflow, and logic

Symbolic Execution

- using SMT solvers, constraints, path conditions, exploration strategies
- building a (toy) symbolic execution engine

Deductive Verification

- Hoare Logic, weakest pre-condition calculus, verification condition generation
- verifying algorithm using Dafny, building a small verification engine

~~Automated Verification~~

- ~~(basics of) software model checking~~

Verification Tools in Practice

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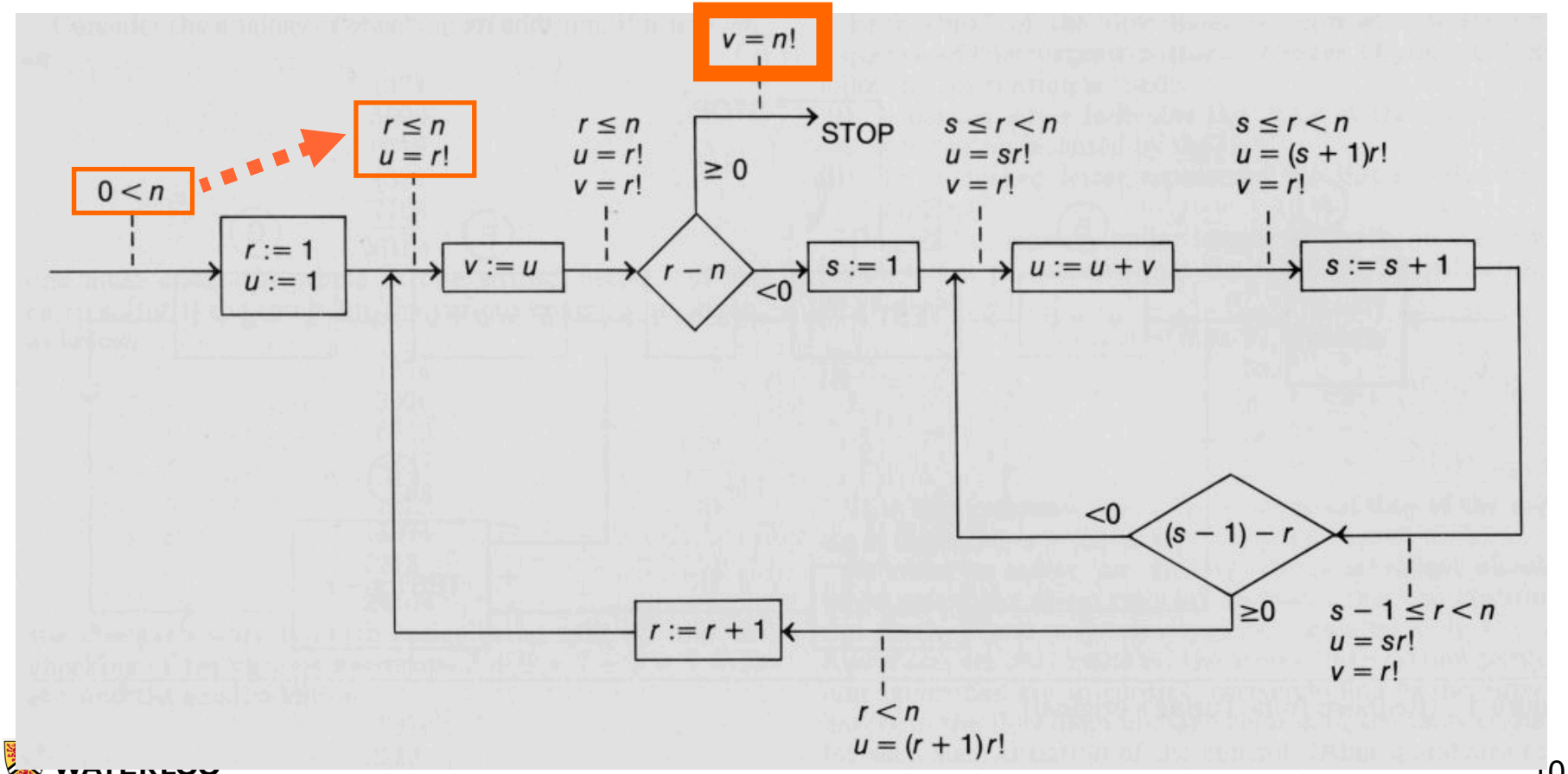
Turing, 1949

Alan M. Turing. “Checking a large routine”, 1949

How can one check a routine in the sense of making sure that it is right?

programmer should make a number of definite assertions which can be checked individually, and from which the correctness of the whole programme easily follows.



Verification Competition

http://www.pm.inf.ethz.ch/research/verifythis.html

Microsoft Visual Studio Products

Code Contracts

- https://marketplace.visualstudio.com/items?itemName=RiSEResearchinSoftwareEngineering.CodeContractsforNET
- https://github.com/Microsoft/CodeContracts

- statically and dynamically checked method pre- and post-conditions

IntelliTest

- https://www.visualstudio.com/en-us/docs/test/developer-testing/intellitest-manual/introduction

- automated test generation by dynamic symbolic execution

WHY3

http://why3.lri.fr/

VeriFast

https://github.com/verifast/verifast

Viper

http://www.pm.inf.ethz.ch/research/viper.html

Open JML

http://www.openjml.org/

The KeY Project

https://www.key-project.org/

Proving that Android's, Java's and Python's sorting algorithm is broken (and showing how to fix it)

February 24, 2015 Envisage Written by Stijn de Gouw. $s

Tim Peters developed the Timsort hybrid sorting algorithm in 2002. It is a clever combination of ideas from merge sort and insertion sort, and designed to perform well on real world data. TimSort was first developed for Python, but later ported to Java (where it appears as java.util.Collections.sort and java.util.Arrays.sort) by Joshua Bloch (the designer of Java Collections who also pointed out that most binary search algorithms were broken). TimSort is today used as the default sorting algorithm for Android SDK, Sun's JDK and OpenJDK. Given the popularity of these platforms this means that the number of computers, cloud services and mobile phones that use TimSort for sorting is well into the billions.

http://envisage-project.eu/proving-android-java-and-python-sorting-algorithm-is-broken-and-how-to-fix-it/

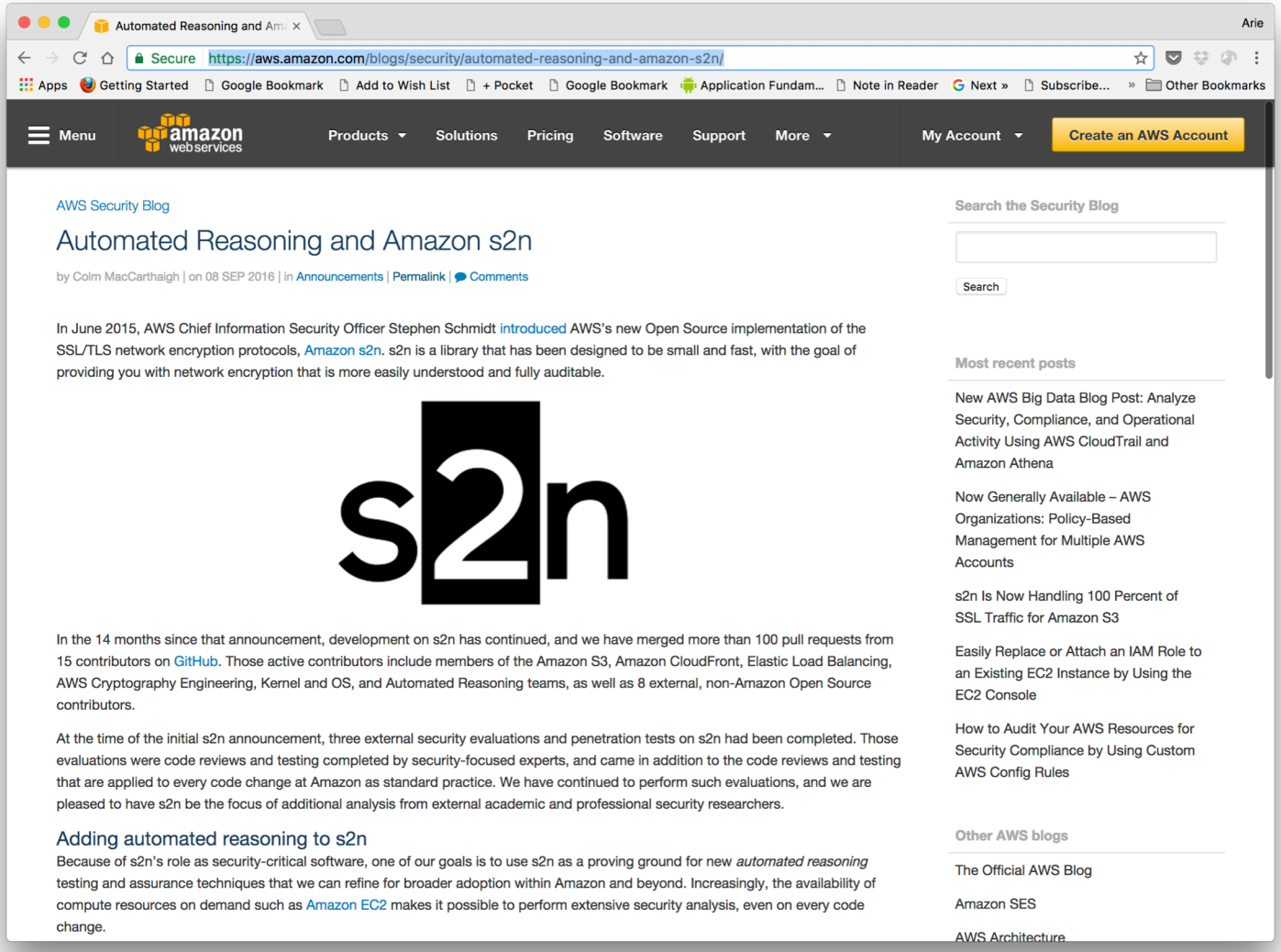
Frama-C

https://frama-c.com/

SPARKPro

http://www.adacore.com/sparkpro/

Amazon S2N



https://aws.amazon.com/blogs/security/automated-reasoning-and-amazon-s2n/

IronClad and InronFleet

https://github.com/Microsoft/Ironclad

Facebook Infer

Automatically prove correct memory handling (e.g., absence of null dereferencing)

http://fbinfer.com/

KLEE

Symbolic execution for C/C++ based on LLVM

https://klee.github.io/

Diffblue: AI for Code

https://playground.diffblue.com/?utm_source=homepage

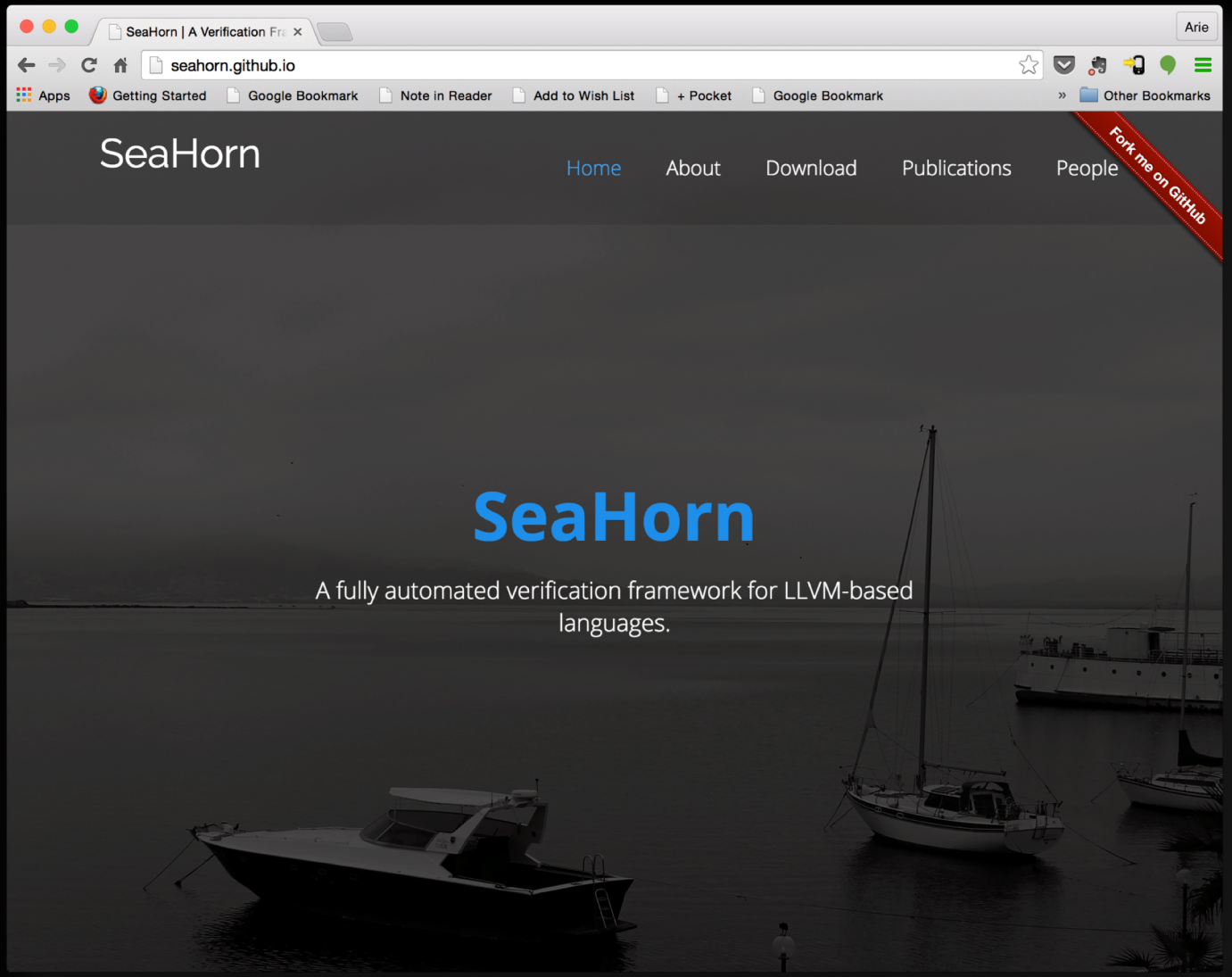
Automated test-case generation for Java

Automated reasoning at AWS

https://aws.amazon.com/blogs/security/tag/automated-reasoning/

https://www.youtube.com/watch?v=JfjLKBO27nw

https://blog.adacore.com/amazon-relies-on-formal-methods-for-the-security-of-aws



http://seahorn.github.io

Is Verification Enough

Can verified software fail?

Do we need both testing and verification?