

Writing Bug-Free Code Using Theorem Provers

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Coding Bliss



The world is **running** on code

HealthCare.gov



We are **benevolent heroes!**

Coding Bloodbath



The world is **crashing** on code



HealthCare.gov



We are **arrogant villains!**

What Makes Software Lousy?

- Unclear requirements
 - Bad interfaces, missing features, unnecessary features
- Bad coding style
 - Hard to maintain, lots of cutting and pasting, convoluted
- Bugs
 - Invariants broken, function contracts not met, resources misused

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"Building error-free trading software is impossible, and that makes today's stock markets even more fragile."

Is error-free code impossible?

Current Practice: Testing



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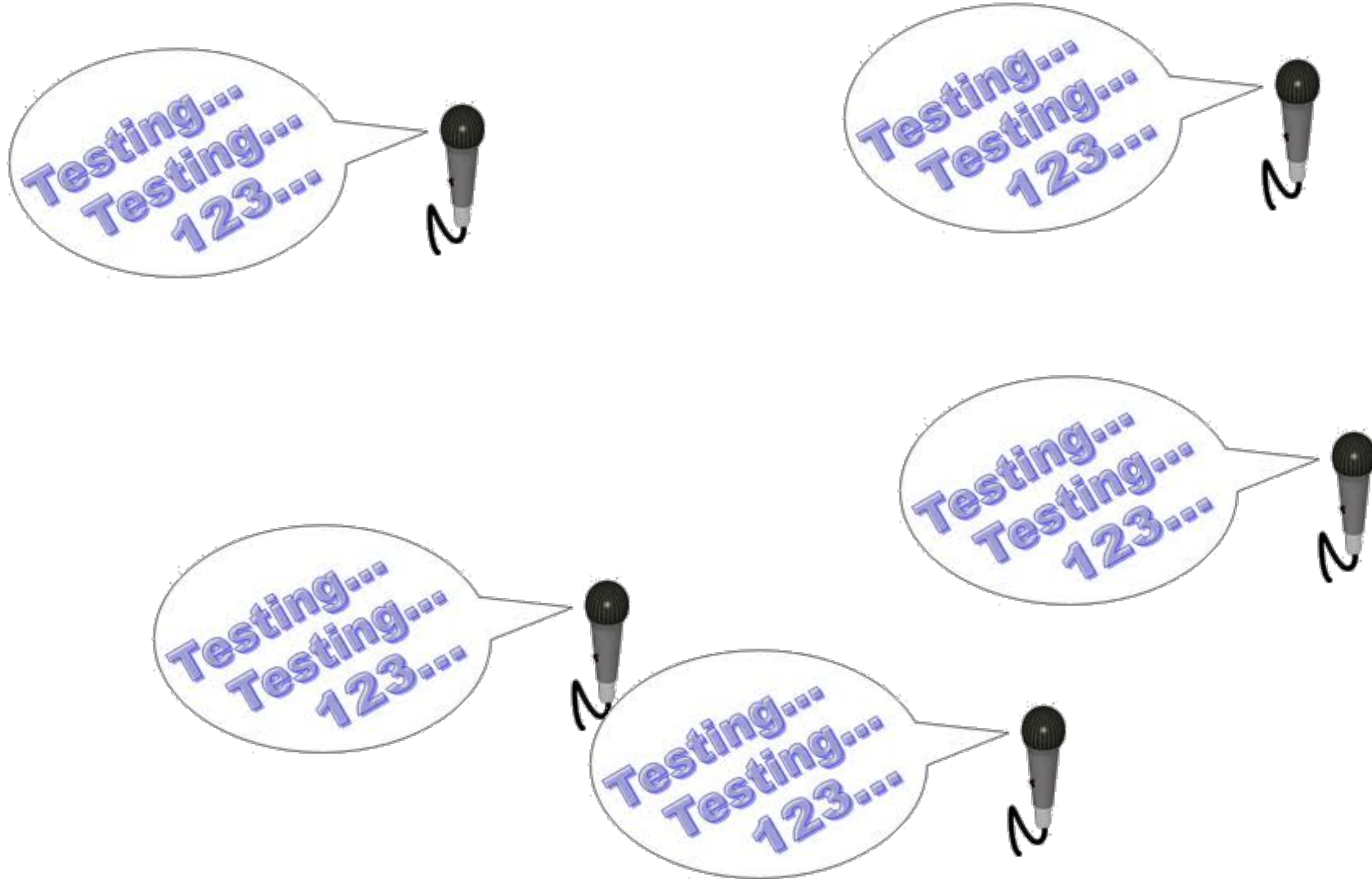
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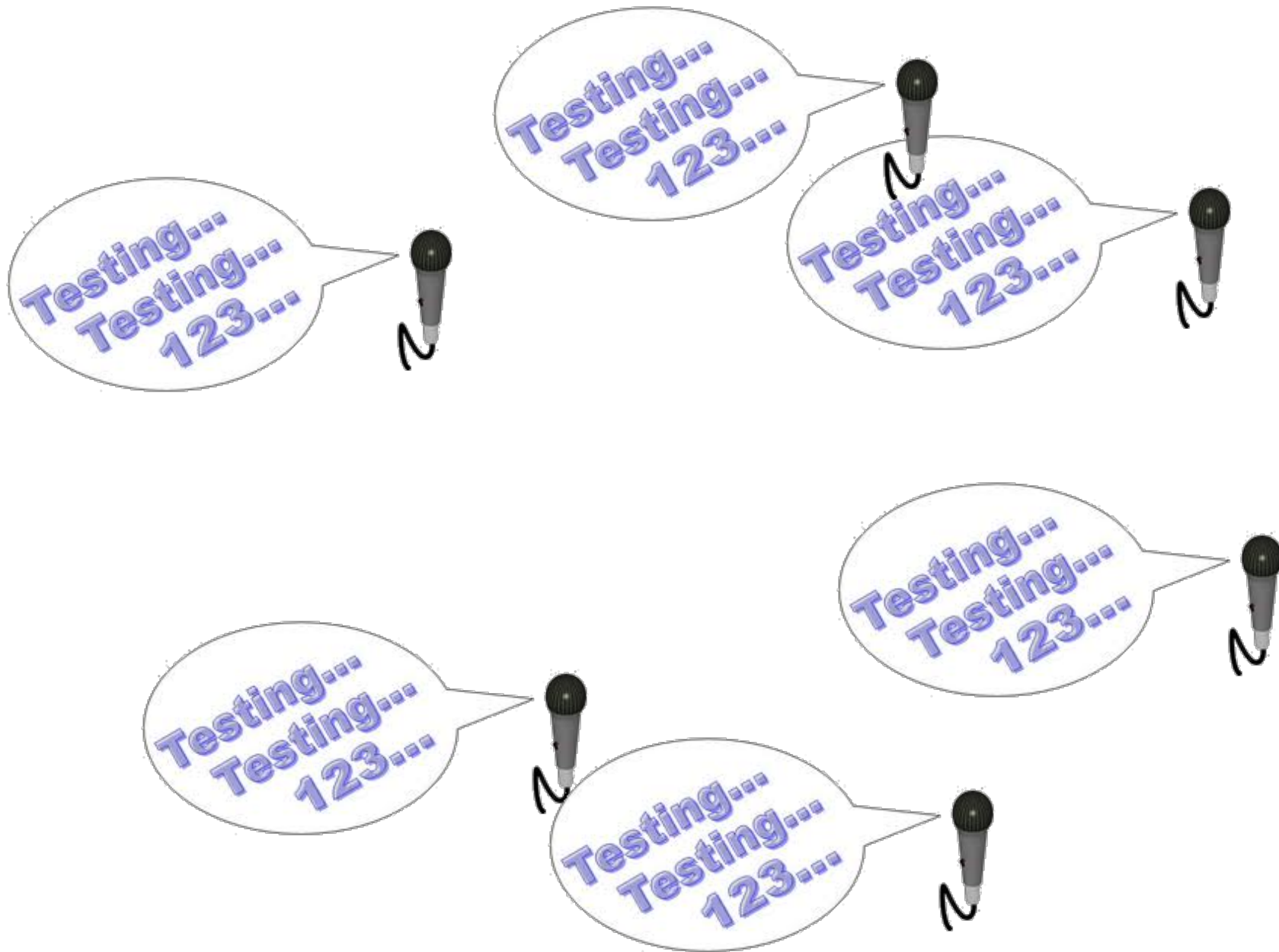
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Testing Pros and Cons

- + Relatively easy to write tests
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- Cannot prove absence of bugs

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A. Yes, with a **theorem prover!**

Theorem-Proving Tools

- Have been around since the late 1970s
- Increased adoption in academia, industry
 - **Quality** of tools has improved
 - **Need** for tools has skyrocketed
- Applied for verification
 - seL4 mobile phone microkernel [Isabelle]
 - CompCert optimizing C compiler [Coq]
 - Quark web browser [Coq]
- Also for mathematics
 - Four-Color Theorem [Coq]
 - Feit-Thompson Theorem [Coq]
 - Kepler Conjecture [Isabelle]

The Agda Theorem Prover

- From Chalmers U. of Technology, Sweden
- Supports verified pure functional programming
 - Inductive datatypes (immutable)
 - Anonymous functions, higher-order functions
 - Pattern-matching, recursion
- One language for programs, proofs
 - Proofs correspond to terminating functional programs
 - Curry-Howard isomorphism
 - Mathematical induction = terminating recursion
 - Minimalistic language, very elegant
 - Supports only *constructive* logic
- Unicode support, user-defined mixfix notation

The Future of Programming?

- Revolutionize open-source
 - Anyone can be a committer
 - (Just require proofs on commit)
- Quantum leap in software quality
 - Prove critical properties
 - Issue: still need to prove the right properties
- Software engineering gets *harder*
 - How to use development budget?
 - More complicated tradeoffs
- Happier programmers
 - Proving software correct is awesome experience
 - Watching it actually run correctly even better!

Conclusion

- Software is increasingly critical for society
- We programmers have an important role
- Great code is a key ingredient
- Testing only goes so far
- Theorem provers: to infinity and beyond!

Slides written in `slideshow` (www.racket-lang.org)

Thank you!

The University of Iowa Computing Conference (UICC)

- Run by U. Iowa ACM student chapter
- Intended for computing students in the region
- Outside speakers
- Programming/puzzle contest
- Will be **Feb. 28/March 1** for 2014

<http://acm.cs.uiowa.edu/uicc/schedule.html>

CS Graduate Program at U. Iowa

- Master of Computer Science (MCS)
 - Improve credentials, knowledge, for industry
 - Typically 2 years, 10 grad classes
 - **New for 2014:** Regional Scholars Fellowship
 - Teaching assistantship for one academic year
 - Tuition, plus stipend (approx \$2000/month)
 - Renewable for second year with GPA of 3.25
- Doctor of Philosophy (PhD)
 - Original research, advanced expertise
 - Preparation for career in academia, industrial research
 - Typically 5-6 years
 - Supported through teaching assistantships, fellowships
 - Recent placements: Yahoo! Research, MIT (postdoc), Amazon