WeBWorK in CS

Teaching Software Testing by Encouraging Contributions to an Open Source Web-based System for the Assessment of Programming

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Outline

• Pedagogical Context
• Systems for Automated Assessment of Programming Assignments
• WeBWorK
• WeBWorK-JAG
• Students’ Contributions to WeBWorK
• Conclusions and Future Work
Pedagogical Context

- Programming is the first skill a computer science major is expected to master.
- Programming fundamentals are taught in CS1 and CS2 courses [CC2005]
  - Fundamental programming constructs, algorithms and problem solving, elementary data structures, recursion, event-driven programming
- Open source for early exposure to collaborative and community-driven development.
- Test-driven development for emphasizing the criticality of formulating requirements in a testable manner and laying the basis for quality coding.
- Peer-review for giving students an awareness of the value of getting an independent person to examine code and detect errors before release and use by others.
Systems for Automated Assessment of Programming Assignments

• Web-based systems to encourage practice (with feedback), and improve and reinforce students’ understanding of concepts

• Types of questions
  – True / false, short answer, multiple-choice, programming

• Grading programs
  – Correctness + quality + authenticity
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Existing Systems

- Boss  [www.dcs.warwick.ac.uk/boss](http://www.dcs.warwick.ac.uk/boss)
- CodeLab  [www.turingscraft.com](http://www.turingscraft.com)
- CourseMarker  [www.cs.nott.ac.uk/CourseMarker](http://www.cs.nott.ac.uk/CourseMarker)
- Gradiance  [www.gradiance.com](http://www.gradiance.com)
- JavaBat  [www.javabat.net](http://www.javabat.net)
- MyCodeMate  [www.mycodemate.com](http://www.mycodemate.com)
- OWL  [owl.course.com](http://owl.course.com)
- Viope  [www.viope.com](http://www.viope.com)
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WeBWorK

- \textit{webwork.rochester.edu}
- Project funded by NSF
- Free, open-source and web-based
- Automated problem delivery and grading
- Initial development and applications in the fields of mathematics and physics
- Currently in use at more than 50 colleges and universities
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WeBWorK

• Problems are written in the Problem Generating macro language (PG)
  – Text, HTML, Latex, Perl
• Underlying engine dedicated to dealing with mathematical formulae
  – \( x+1 = (x^2-1)/(x-1) = x + \sin(x)^2 + \cos(x)^2 \)
• Individualized and parameterized versions of problems
WeBWorK for Programming Fundamentals

- atlantis.seidenberg.pace.edu/webwork2/demo
- True / false, short answer and multiple choice problems for Java, Python and SML
- Extension of WeBWorK for use in programming fundamentals
- Evaluation of Java program fragments by interfacing WeBWorK with JUnit [www.junit.org]
  - WeBWorK-JAG = WeBWorK + JUnit
set1: Problem 1

SUM OF EVEN NUMBERS

Write a method that computes the sum of the even numbers from 0 to a given limit (included).

The method will be called `sumEven` and must:
- Be declared public and static;
- Take one parameter of type `int` representing the limit;
- Return an `int` containing the sum; and
- Throw an `IllegalArgumentException` for an argument strictly smaller than 0.

You have attempted this problem 0 times.
You have unlimited attempts remaining.
set1: Problem 1

The above answer is correct.

SUM OF EVEN NUMBERS

Write a method that computes the sum of the even numbers from 0 to a given limit (included).

The method will be called `sumEven` and must:

- Be declared public and static;
- Take one parameter of type `int` representing the limit;
- Return an `int` containing the sum; and
- Throw an `IllegalArgumentException` for an argument strictly smaller than 0.

```java
public static int sumEven(int n) { 
    int res = 0; 
    for (int i = 0; i <= n; i++) { 
        if (i % 2 == 0) 
            res = res + i; 
    } 
    return res; 
}
```
set1: Problem 1

The above answer is NOT correct.

SUM OF EVEN NUMBERS

Write a method that computes the sum of the even numbers from 0 to a given limit (included).

The method will be called `sumEven` and must:

- Be declared public and static;
- Take one parameter of type `int` representing the limit;
- Return an `int` containing the sum; and
- Throw an `IllegalArgumentException` for an argument strictly smaller than 0.

```java
public static int sumEven(int n) {
    // Your code here
}
```
set1: Problem 1

Entered

```
public static int sumEven(int n) { int res = 0; for (int i = 0; i <= n; i++) { if (i % 2 == 0) res = res + i; } return res; }
```

Answer Preview

- You only got 9 out of 11 tests right.
- You need to work on:
  - Test failed for input = -5 - The method should return an IllegalArgumentException for negative numbers!
  - Test failed for input = -1 - The method should return an IllegalArgumentException for negative numbers!

Messages

The above answer is NOT completely correct.

SUM OF EVEN NUMBERS

Write a method that computes the sum of the even numbers from 0 to a given limit (included).

The method will be called sumEven and must:
- Be declared public and static;
- Take one parameter of type int representing the limit;
- Return an int containing the sum; and
- Throw an IllegalArgumentException for an argument strictly smaller than 0.

```
public static int sumEven(int n) {
    int res = 0;

    // Your implementation here
}
```
Contributing to WeBWorK

• Students' contributions to WeBWorK
  – WeBWorK-JAG questions (Java + JUnit)

• Contributed questions were peer-reviewed and tested by students, and then integrated in the WeBWorK library of problems by the instructors
Contributing to WeBWorK – Students’ Results

- WeBWorK-JAG questions
  - Poor formulation of the questions (scope not clear, modifiers not stated, requirement for the use of a specific algorithm)
  - Well-written test cases for method signatures
  - Not exhaustive test cases for the method (null object, equivalence class identification, exceptions, invalid inputs, no white box testing)
  - Coarse or inexistent feedback for failure test cases
  - Crucial role of QA to catch problems
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Contributing to WeBWorK – Students’ Feedback

• When specifying the question students had the user in mind (not so much when writing the tests)
• Students became familiar with the use of the Reflection API
• Writing WeBWorK-JAG questions forced students to think about testing first
• Students improved their testing skills (including regression testing)
Conclusions and Future Work

• Development of a novel pedagogy encouraging students to contribute their own questions to the system WeBWorK library and introducing them to crucial practices of software engineering
• Create a community of contributors to monitor quality, share work and extend the WeBWorK library
• Stay tuned…
  – WeBWorK workshop at Pace University in the spring 2008
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