Formal Methods for Personalized (Lab-Based) Education

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CPSGrader.org

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Formal Inductive Synthesis for Education (w/ focus on lab-based education)

Topics in Education
- Lab-based

Formal Methods (computational proof) + Machine Learning

can be very effective for:
- Grading
- Personalized Feedback / Guidance
- Exercise generation
- ...

Physics
Robotics
Integrated Circuits
Embedded Systems / Cyber-Physical Systems / Internet of Things
Goal: **Online Virtual Lab** with learning experience “comparable” to **On-Campus Real Lab**
EECS149.1x: Cyber-Physical Systems on edX (May-June 2014)
Virtual Lab: CyberSim + CPSGrader

Technology based on Formal Methods + Active Learning
- Run-time verification of Properties in Signal Temporal Logic
- Automatic Synthesis of Temporal Logic Testers [EMSOFT 2014]
- Clustering-based Active Learning Framework [L@S 2015]
Instructor View of CPSGrader

Corpus of Solutions (code)
Instructor View of CPSGrader

Corpus of Solutions (code)

Clustering

Inductive Synthesis

Temporal Logic Testers
(monitored on simulation/execution of robot)

Instructor

NLP

Temporal Logic Templates
Student Feedback has been Positive: Online and On Campus

• EECS149.1x on edX
  – 86% found auto-grader feedback useful for debugging
  – >90% of solutions that passed CPSGrader worked on the real robot with no or minor modifications [optional hardware track]

• EECS149 on campus at UC Berkeley
  – Course taught by other instructors [Lee & Sangiovanni-Vincentelli]
  – Enrollment nearly doubled from previous year!
    • Same lab space and similar resources!
  – Debug Tests: 75% rated as somewhat to very useful
  – Feedback: 82% rated as somewhat to very useful
Formal Inductive Synthesis is very promising

• **CPSGrader** – Automatic grading and personalized feedback in lab-based education
  
  – Released open source at http://cpsgrader.org
  
  – Lots of future work:
    * Combination with NLP, crowdsourcing, ...
    * Other lab-based courses: frequency-domain properties, ...
    * Extra/partial credit

• **FMEE** – graduate course exploring applications of Formal Methods for (Engineering) Education

  – Constrained Random Sampling for Problem Generation
    * E.g., to deter cheating

  – More formal methods + machine learning
    * E.g., FM can generate “interesting data points” for ML

  – http://www.eecs.berkeley.edu/~sseshia/fmee/