Programming Languages, Analysis and Software Engineering

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Part III: Some Proposals for BTech/BE or Mtech/ME projects

SAT

Background:

- CNF SAT is a well studied problem

Question:

- Given a boolean formula in CNF, does there exists a satisfying assignment?
- This problem is NP Complete, but DPLL based solvers are very competitive and scale to formulas with millions of clauses
- SAT competitions are run every year. http://www.satcompetition.org/

  Warning: this is extremely competitive

QBF

Quantified formulas over boolean variables

Example 1.

$\forall x.\ \exists y.\ (x \leftrightarrow y)(\text{read} \leftrightarrow \text{as} =)$

Valid

Example

$\exists x.\ \forall y.\ (x \leftrightarrow y)(\text{read} \leftrightarrow \text{as} =)$

NotValid

QBF Solvers

Given a QBF formula, is it satisfiable or unsatisfiable?

PSPACE complete problem

Expansion to SAT will be likely exponential

QBF competition at: http://www.qbflib.org/

Widely believed that a breakthrough is possible

Analysis and design of concurrent-data structures

- For sequential data structures, the theory and practice of design and analysis of algorithms is well understood
- How about concurrent data structures?
- Sample papers:
  - A Pragmatic Implementation of Non-Blocking Linked Lists
  - Simple, Fast, and Practical Non-Blocking and Blocking Concurrent Queue Algorithms
  - High Performance Dynamic Lock-Free Hash Tables and List-Based Sets
  - Scalable Lock-Free Dynamic Memory Allocation
  - Maged Michael's publications

Analysis and design of concurrent-data structures

- Can we come up with an efficiency measure (analog of “O” notation for sequential algorithms) to measure effectiveness of a concurrent data structure?
- How can we compare two concurrent data structures analytically?
  - Lock based algorithms work well under high-load (lots of conflicts)
  - Optimistic concurrency based algorithms work under low-load (few conflicts)
  - Do we need a probabilistic model of conflicts to compare data compare structures?
- Can we do systematic empirical evaluation of concurrent data structures?
- Can we design efficient “lock-free” data structures for trees, stacks, queues, etc?

Concurrent Programs

- Concurrency bugs happen due to:
  - Race conditions
  - Atomicity violations
  - Ordering violations
  - Memory model issues

- See survey of bugs at:

  "**Learning from mistakes: a comprehensive study on real world concurrency bug characteristics", ASPLOS 2008**

  http://portal.acm.org/citation.cfm?id=1353534.1346323&coll=ACM&dl=ACM

Concurrency Tools

- Can you build automated tools to detect these kinds of bugs?
  - Static analysis tools
  - Runtime tools
- Can you build tools to identify root causes of concurrency errors?
  - Statistical techniques?

Programming model for networking in multi-player games

- In multiplayer games, networking code is vital to the game experience
  - But low priority compared to game logic, graphics, story
- Not enough time and effort for experimentation/ analysis

Question:

- Can you come up with a configurable network code model for games?
  - Same code should work both in single node and multi-node situations.
- Enable experimentation and rapid development