Introducing 8th Grade Girls to Fault Tolerant Computing (An Experience Report)

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The Context
- “Future Engineers’ Summer Camp”
  - Piloted at OSU Summer 2002
  - Workshop for 8th grade girls
  - 30 participants
  - 1 week (days only) on campus
- Theme: Introduction to “engineering and science”
  - Mechanical, chemical, civil, astronomy, environmental, industrial, ...
  - Lectures, lab tours, activities

The Challenge
- Design a 3-hour module for CS
- Goals:
  - Fun
  - Educational
  - Reflection of CS as a discipline
- Requirements:
  - No CS background assumed

Approach 1: Logo
- Use a simple imperative programming environment
  - E.g. “Darwin’s World” exercise in CS 1/2
    - Simple programming language to control bug movement, replication
    - Bugs interact, infect, thrive, die
  - Ref: SIGCSE ’99 panel on nifty assignments
- Appeal:
  - Conditionals, iteration, recursion, ...
- Problems:
  - Syntax is a distraction
  - Low engagement for this audience

Approach 2: Using App’s
- Use engaging applications
  - E.g. tool for designing web pages
- Appeal:
  - Gender-appropriate applications can be chosen
  - Clear, identifiable skill is learned
  - Sense of accomplishment from an impressive final product
- Problem:
  - Not CS!

Our Approach
- Teach:
  1. Software engineering principles
  2. Parallel programming
  3. Self-stabilizing distributed algorithms
- Three graduate-level CS topics!
  - Each builds on the previous
  - Each consists of lecture + activity (1 hr)
- Consistent theme:
  - Programs as recipes
  - Computers as chefs
**Topic 1: Programs**
- Lego Mindstorm robots
- Light sensors
- Follow grid lines
- Instructions
  - Turn, forward, take sample
  - Printed on cards
- Cards stacked to form programs
  - Straight-line
  - Simple requirements
  - Uploaded to robots

**Instructions**
- printed on cards
- cards stacked to form programs
- straight-line
- simple requirements
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**Topic 2: Parallel Programs**
- Each person holds a number
- Physically move to represent data movement
- Sequential sort
- Bubble sort
- Parallel sorts
  - Even-odd transposition
  - Radix
- Differences apparent
  - Execution time
  - Multiple threads
- SIGCSE '94 paper

**Topic 3: Fault Tolerance**
- Lecture
  - Nature of faults (chef analogy)
  - Easy answer: redundancy
  - Follows directly from parallel algorithm unit
- Self-stabilizing token ring algorithm
  - Correct state: 1 token (mutual exclusion)
  - Possible faults: token loss or duplication
  - Converges to correct state
  - Distributed control

**Fault Tolerance Activity**
- Design goals
  - Simple rules
  - Reinforce distributed nature of algorithm
  - Dramatic difference between correct & incorrect states
  - Satisfaction in re-establishing correct state
- Solution:
  - Use music!
  - Students are in a ring, each with a chime
  - When they have the token, they play their note
  - Correct (1 token) = melody
  - Incorrect (multiple/none) = chaos / silence

**Fault Intolerant Token Ring**
- Problem: What about faults?
  - What happens if token is lost?
  - One fault means disaster!

**Prevent Loss of Token: Binary Ring**
- Rule (for most people):
  - if left neighbor is different from me, then I have the token
  - Make my number equal to that neighbor's
Completing the Ring

0 0 0 "1" token
1 1

- One person is special: if left neighbor is same as me, then I have the token
- Make my number differ from that neighbor's

Fault: Corruption of Values

0 0 0 "1" token
1 1

- Problem: multiple tokens in ring
- Tokens chase each other around ring
- One fault means disaster

k-State Token Ring

- Solution: use more values than people!
- Same rule
- If left neighbor different from me:
  - I have the token! (use it)
  - Change my value to be equal to neighbor
- Again, one person is special
- If left neighbor same as me
  - I have the token (use it)
  - Change my value to be one bigger

Activity

- Form a ring
- Each person has number cards
- Each person has a chime
- When you get the token:
  - Play your chime
  - Then change your number
- We'll run different versions
- I'll introduce "faults" and see if you can recover!

FT Demo: Tips for Success

- Recognizable tune with equal note lengths
  - TTL5, a scale, Frère Jaques, Carmen Ohio...
  - Use a large group (14 notes worked well)
- Do not align tune with processor 0
- Supervise the "special processor"
- Binary ring:
  - Allow tune to emerge, then disrupt
  - After fault, make sure all 3 tokens appear
  - Change tune after binary ring
- K-state ring:
  - Disrupt before tune emerges
  - Start from random state for effect

Participant Evaluation

- "How much did you know about CS before?"
  - 2.8 (1 = none, 5 = a lot)
- "Is CS now more or less interesting?"
  - 4.0 (1 = less, 5 = more)
- "Most important thing learned?"
  - "It's really fun"
  - "Computers need specific instructions"
  - "Sequential programs are slow"
  - "How a program can recover from faults"
  - "In which activity did you learn the most?"
- Most popular selection: CS
Conclusions

- Effectiveness of anthropomorphism
- Caveat: encourages operational reasoning
- Try the fault tolerance activity!
- Works best as a 3-part series
- But each part can work individually too
- Age neutral
- Middle school, HS, UG, Grad
- Slides, notes, and code available: http://www.cis.ohio-state.edu/~paolo/FESC02

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