CS 161
Introduction to CS I
Lecture 28

C++ in Space
Week 10 tips

• Proficiency demo!
• Check Canvas for any missing grades
  • Notify cs161-020-ta@engr.orst.edu by Wednesday (3/11)
  • Your Canvas grade may not be your final course grade
• Final exam: Monday, 3/16, 6-7:50 p.m., LINC 128
  • All T/F and multiple choice (no short answer)
  • Review Midterm 1 and 2 solutions
  • See additional practice questions for structs and recursion (website)
  • No Thursday review session: review in class instead on Friday
• Extra credit (for final exam): survey of course materials
Assignment 5 creativity!

• Excellent diversity of items!
• airJordan, album, baby tooth, ball, barnacle, bean, bomb, book, bookshelf, brain, cake, car, cat, clothing, coin, computer, cookie, cuisine, dice, dog, door, dvd, egg, elect_device, employee, equipment, food, fruity, game, gem, goods, healing crystal, hot wheels, house, ice cream, instrument, jersey, jewelry, lego, lightsaber, lipstick, memory, monster, music, necklace, ore, pencil, people, phone, photo, pin, plant, pokemon, poster, prosthetic, record, rock, room, scrunchie, ship, shoe, song, spool, stock, surfboard, sword, tea, teddy, ticket, torus, transit_card, turtle, vinyl, water bottle, weapon, wine, woodchip, yoyo...
C++ in Space

• What's the big difference?
<table>
<thead>
<tr>
<th></th>
<th>Laptop on Earth</th>
<th>Mars Odyssey spacecraft</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Configuration</strong></td>
<td>CPU: 2 GHz</td>
<td>CPU: 33 MHz</td>
</tr>
<tr>
<td></td>
<td>RAM: 16 GB + virtual memory</td>
<td>RAM: 128 MB</td>
</tr>
<tr>
<td></td>
<td>HD (SSD): 500 GB</td>
<td>HD (SSD): 1 GB</td>
</tr>
<tr>
<td><strong>Testing</strong></td>
<td>Human user</td>
<td>(1) Simulator</td>
</tr>
<tr>
<td></td>
<td>Crash: bug report, power cycle</td>
<td>(2) Testbed</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Crash: break testbed?</td>
</tr>
<tr>
<td><strong>Runtime</strong></td>
<td>Hazards: spills, drops</td>
<td>Hazards: radiation, temperature</td>
</tr>
<tr>
<td></td>
<td>Crash: bug report, power cycle</td>
<td>Crash: attempt self-reset (“safe mode”)</td>
</tr>
</tbody>
</table>

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Operational Constraints in Space

- **Processor limitations**
  - Radiation-hardened: RAD6000 (33 MHz, 128 MB of RAM)
  - Can't run it at 100% (risk!)
- **Memory limitations**
  - No virtual memory
  - What happens if you run out?
- **Storage limitations**
  - Hundreds of MB to a few GB
  - Custom filesystem designs (e.g., to handle radiation)
Programming Constraints

• Strict programming guidelines
  • For predictability, clarity, and safety
• Examples (each mission differs):
  • No dynamic memory allocation
  • No recursion
  • No file input or output
  • No goto
  • Declare variables at smallest possible level of scope
  • No more than two levels of indirection (&&value)
  • No more than two levels of dereferencing (**ptr)
• What else would you add?
Programming Constraints (2)

• Minimize library dependencies
• To enable "lights out" operations, fault protection and recovery is essential

• What happens if the code crashes?
Impact of Bugs for Spacecraft

1. Inconvenience: Additional effort / hours / staff needed
2. Damage to reputation (no more contracts?)
3. Degraded mission
   • Shortened lifetime
   • Loss of data – Cassini backup script
NASA Lessons Learned

• https://llis.nasa.gov/
• #1781: "Verify the Proper Performance of Critical Backups" (Cassini)
  • "When a 2004 backup tape for a Cassini instrument testbed was needed in late 2005 to restore important files, it was discovered that a coding error in the backup script had been causing the backup files to be overwritten and the backup data to be lost. Do not assume that critical data backups are being properly performed, but assure that a computer system administrator familiar with both the script and the backup hardware verifies the actual performance of the backups."
Impact of Bugs for Spacecraft (2)

4. Loss of mission
5. Loss of spacecraft
   • Mars Climate Orbiter
   • Mars Global Surveyor
6. Loss of life
NASA Lessons Learned

• #1805: "Mars Global Surveyor (MGS) Spacecraft Loss of Contact"
  • "Contact was lost with the Mars Global Surveyor (MGS) spacecraft in November 2006 during its 4th extended mission. A routine memory load command sent to an incorrect address 5 months earlier corrupted positioning parameters, and their subsequent activation placed MGS in an attitude that fatally overheated a battery and depleted spacecraft power."

https://llis.nasa.gov/lesson/1805
Dust Devils on Mars

- Seasonal activity. But when and where?
- Mars Exploration Rovers: Spirit and Opportunity
  - 128 MB RAM – dust devil detector given only 4 MB
  - 33 MHz processor (RAD6000)
Autonomous Science on Mars

• Mars Exploration Rovers
• Which rocks are interesting?
• Given limited time, which ones to take close-up pictures of?
Rock “signature” matching

<table>
<thead>
<tr>
<th></th>
<th>Desired</th>
<th>Rock 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Albedo</td>
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<tr>
<td>Roundness</td>
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<tr>
<td>Texture</td>
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</tbody>
</table>

Rock 1
Rock “signature” matching

![Rock 2](image)

<table>
<thead>
<tr>
<th>Feature</th>
<th>Desired</th>
<th>Rock 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size</td>
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Desired  Rock 2
Autonomous Science on Mars

• MSL: Mars Science Laboratory
  – 128 MB RAM – AEGIS given only 16 MB
  – 133 MHz processor (RAD750)

• AEGIS: Autonomous Exploration for Gathering Increased Science
  – Find rocks in images
  – Prioritize rocks
  – Fire ChemCam laser and collect spectra
  – Send results to Earth

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Programming for Spacecraft

• Enables autonomous operations (too far away for human control)
  • Navigation
  • Exploration
  • Data collection
  • ...

• Strict code quality, testing, verification requirements
  • Bugs can cause loss of time, data, money, careers, ... lives
HOUSE CUP AWARDS

Babbage  Lovelace  Turing  Hopper

1030 points  1470 points  1320 points  1930 points
Week 10 continues

- Demonstrate your proficiency in lab! Flex your muscles!
- Review and study for the final exam (in-class review Friday)
- Assignment 6 (due Saturday, March 14)

Best wishes to you all.
It has been wonderful having you in class!

3/11/2020