CS 6210 Fall 2016
Bei Wang

Lecture 3
Floating Point Systems and Roundoff Errors

Tracking bubbles in a Rayleigh–Taylor Instability

Follow up on Mark's talk on Tuesday:

1. **Rayleigh–Taylor instability**, or **RT instability** (after Lord Rayleigh and G. I. Taylor), is an instability of an interface between two fluids of different densities which occurs when the lighter fluid is pushing the heavier fluid
2. Video: http://www.pascucci.org/animations/Bubbles_tracking_video_clip.mov

Pre-requisite of this class

1. Graduate breadth course to give students exposure to the algorithms and implementations often used in scientific computing.
2. For the diligent student, very little previous knowledge is required (other than basic calculus, linear algebra and ODEs).
3. Followed by **CS 6220: Advanced Scientific Computing II** (Prof. Mike Kirby): an advanced graduate course that focuses on the numerical solution of PDEs.

News and Announcement

1. Start your HW early! Read the book!
2. Submit HW on Canvas! https://utah.instructure.com/login/canvas
3. Book material + (fun/in depth) additions **slides + whiteboards**
4. **Scientific Computing Miniseries** guest speakers
    a. 8/30 Mark Kim (SCI): **Fixed-Rate Compressed Floating-Point Arrays**
    b. 9/20 Sidharth Kumar (SCI): **Mira and Parallel I/O Library**

Review and some extra notes

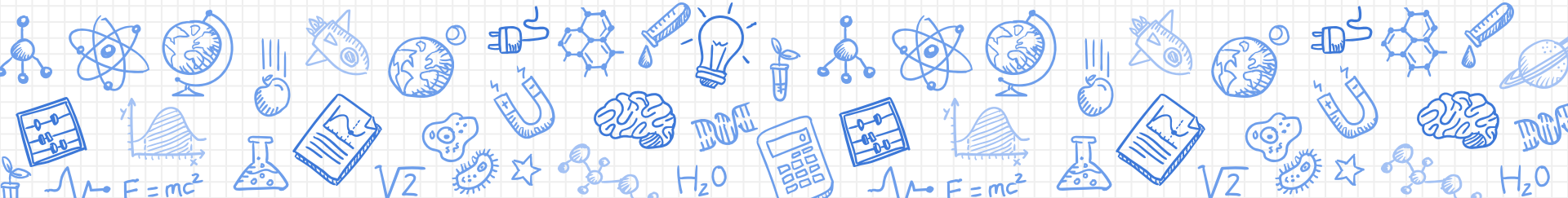
1. A problem is **ill-conditioned** if a small perturbation in the data produces a large difference in the result. Otherwise, it is **well-conditioned**. (See Example.)
2. **Well-posed** problem
   a. A solution exists
   b. The solution is unique
   c. The solution's behavior changes continuously with the initial condition
3. A well-posed problem can still be ill-conditioned.
4. **Condition number** of a function

Take home message

1. Real number representation: floating point system
2. **Rounding unit**
3. 64 bit word: double precision (IEEE standard word)
4. **Exact rounding**
5. **Guard digits**
6. General floating point systems
7. Spacing of floating point numbers
8. **Cancellation error**
9. **Good coding practice in floating point arithmetic**

Case Study

Ariane 5 Incident Revisited



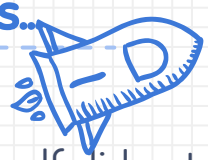
From the full report...

"The internal SRI software exception was caused during execution of a data conversion from 64-bit floating point to 16-bit signed integer value. The floating point number which was converted had a value greater than what could be represented by a 16-bit signed integer. This resulted in an Operand Error. The data conversion instructions (in Ada code) were not protected from causing an Operand Error, although other conversions of comparable variables in the same place in the code were protected."

But is this simply a programming error?

http://sunnyday.mit.edu/accidents/Ariane5accidentreport.html

We can not blame everything on the software engineers...



Although the source of the Operand Error has been identified, this in itself did not cause the mission to fail.

The specification of the **exception-handling mechanism** also contributed to the failure.

In the event of exception, the system specification stated that: the failure should be indicated on the databus, the failure context should be stored in an EEPROM memory, and finally, the SRI processor should be shut down.

It was the decision to cease the processor operation which finally proved fatal.

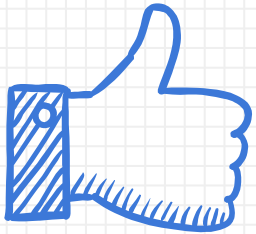
Lesson learned...

1. Although the failure was due to a systematic software design error, mechanisms can be introduced to mitigate this type of problem, e.g. the computers within the SRIs could have continued to provide their best estimates of the required attitude information.

2. Critical software – in the sense that failure of the software puts the mission at risk – must be identified at a very detailed level, that exceptional behaviour must be confined, and that a reasonable backup policy must take software failures into account.

For your procrastination reading list

1. [Lions 1996] Ariane 5 Flight 501 Failure full report: http://sunnyday.mit.edu/accidents/Ariane5accidentreport.html



THANKS!

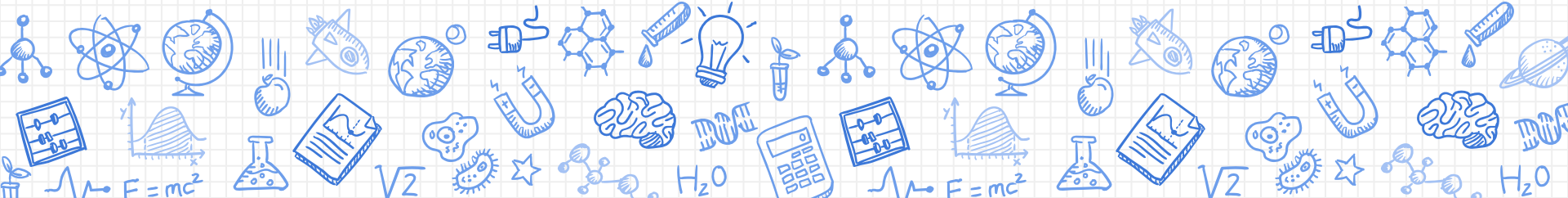
Any questions?

You can email us at

1. Instructor: beiwang@sci.utah.edu
2. TA: sourabh@sci.utah.edu

Extra Notes

So it goes.



Credits

Special thanks to all the people who made and released these awesome resources for free:

- ✘ Presentation template by SlidesCarnival
- ✘ Photographs by Unsplash