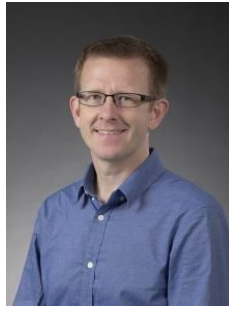


CS370 Numerical Computation - Introduction

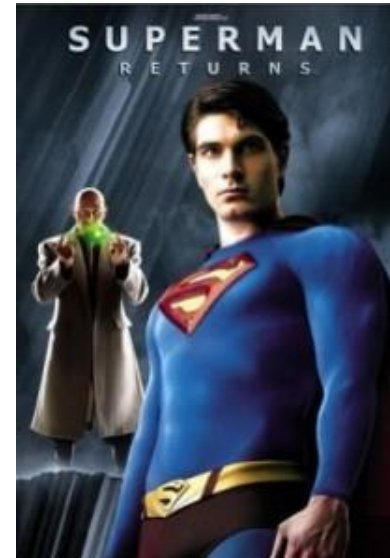
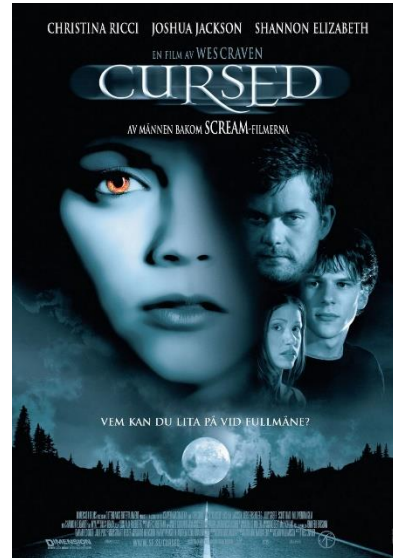
Term: Spring 2016

Instructor: Christopher Batty

Who am I?

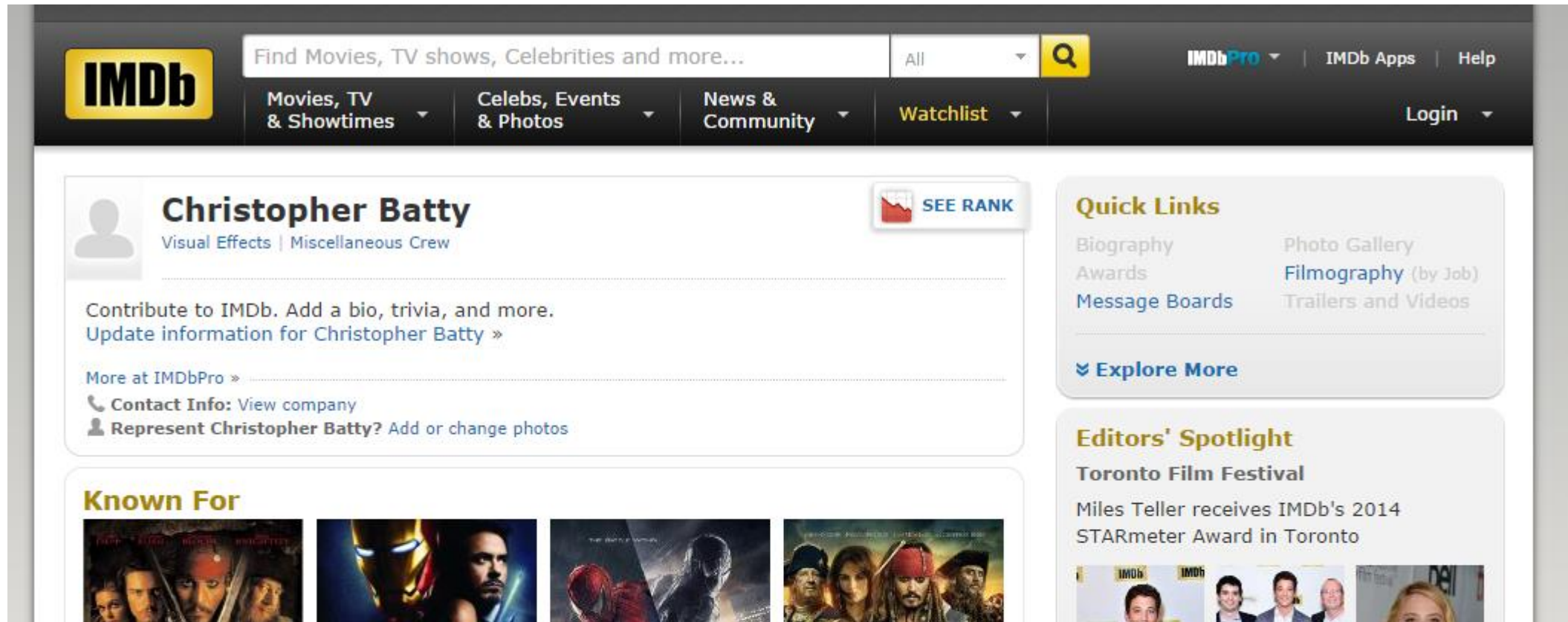


- CS Professor, part of the Scientific Computing (SciCom) group and Computer Graphics Lab (CGL) here at Waterloo.
- Former visual effects software engineer at *Frantic Films*.




Who am I not?



This guy has my name too, so he got an IMDB entry instead of me!
Grrr...



The screenshot shows the IMDb profile page for Christopher Batty. The header includes the IMDb logo, a search bar, and navigation links. The profile section features a placeholder for a profile picture, the name Christopher Batty, and his roles in Visual Effects and Miscellaneous Crew. There is a 'SEE RANK' button and a prompt to contribute to the profile. Below this, there are links for contact info and representing the profile. The 'Known For' section displays four movie posters: The Matrix, Iron Man, Spider-Man, and Pirates of the Caribbean. On the right, there are 'Quick Links' for Biography, Awards, Message Boards, Photo Gallery, Filmography, and Trailers and Videos, along with an 'Explore More' link. The 'Editors' Spotlight' section mentions Miles Teller receiving the 2014 STARmeter Award in Toronto.

IMDb Find Movies, TV shows, Celebrities and more... All  **IMDbPro** | **IMDb Apps** | **Help**


Movies, TV & Showtimes **Celebs, Events & Photos** **News & Community** **Watchlist** **Login**


 **Christopher Batty**  **SEE RANK**

Visual Effects | Miscellaneous Crew





Contribute to IMDb. Add a bio, trivia, and more.
[Update information for Christopher Batty »](#)

More at IMDbPro »

 **Contact Info:** [View company](#)

 **Represent Christopher Batty?** [Add or change photos](#)

Known For

Quick Links






[Biography](#) [Photo Gallery](#)
[Awards](#) [Filmography \(by Job\)](#)
[Message Boards](#) [Trailers and Videos](#)

[Explore More](#)

Editors' Spotlight

Toronto Film Festival

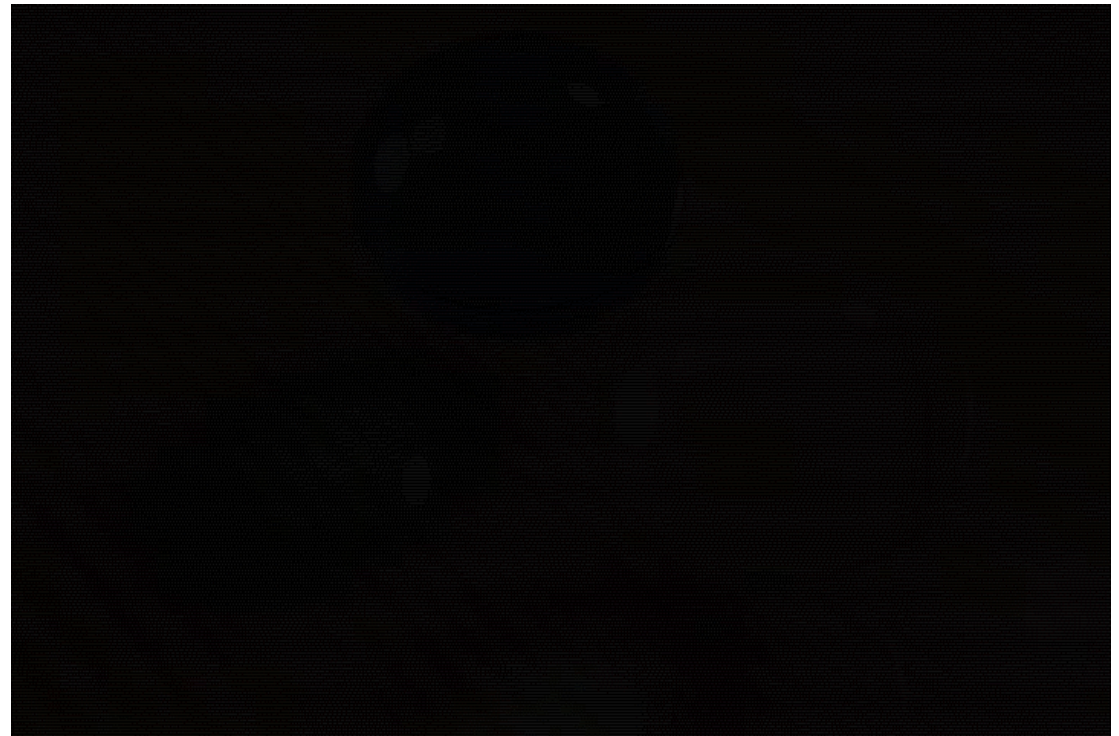
Miles Teller receives IMDb's 2014 STARmeter Award in Toronto

What do I do?

Research areas: Computer Animation, Computational Physics.

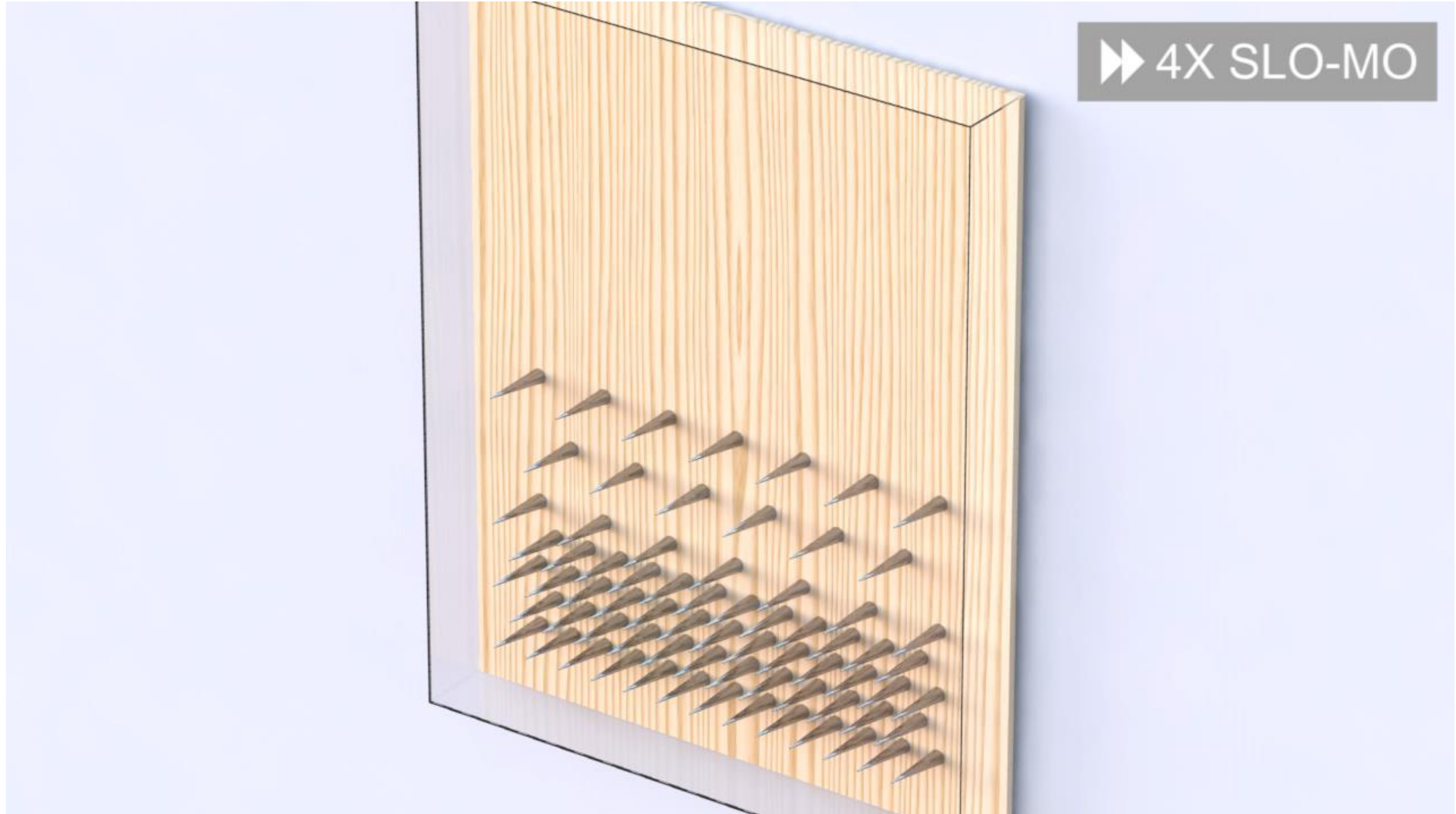
- i.e., I use numerical computing to animate/simulate visually interesting natural phenomena, mostly fluids.



What do I do? Blow bubbles.



What do I do? Torture gooey penguins.



Where/when am I (available)?

- Email: christopher.batty@uwaterloo.ca
- Office: DC3605
- Office Hours: Mon, 12:30pm-1:30pm, starting next week.

But enough about me...

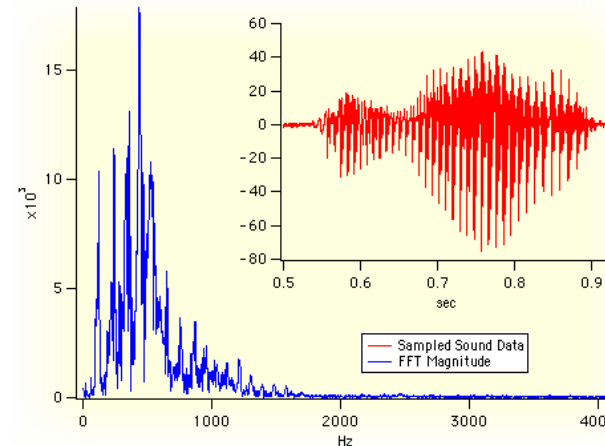
What is numerical computation?

In a nutshell: Using computer algorithms to (approximately) solve a range of mathematical problems.

- Representing and manipulating numbers.
- “Fitting”, manipulating, and analyzing data sets.
- Solving differential equations (approximately)
- Solving systems of equations (e.g. linear algebra) or optimization problems (approximately)
- Understanding properties of problems and numerical algorithms.

Why numerical computation?

- Weather prediction
- Financial modeling and prediction
- Computer graphics and animation
- Physics
- Engineering
- Biology (disease, populations, etc.)
- Image and sound processing
- Search engines
- Machine learning
- ...

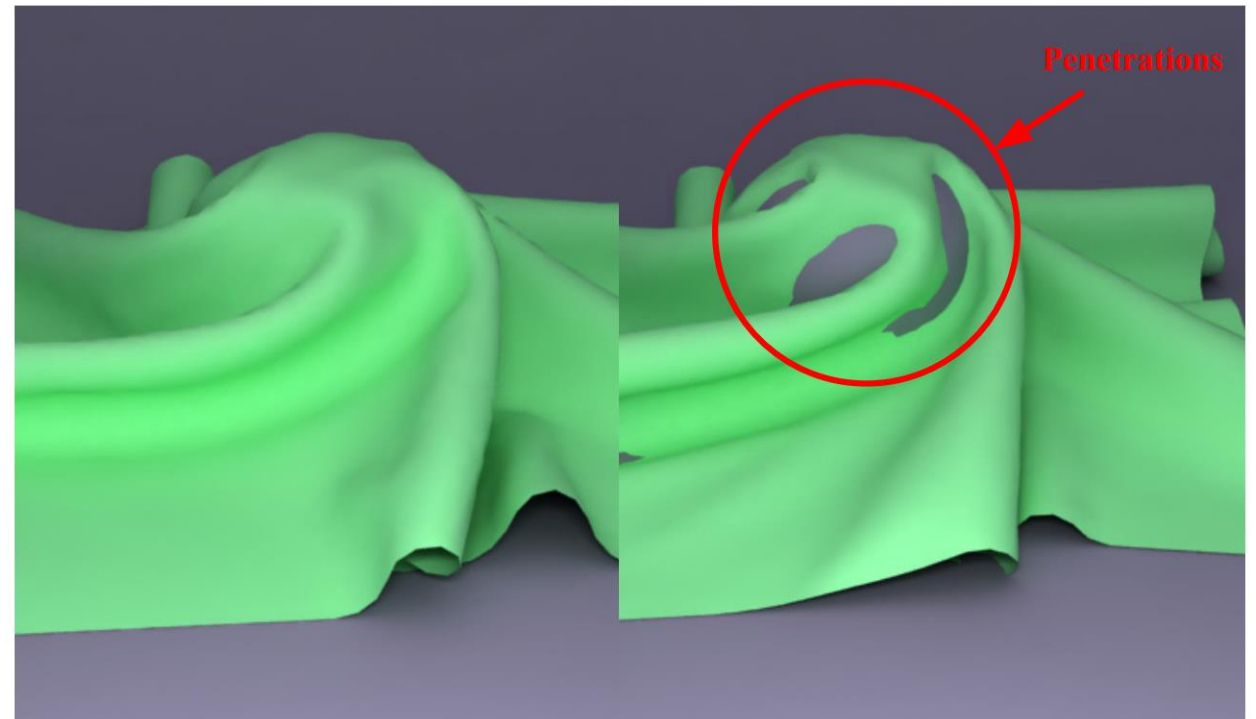


Overall Course Structure

1. Floating Point (~1 week)
2. Interpolation and Splines (~2 weeks)
3. Ordinary differential equations (~3 weeks)
4. Fourier analysis (~3 weeks)
5. Numerical Linear Algebra (~3 weeks)

1. Floating Point

- Understand how to represent and manipulate *real* numbers digitally.
- Analyze the resulting error behaviour.
- Allows us to predict or control accuracy of computations, and avoid/reduce errors.



e.g., Floating point errors can lead to visual problems in cloth simulation. [Tang et al. 2014]

FP Example: Robust, error-free cloth collisions

Benchmark: Funnel

- 2K-42K triangles
- Multiple inter-object and intra-object collisions
- Average CCD query time: 21 ns
- Incorrect CCD query results due to floating point ops: 131 queries

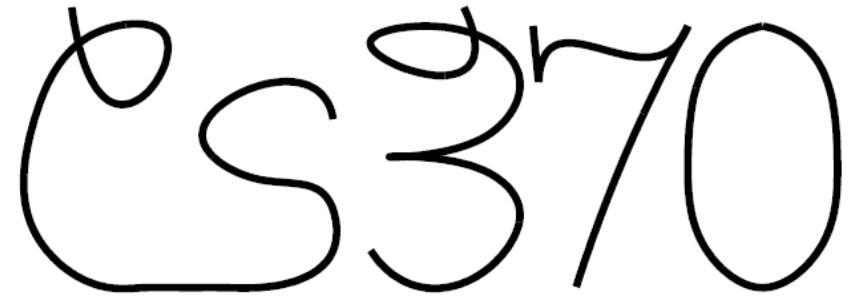


2. Interpolation and Splines

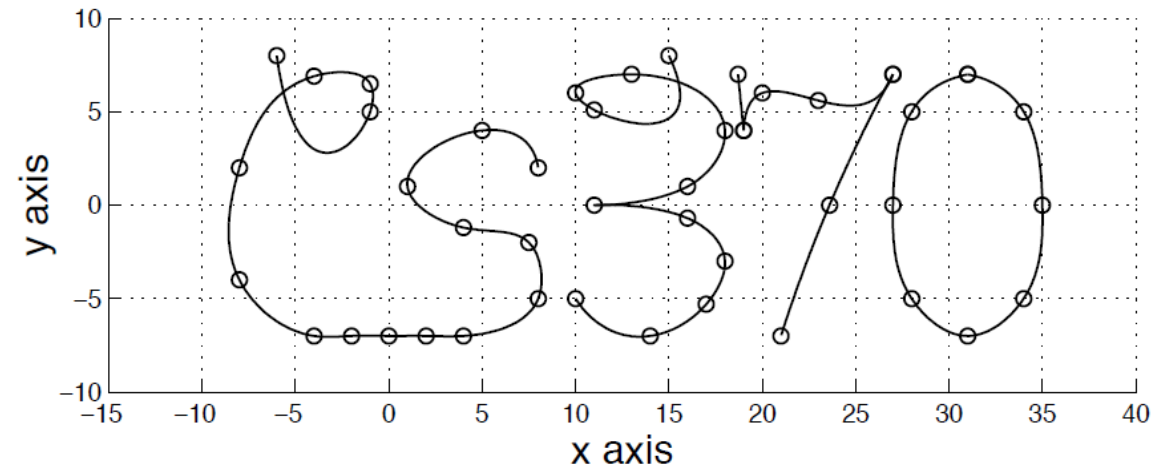
Given some discrete data set,
how can we:

- *fit* a “smooth” function that goes near/through the data?
- *interpolate* to create new points not present in the original data?

End Result Using Splines

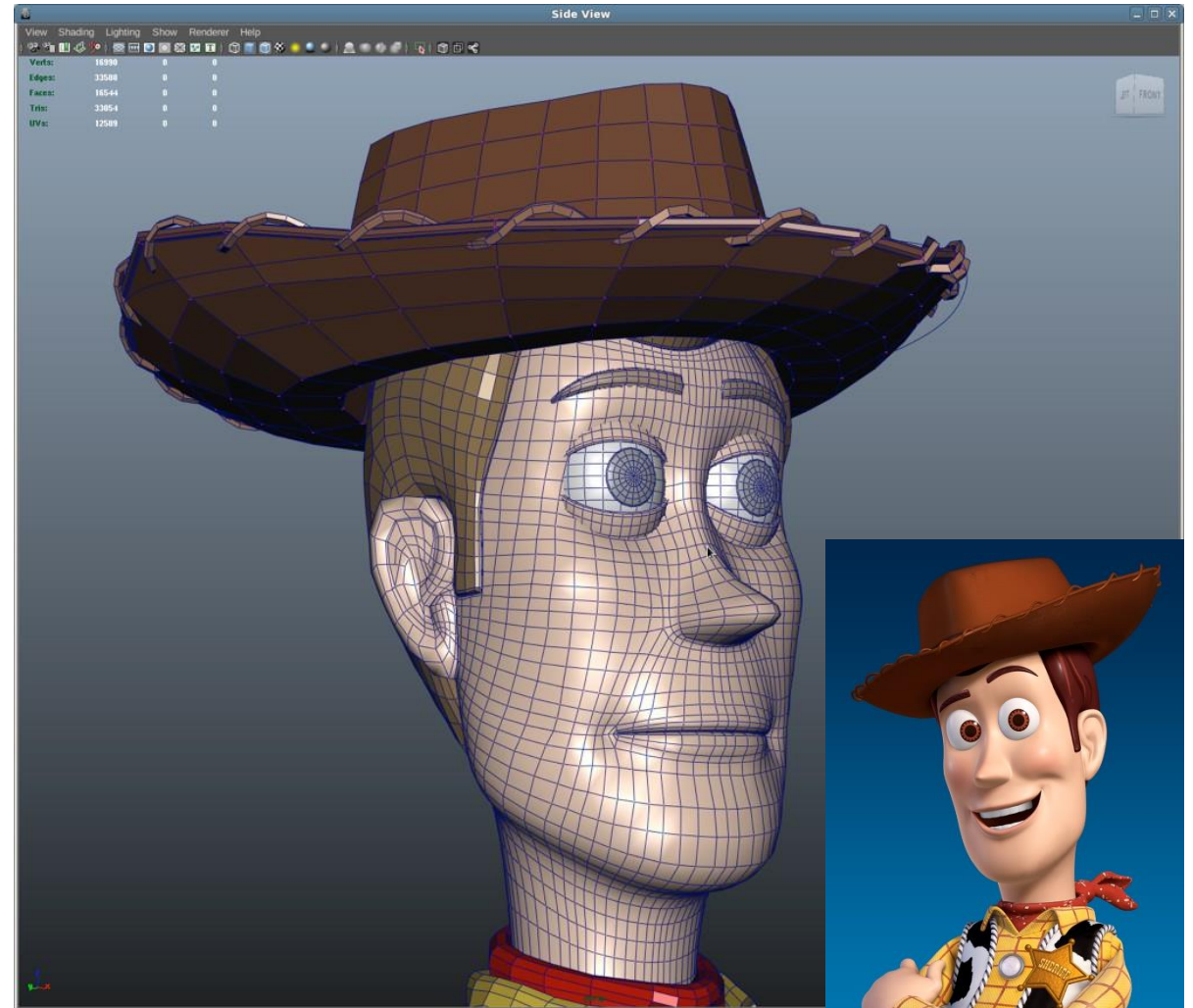


Curve and Point Data



Interpolation Example: Character Modeling

- An artist uses a smaller set of wireframe “mesh” points to design Woody’s face.
- The final smooth surface is *interpolated* from the mesh.



3. Ordinary Differential Equations

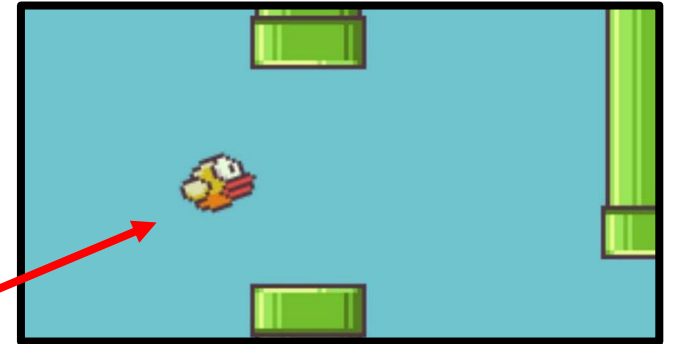
Consider a *differential equation* such as

$$y''(t) - ty'(t) + ay(t) = \sin(t)$$

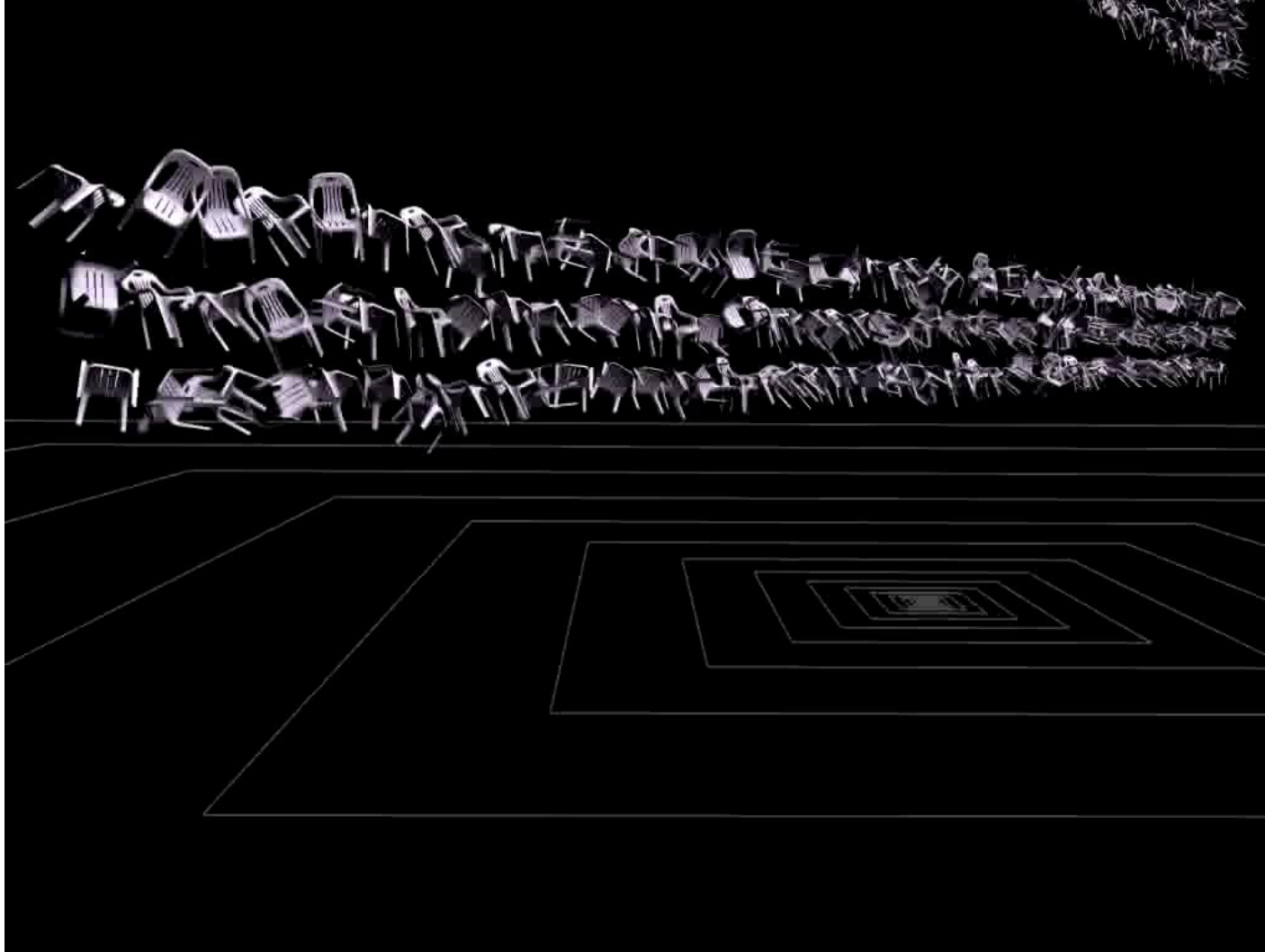
describing some phenomenon, such as

- Disease spread
- Predator-prey behaviour
- Physical systems (springs, projectile motion, fluids!,etc.)
- Population growth
- Financial markets

Can we write an algorithm to (approximately) solve it?



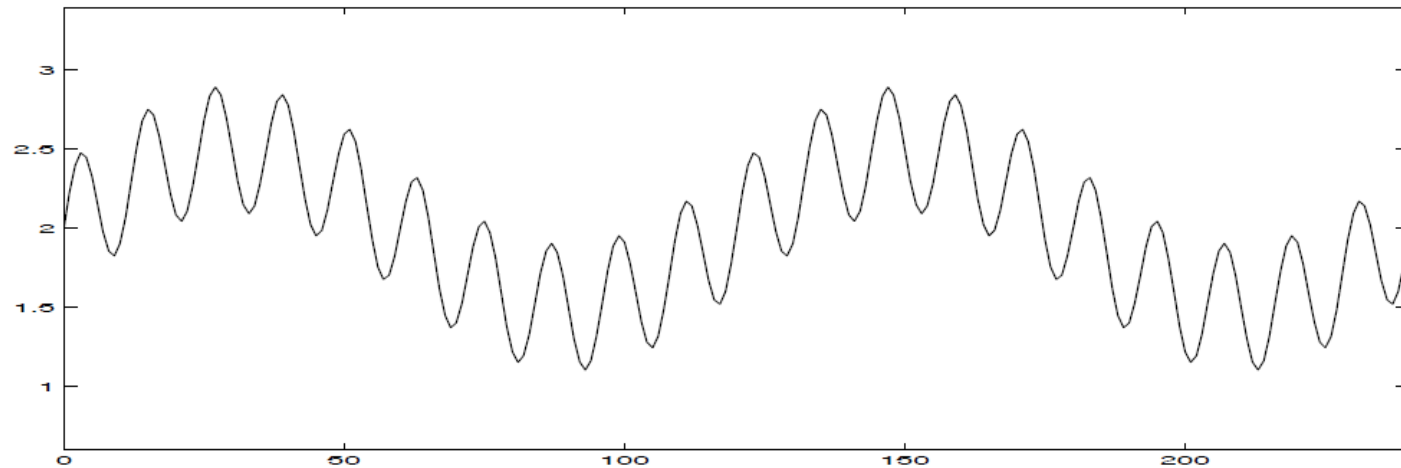
ODE Example: Deformable Objects



4. Fourier Analysis

By representing a given signal, function, or data set (e.g., sound, images, video, etc.) as a sum of sinusoids, we can do useful processing.

A Signal Composed of Two Sinusoids



Fourier Transform Example: JPEG Compression

By discarding the less important “frequencies” in the data, we can save space.



(a) Original



(b) Compressed by 85%

5. Numerical Linear Algebra

Numerical properties of matrices, and numerical approaches to...

- Solving systems of linear equations.
- Factoring matrices.
- Solving eigenvalue problems.

$$\begin{bmatrix} 2 & 2 & 2 \\ 1 & 1 & 3 \\ 1 & 4 & 1 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} = \begin{bmatrix} 2 \\ 5 \\ 10 \end{bmatrix}.$$

NLA Example: Google Pagerank

Ranking websites can be modeled as solving a particular huge eigenvalue problem.

i.e., given matrix A , find vector x and scalar λ such that

$$Ax = \lambda x.$$

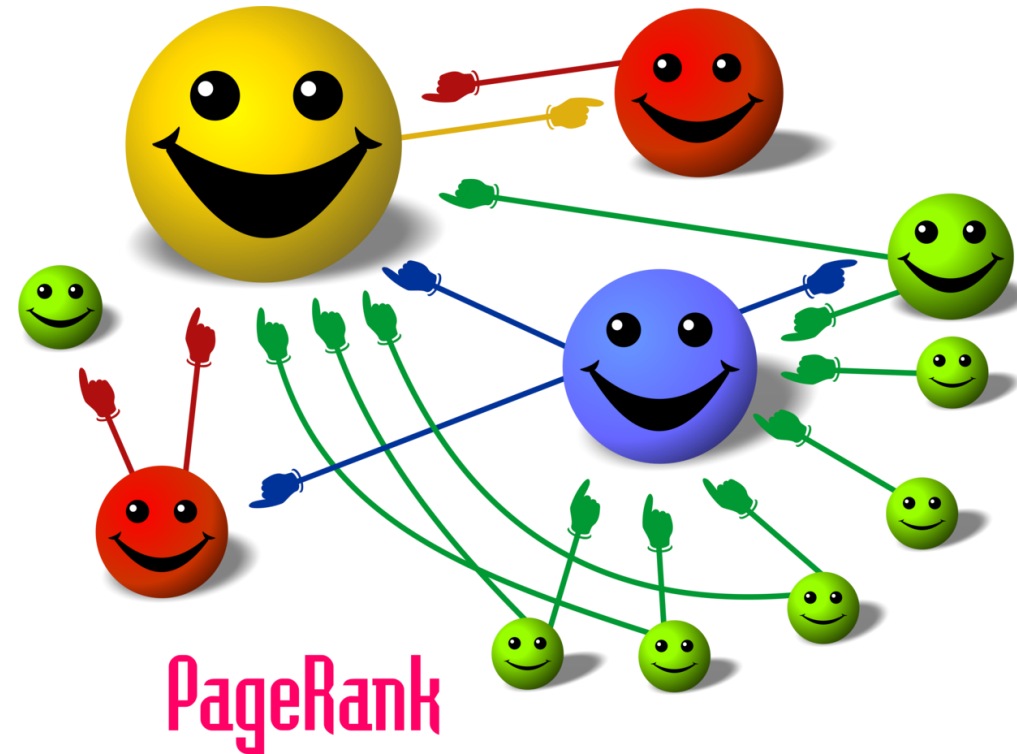


Image courtesy of Wikipedia.

Administrative Details!

Pre-requisites

Familiarity with...

- Basic calculus (Taylor series, derivatives, integration, etc.)
- Complex numbers (see course notes, Appendix E, for a review).
- Basic linear algebra (manipulating matrices, vectors, solving linear systems via Gaussian elimination, etc.)
- Procedural programming.



Programming assignments will use MATLAB.

MATLAB is a programming environment and language, designed for numerical computing. It's available in the labs.

- A MATLAB tutorial will be given by one of the TAs during the week of May 9 (date & time TBA).
- There are some resources on the course website; many other tutorials can be found online.

You are responsible for getting up to speed with MATLAB.

Grade breakdown

Assignments (4): 32% (8% each)

Mid-term Exam: 28%

Final Exam: 40%

Assignments will feature a mix of analytical questions and programming (MATLAB) questions.

Mid-term exam is on June 16 @ 7pm.

Final exam will be announced later.

Course Notes

The printed course notes are available at Media.doc in DC.

I will also post slides after class.

Optional text books:

- Numerical Computing with Matlab, Cleve B. Moler, SIAM, 2004.
- Numerical Analysis, Timothy Sauer, Pearson Addison-Wesley, 2006.

Websites

Course materials and Q&A forum are hosted on Piazza:

<https://piazza.com/uwaterloo.ca/spring2016/cs370>

Please prefer Piazza over email, so others can answer or learn from your questions.

Grades and assignment submission will be done through LEARN.

<https://learn.uwaterloo.ca/>

Teaching Assistants

Ke Nian (knian@uwaterloo.ca)

Shan Huang (s62huang@uwaterloo.ca)

Junnan Chen (j486chen@uwaterloo.ca)

Ce Ju (c3ju@uwaterloo.ca)

Refer to Piazza for current TA office hours.

Assignments - Submission

- Assignments are due by 4pm on the due date.
- Submit assignments to the appropriate Dropbox on LEARN with:
 - written parts and all results/output in a single PDF.
 - any and all (Matlab) code in a single zip file.
- You are responsible for verifying that your submission files have been uploaded successfully! (Corrupt files can't be graded.)

Assignments

Late Policy:

- Assignments submitted within 24 hours of the deadline will be marked, and receive half credit.
- After 24 hours, further submissions will not be marked.

Submitted assignments must be your own work. **The standard academic integrity rules apply.**

Additional Administrative Details

Please carefully ***read through the posted course outline (syllabus)*** for further administrative details.