COSC 6344 Visualization

University of Houston, Fall 2015

Instructor: Guoning Chen  
chengu@cs.uh.edu
Course Information

• **Location:** AH 302
• **Time:** 10am~11:30am Tu/Th
• **Office Hours:** 11:30am~12:30pm Tu /Th
  or by appointment
• **Office:** PGH 566
• **Course webpage:**
  [http://www2.cs.uh.edu/~chengu/Teaching/Fall2015/Visualization_fall2015.html](http://www2.cs.uh.edu/~chengu/Teaching/Fall2015/Visualization_fall2015.html)
Course Information

• **Prerequisites:**
  – Knowledge and experience in programming, especially C/C++ programming.
  – Knowledge on linear algebra, calculus, geometry, numerical analysis.
  – Experience on computer graphics and OpenGL (recommended)

• **Textbook:** (recommended)
  – Reading materials and course notes given in class or on course page.
Course Information

• **Grading:**
  - 6 assignments (50%)
  - 1 mid-term exam (15%)
  - 1 final project presentation (25%)
  - course participation (10%)

• **Late Policy:** Late assignments will be marked off 10% for *each weekday* that it is late. You can ask for a delay for *one assignment* for up to *5 weekdays*.

• **Academic Dishonesty:** Do you own work! No code copy!
# A Glimpse of the Schedule (tentative)

<table>
<thead>
<tr>
<th>TIMELINE</th>
<th>MATERIAL COVERED</th>
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<tbody>
<tr>
<td>WEEK 1</td>
<td><strong>Class Preliminaries</strong>&lt;br&gt;Introduction – History of visualization, Visualization pipeline, Data types and representations</td>
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<tr>
<td>WEEK 2</td>
<td><strong>Elementary plots</strong> <em>(Assignment 1 out)</em>; OpenGL tutorial, skeleton code</td>
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<td>WEEK 3</td>
<td><strong>Visualization systems</strong>; Colors coding for scalar field visualization <em>(Assignment2 out)</em></td>
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<td>WEEK 4</td>
<td><strong>Iso-surfacing</strong>; Direct volume rendering – Ray casting <em>(Assignment3 out)</em></td>
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<td>WEEK 5</td>
<td>Direct volume rendering – Splatting; Transfer function design <em>(Assignment 4 out)</em></td>
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<td>WEEK 6</td>
<td>Flow visualization introduction; Flow visualization techniques in 2D (arrow and color plots and streamlines); Streamline placement, Information theory framework</td>
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<td>WEEK 7</td>
<td>Flow visualization techniques in 2D - texture-based <em>(Assignment 5 out)</em>; Topology-based vector field visualization I</td>
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<td>WEEK 8</td>
<td>Topology-based vector field visualization II; Final project topic review</td>
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<td>WEEK 9</td>
<td><strong>Non-topological feature-based flow visualization</strong>; 3D flow visualization <em>(Assignment 6 out)</em> <em>(Final project proposal due)</em></td>
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<td>WEEK 10</td>
<td>Mid-term exam (IEEE Visualization 2015)</td>
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<td>WEEK 11</td>
<td><strong>Tensor data application</strong> – introduction and math; Geometric-based tensor visualization</td>
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<td>WEEK 12</td>
<td><strong>Texture-based tensor field visualization</strong>; Glyph-based technique</td>
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<td>WEEK 13</td>
<td><strong>Information visualization</strong> – graph and hierarchy data visualization</td>
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<td>WEEK 14</td>
<td><strong>Information visualization</strong> – high dimensional data visualization <em>(Thanksgiving)</em></td>
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<td>WEEK 15</td>
<td>Visual analytics, user study theory</td>
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<td>WEEK 16</td>
<td><strong>Final project presentations</strong></td>
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Background
Data is generated everywhere and everyday
How to efficiently help data owners extract useful information (e.g., patterns and trends) and understand it?

Sources: Lesk, Berkeley SIMS, Landauer, EMC
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Cognitive study has shown that human visual system is the most effective channel to transport information to the brain. Visual representation is one effective way to convey information.

Leading to the introduction of visualization.
History of Visualization

• Visualization = rather old  L. da Vinci (1452-1519)

• Often an intuitive step: graphical illustration

What is Visualization?

The Foundation of Modern Visualization?

• In 1987
  – the National Science Foundation (of the U.S.) started “Visualization in scientific computing” as a new discipline, and a panel of the ACM coined the term “scientific visualization”
  – Scientific visualization, briefly defined: The use of computer graphics for the analysis and presentation of computed or measured scientific data.

  – to form a mental vision, image, or picture of (something not visible or present to the sight, or of an abstraction); to make visible to the mind or imagination

• Visualization transforms data into images that effectively and accurately represent information about the data.
  – Schroeder et al. The Visualization Toolkit, 2nd ed. 1998
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Means to enable the insights into Data
History of Modern Visualization

• Visualization = being its own discipline for more than 25 years
  – First dedicated conferences: 1990
  – Conferences:
    • IEEE Visualization (SciVis, InfoVis, VAST)
    • EuroVis
    • PacificVis
    • Others
  – Journals:
    • IEEE Transactions on Visualization and Computer Graphics
    • Computer Graphics Forum
    • Others
Why is Visualization Important?
Why is Visualization Important?

- To effectively convey information to data stakeholders

### Table 7.2

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SAOD Table 7.2 (p. 7.6)
Why is Visualization Important?

• To effectively convey information to data stakeholders
• To make invisible phenomena visible

- Astrophysics source: VACET
- Combustion source: VACET
- Aerodynamics around missiles [Kelly et al. Vis06]
- Automobile design [Chen et al. Vis11]
Why is Visualization Important?

- Education
Why is Visualization Important?

• Education

\[
\frac{dy}{dx} = \lim_{h \to 0} \frac{f(x + h) - f(x)}{h}
\]
Why is Visualization Important?

- Education

\[
\frac{dy}{dx} = \lim_{h \to 0} \frac{f(x + h) - f(x)}{h}
\]
Why is Visualization Important?

• Education

• Understand mathematical concepts and physical phenomena that are invisible

Source: SuperStock

Recommended site:  http://www.pbs.org/wgbh/nova/
What Does Visualization Do?

• Three types of goals for visualization
  – ... to present
    • “everything” known about the data,
    • Vis. used for Communication of Results
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• Three types of goals for visualization
  – ... to present
    • “everything” known about the data,
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  – ... to analyze
    • There are hypotheses,
    • Vis. used for Verification or Falsification
What Does Visualization Do?

• Three types of goals for visualization
  – ... to present
    • “everything” known about the data,
    • Vis. used for Communication of Results
  – ... to analyze
    • There are hypotheses,
    • Vis. used for Verification or Falsification
  – ... to explore
    • Nothing is known,
    • Vis. used for data exploration
Evolution of Visualization Research

• From direct visualization to derived information visualization.

• From simple data forms to more complex forms.

• From represent the data with fidelity to reveal new findings.

• From scientific visualization to information visualization, bio-visualization, geographical data visualization, and beyond.
SciVis vs. InfoVis

• **Scientific visualization** is mostly concerned with:
  – (physical) spatial or spatio-temporal data (dimension < 4)
  – Representation: spatial discretization (or samples)
  – Examples: temperature/pressure fields, potential fields, wind fields, etc.

• **Information visualization** focuses on:
  – high-dimensional, abstract data (no geometric meaning)
  – discrete data in the nature
  – Examples: financial data, logs and records, tweeter posts, family trees or organization structure, computer/social networks, survey data, etc.
Age of Big Data

For two weeks this summer, when the world comes together for the 2012 Summer Games, an unprecedented spike in the sheer volume of big data is expected to be generated on a global scale. Are today’s businesses and IT systems ready to support the record-setting amount of big data that the world is on pace to create during the 2012 Summer Games?

2000 hours of live sports media coverage (covering every single sport each day of the Games)

14,000+ TV and broadcast stations worldwide tuning in to watch the opening ceremonies

2000,000 hours of Facebook activity expected to be recorded during the 2012 Summer Games

60GB of information per second expected to flow across British Telecom’s networks [the equivalent of all of Wikipedia every 9 seconds]

30% more results data will be processed during the 2012 London Games than during the 2008 Beijing Games

8.5B devices expected to be connected to the Internet in 2012

1B people expected to visit the official website of the 2012 Summer Games

13,000+ tweets per second expected to be posted to Twitter during the Summer Games

2012 London Summer Games

Big Data By the Numbers

The Age of Big Data Has Arrived

Companies in all sectors have at least 100 terabytes of stored data in the United States; many have more than 1 petabyte

1. Storage data by sector derived from IDC.
2. Firm data split into sectors, when needed, using employment
3. The particularly large number of firms in manufacturing and health care provider sectors make the available storage per company much smaller.

We are not concerned with the big data issue in this course but rather building the foundation for eventually addressing the big data challenges!!!
Goals and Topics
Goals of this Course

• Know the representative methods and standards of classic visualization problems

• Familiar with classical techniques for the visualizations of various data types

• Able to develop the customized visualization techniques and systems for the practical and research needs
Topics to Be Covered in this Course

• What will be covered?
  – Colors, plots
  – Scalar field visualization
  – Vector field visualization
  – Tensor field visualization
  – Information visualization (graphs, high-dimensional, etc.)
  – Hop topics in visualization

• Will make use of a lot of branches in mathematics
  – Calculus, trigonometry, linear algebra, discrete math, differential geometry, topology, dynamical systems, numerical algebra, etc

• Will also need knowledge in from the following sub-field computer science
  – Algorithms, data structures, graphics, human-computer interaction, imaging, etc.

• It will be a plus+ to have the following background
  – **Art and design**, Psychophysics, scientific computing
Preview of Topics

• Color theory and visual representation

HSV Color Wheel

Which is brighter?

Blue: 380 nm  Green: 520 nm  Red: 780 nm
Preview of Topics

• Plots
Preview of Topics

• Scalar field visualization 2D

is given by a function

\[ f(x_1, \ldots, x_n) : \mathbb{R}^n \rightarrow \mathbb{R} \] with \( n \) independent variables \( x_i \)

Examples include high fields, temperatures, pressures, potential energy, eigenvalues,...

Source: V_Sim
http://www-drfmc.cea.fr/L_Sim/V_Sim/
Preview of Topics

• Scalar field visualization 3D

The impact of a ball entering the porous solid from the left

Volume Rendering

Zebra fish head (image by Fluorender)
Preview of Topics

• Scalar field visualization III
  – Topology

The impact of the ball entering the porous solid from the left
Preview of Topics

• Vector field visualization I
  – Hedge-Hodge
  – Particle tracing
  – Integration-based

\[ \vec{V} = \vec{F}(x, y, z, t) \]
Preview of Topics

• Vector field visualization II
  – Texture-based

(Bruno Jobard, Gordon Erlebacher, and M. Yousuff Hussaini)
Preview of Topics

• Vector field visualization III
  – Feature-based
Preview of Topics

• Tensor field visualization

Second order tensor

\[
T = \begin{bmatrix}
T_{00}(x, y, z) \\
\vdots
\end{bmatrix}
\]
Preview of Topics

- Tensor field visualization

Texture-based

Glyph-based

Geometry-based
Preview of Topics

• Information visualization

Graph visualization http://infosthetics.com

Text visualization http://willscullypower.wordpress.com/

High-dimensional data visualization
http://eagereyes.org

Tree/hierarchy data visualization
http://infosthetics.com
Preview of Topics

• Visualization systems
  – General purpose (open source)
    • Paraview
    • VisIt
    • SCIRun
Preview of Topics

• Recent hot topics in visualization
  – Multi-field visualization
  – Uncertainty visualization
  – Big data visualization
  – Novel applications