Project 2 is due today! What I am looking for: efforts.
Project 3 is posted today!
Topological structures and TTK
Review: Contour Trees and Morse-Smale Complex
Data has shape

Elevation on a terrain: function on a 2D domain

Shape of data? Contour Tree
Data has shape

Elevation on a terrain: function on a 2D domain

Shape of data?

Morse-Smale Complex
A Map of Science Example
Map of Science?

554 subdiscipline belong to 13 scientific discipline

protein science

data mining
Map of Science

Mercator coordinate visualization of a spherically embedded graph representing the interconnectivity of science from data in [Borner et al. 2012]
The network was embedded in a low-dim space that the authors concluded by visual inspection, that “the consensus map has a circular form”.
With TDA: what is the shape of the map of science?

Three high persistence cycles found on the network of science—showing interconnectedness of specialties—left: core science and engineering, middle: healthcare, right: science (non-engineering)
What is data?
Vector Fields
stationary, time-varying combustion simulation
ocean eddie simulation
lifted jet flame simulation

Large Complex Data
Vector Fields
stationary, time-varying combustion simulation
ocean eddy simulation
lifted jet flame simulation

Point Clouds
high-dim para space
nuclear engineering
cosmic phenomena
material science
high-energy physics

Large Complex Data
Vector Fields
stationary, time-varying
combustion simulation
ocean eddy simulation
lifted jet flame simulation

Point Clouds
high-dim para space
nuclear engineering
cosmic phenomena
material science
high-energy physics

Large Complex Data

Networks
brain imaging (MRI)
brain networks
biological networks
social networks
Large Complex Data

Vector Fields
- stationary, time-varying
- combustion simulation
- ocean eddy simulation
- lifted jet flame simulation

Point Clouds
- high-dim para space
- nuclear engineering
- cosmic phenomena
- material science
- high-energy physics

Networks
- brain imaging (fMRI)
- brain networks
- biological networks
- social networks

Multivariate Ensembles
- windstorm, precipitation
- hurricane forecasting
- fire weather prediction
Vector Fields
Combustion and Ocean
Make the flow patterns visible & Interpretable

Sources: Dan Maljovec, Cameron Beccario, [Correa, Silver, Chen 2007]
[Burger, Kondratieva, Kruger, Westermann 2008]
Quantify feature stability

Simulation: [Hawkes, Sankaran, Pebay, Chen 2006]
Separate features from noise at multi-scale

Ocean Eddy Simulation

Map: Courtesy of SlidesCarnival & Unsplash
Simulation: [Maltrud, Bryan, Peacock 2010]
Visualize flow in 3D

Before Simplification

Vortex Example
Understand turbulent flow

Source: NASA
Material Science

Your iPhone Battery
How long can your battery last?
Ion diffusion geometry extraction in battery
Networks
Brain networks
Inadequate Network Visualization
Brain Network Visualization

Avoid network hairballs while preserving structure?
Topology and brain networks
Autism Brain Networks

Can we tell autism subject from control?
Autism Brain Networks

input data
rs-fMRI
sMRI
behavior

feature extraction
functional parcellation
shape
structural network
functional network
topological data analysis
topological features
shape features
behavioral features
Bayesian multivariate correlation analysis

statistical models
Astronomy
Telescopes and Black Holes
Largest radio telescopes in the world
Radio telescope Data
NGC 404: Mirach's Ghost Galaxy
Feature Denoting and Source Finding
Denoising at Multi-scale and Source Finding
Stepping Through Slices
MOMENT 0 ANALYSIS

original

simplified
Observing the red shift
Observing the red shift
Observing the red shift
Software Visualization
Circular patterns in a program
An example

File: sort.cpp

```cpp
void bubblesort(std::vector<double> & v)
{
    bool swapped = false;
    for(unsigned end=v.size()-1; end >= 0; end--){
        if(v[i] > v[i+1]){
            std::swap(v[i], v[i+1]);
            swapped = true;
        }
    }
    if(!swapped) break;
}
```
Convert memory reference traces to a point cloud

- Execute an application to capture memory reference trace
- Convert to high-dimensional point cloud
- Topological analysis identify cycles
- Visualize result
Capturing a memory reference trace

```cpp
File: sort.cpp
1: void bubblesort(std::vector<double>& v) {
  2:   for (unsigned end = v.size() - 1; end >= 0; end--) {
  3:     bool swapped = false;
  4:     for (unsigned i = 0; i < end; i++) {
  5:       if (v[i] > v[i + 1]) {
  6:         std::swap(v[i], v[i + 1]);
  7:         swapped = true;
  8:       }
  9:     }
 10:     if (!swapped) break;
 11:   }
12:}
```
Memory reference trace to point cloud
Topological data analysis to identify cycles
Topological data analysis to identify cycles

Cycle is found with birth time $\varepsilon_1$
Topological data analysis to identify cycles

Cycle has died at time $\varepsilon_2$
Data dependent structures

```cpp
void bubblesort(std::vector<double> & v){
    for(unsigned end=v.size()-1; end >= 0; end--){
        bool swapped = false;
        for(unsigned i=0; i<end; i++){
            if(v[i] > v[i+1]){
                std::swap(v[i], v[i+1]);
                swapped = true;
            }
        }
        if(!swapped) break;
    }
}
```
Data dependent structures

```cpp
// File: sort.cpp
1: void bubblesort(std::vector<double>& v){
2:     for(unsigned end=v.size()-1; end >= 0; end--){
3:         bool swapped = false;
4:         for(unsigned i=0; i<end; i++)
5:             if(v[i] > v[i+1]){
6:                 std::swap(v[i], v[i+1]);
7:                 swapped = true;
8:             }
9:         }
10:     if(!swapped) break;
11: }
12: }
```
Data dependent structures
Data dependent structures
Algorithm dependent structures

```
File: matmult.cpp
1: unsigned int i, j, k;
2: for (i = 0; i < N; i++)
3:   for (j = 0; j < N; j++)
4:     for (k = 0; k < N; k++)
```
Algorithm dependent structures

```
File: blocked-matmul.cpp
1:  unsigned int i, j, k, j0, k0;
2:  for (k0 = 0; k0 < N; k0 += b)
3:      for (j0 = 0; j0 < N; j0 += b)
4:          for (i = 0; i < N; i++)
5:              for (k = k0; k < min(k0 + b, N); k++) {
6:                  r = linA[i*N + k];
7:                  for (j = j0; j < min(j0 + b, N); j++)
8:                      linC[i*N + j] += r*linB[k*N + j];
9:              }
```
Algorithm dependent structures

Naïve Matrix Multiply

Blocked Matrix Multiply
Non-loop based structures

```cpp
File: MPM.cpp
1: for(unsigned ii=1; ii<i+1; ii++) {
2:   for(unsigned jj=j; jj<j+1; jj++) {
3:     g->mass(ii, jj) += g->S(ii, jj) * mp->mass(p) * mp->position(p)[0];
4:     g->momentum(ii, jj) += g->S(ii, jj) * mp->mass(p) * mp->velocity(p)[0];
5:   }
6: }

File: Grid.h
1: double S(int i, int j, const Point &p) { ... }
2: unsigned indexify(unsigned i, unsigned j) const { ... }
3: double S_x(int i, double x) { ... }
4: double S_y(int j, double y) { ... }
5: static double compute_shape_function(int cell, double position, double cell_size) {
6:   // This is the distance of "position" from the position of "cell".
7:   const double cell_distance = std::abs(position - cell_size * cell) / cell_size;
8:   // Perform case analysis.
9:   if(cell_distance >= 1.0) {
10:      return 0.0;
11:   } else {
12:      return 1.0 - cell_distance;
13:   }
14: }
```
Topology Tool Kit
TTK
Installation Demo

https://youtu.be/etAe13KEWsk
Dragon Demo (contour tree)

TTK usage tutorial - Dragon demo

https://youtu.be/YVk9vRKIEX8
A few tips on Project 2

- Start today! The installation is going to take a while (4+ hours).
- Follow the demo closely, however pay attention to some differences in different versions of TTK.
- Follow the reading materials for this week.
Thanks!

Any questions?

You can find me at: beiwang@sci.utah.edu
CREDITS

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Presentation Design

This presentation uses the following typographies and colors:

Free Fonts used:
https://www.fontsquirrel.com/fonts/open-sans

Colors used

![Colors](image-url)