### Data Visualization (CSCI 490/680)

### Vector Fields & Text

Dr. David Koop





## Visualizing Volume (3D) Data



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2D visualization slice images (or multi-planar reformating MPR)

Indirect 3D visualization isosurfaces (or surface-shaded display SSD)

Direct **3D** visualization (direct volume rendering DVR)





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### Volume Ray Casting











### Volume Ray Casting

# Image Plane Eye

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## Data Set

### 





### Types of Compositing



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### Accumulation

- If we're not just calculating a single number (max, average) or a position (first), how do we determine the accumulation?
- Assume each value has an associated color (c) and opacity ( $\alpha$ )
- Over operator (back-to-front):
  - $C = \alpha_f \cdot C_f + (1 \alpha_f) \cdot \alpha_b \cdot C_b$
  - $-\alpha = \alpha_f + (1 \alpha_f) \cdot \alpha_b$
- Order is important!

















### Transfer Functions

- Where do the colors and opacities come from?
- Idea is that each voxel emits/absorbs light based on its scalar value
- ...but users get to choose how that happens
- x-axis: color region definitions, y-axis: opacity







### Fields in Visualization



### Scalar Fields (Order-0 Tensor Fields)

### Each point in space has an associated...

 $s_0$ 

Scalar

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Vector Fields (Order-1 Tensor Fields)

 $v_0$  $v_1$  $v_2$ Vector



(Order-2+)











### Vector Fields



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#### Wind [earth.nullschool.net, 2014]









### Vector Fields



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#### Wind [earth.nullschool.net, 2014]









## Glyphs

- Represent each vector with a symbol
- For vector fields, can encode direction, magnitude, scalar value
- Good:
  - Show precise local measures
  - Can encode scalar information as color
- Bad:
  - Possible sampling issues
  - Clutter (Occlusion): Can remove some points to help
  - Clutter is worse in higher dimensions









### Streamlines & Variants

- Trace a line along the direction of the vectors
- Streamlines are always tangent to the vector field
- Basic Particle Tracing:
  - 1. Set a starting point (seed)
  - 2. Take a step in the direction of the vector at that point
  - 3. Adjust direction based on the vector where you are now
  - 4. Go to Step 2 and Repeat

### ne vectors he vector field

# vector at that point tor where you are now





### Streamlines

### [x,y] → [-y, (1/2)x], Step: 0.5



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### Higher-Order Interpolation Comparison











## Project

- Presentations on Dec. 5:
  - Turn in state of the visualization to Blackboard by Dec 4 at 11:59pm
  - 5 minutes per presenter
  - Showcase the visualization (not slides)
    - Brief introduction to your data and questions
    - Discuss design decisions
  - Demonstrate the interactive features of your project
- Should run in a web browser so we will use my laptop • Have until Dec. 6 to turn in final code and report

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### • Continue to be creative but also remember expressiveness and effectiveness







### Final Exam

- Thursday, Dec. 12, **10-11:50am**
- Covers all topics but emphasizes second half of the course • Similar format as Midterm (multiple choice, free response) 680 Students will have a few questions related to the research papers





### Streamlines & Variants

- Steady vs. Unsteady The Aracteristic Lines
  - In unsteady flows, the vector field changes over time
- Variants: Pathlines and Streaklines









### Streamlines & Variants

- Steady vs. Unsteady The aracteristic Lines
  - In unsteady flows, the vector field **changes** over time
- Variants: Pathlines and Streaklines









### Streamlines vs. Pathlines



### Streamlines

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### Pathlines



[Weinkauf & Theisel, 2010]

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### Streaklines and timelines



streamlin



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ines	timelines	
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# Streamline Streaklines in real life



NASA

http://www.dfrc.nasa.gov/gallery/photo/index.html NASA Photo: ECN-33298-03 Date: 1985

1/48-scale model of an F-18 aircraft in Flow Visualization Facility (FVF)

Streaklines INASA

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### Mapping Methods Based on affere Tracing





Stream Tubes [Weiskopf/Machiraju/Möller]







### Streak Surfaces













## 2D Vector Field Visualization Techniques



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[Laidlaw et al., 2005]



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## Line Integral Convolution

- Goal: provide a global view of a steady vector field while avoiding issues with clutter, seeds, etc.
- Remember convolution?
- Start with random noise texture
- Smear according to the vector field
- Need structured data



[Weiskopf/Machiraju/Möller]











## 3D LIC









## Critical Points

- Remember finding min/max for functions?
- Want to understand the general structure of a field, not the exact values
- Find critical points, understand there is a general trend in between
- How?
  - Derivative for functions
  - For fields...gradients















## lopology

- The general shape of data
- Visualizations that can be "stretched" to resemble each other are topologically equivalent
- Technically, continuous transformations don't change anything Connect critical points to obtain a general picture of the data Can talk about topology in both scalar and vector fields









## 2D Scalar Field Topology







## 2D Scalar Field Topology







## Scalar Field Topology

- Where the gradient is zero, we have critical points (max, min, saddle)
- information to show the topology (with some reasonable assumptions about how the scalar field looks)

 Examine the gradient (changes between points on the grid) of the scalar field Can build Reeb Graph, Contour Tree, or Morse-Smale Complex from this









### Scalar Field Topology

**2D Scalar function** →

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### **Reeb Graph/Contour Tree/Merge Tree**



### **Morse-Smale Complex**











## Vector Field Topology

field, try to identify structure (topology) of the field



Figure 7.1

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# Instead of "guessing" correct seed points for streamlines to understand the

A phase portrait.











### Critical Points





Repelling Focus R1, R2 > 0 I1, I2 != 0



Attracting Focus R1, R2 < 0 I1, I2 !== 0







## Critical Points

- Critical Points
  - Find where the vector field vanishes (the zero vector or undefined)
  - Attracting Nodes (Sinks), Repelling Nodes (Sources), Attracting Foci, Repelling Foci, Saddles, Centers
- How to find such points?
  - Can use a similar idea to Marching Cubes
  - Use the eigenvalues of the Jacobian matrix to classify







### Topological Skeleton









### More Examples












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### Text Visualization

- Why visualize text? Text is already visual, right?
- How much text? What granularity? (What is an item?)
  - Single string
  - Words/lines
  - One document
  - Multiple documents (corpus)
- Considerations:
  - Legibility
  - Variable length
  - Locality
  - Occurence

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### Data Sources

- Literature: books, poetry
- Social Media: tweets, posts
- Web: Pages, posts, emails
- Code







# Tag Cloud (One Document)

- Derived data: number of occurrences of words
- Channel: Font size
- Potential problem: Think about ink...



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## TextArc (One Document)

ALICE'S ADVENTURES IN WONDERLAND

THE MILLENNIUM FULCRUM EDITION 3.0

Lewis Carroll

CHAPTER I

Down the Rabbit-Hole Mardie Alice was beginning to get very tired of sitting by her sister on the bank, and of having nothing to do: once or twice she had peeped into the book her sister was reading, but it had no pictures or conversations in it, `and what is the use of a book $_{
m e}^{
m s}$ thought Alice `without pictures or conversation?'

So she was considering in her 6WA9hind (as well as she could, for the hot day made her feel very sleepy and stupid), whether the pleasure of making a daisy-chain would be worth the trouble of getting up and picking the daisies, when suddenly a White Jahass Rabbit with pink eyes ran close by her.

There was nothing so VERY remarkable in that; nor did Alice. think it so VERY much out of the way to hear the Rabbit say to itself, `Oh dear! Oh dear! I shall be late!' (when she thought, it over afterwards, it occurred to her that she ought to have

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Read













### TextArc

- Three rules:
  - word

  - Central words move to the middle (links to its mentions)

- Show the entire text in an ellipse around the page: line-by-line and word-by-

- Like tag clouds, use larger font-size and brighter text for frequent words







### Word Tree (One Document)



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this nation will rise up and live out the true meaning of its creed: "We hold these truths to be self-evident,

-on the red hills of Georgia the sons of former slaves and the sons of former slave owners will be able to sit down

even the state of Mississippi, a state sweltering with the heat of injustice, sweltering with the heat of oppression.

down in Alabama, with its vicious racists, with its governor having his lips dripping with the words of interposition

every valley shall be exalted, and every hill and mountain shall be made low, the rough places will be made plai

my four little children will one day live in a nation where they will not be judged by the color of their skin but by the

down in Alabama, with its vicious racists, with its governor having his lips dripping with the words c

every valley shall be exalted, and every hill and mountain shall be made low, the rough places will

[Wattenberg & Viegas, 2007]



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### Word Tree

- A "Visual Concordance"
- Shows phrasing, relationships between words
- Starting point is a single word or snippet
- Branches to show common words/phrases that follow
- Goal is to show context: "keyword-in-context"





### Interaction in Word Tree



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### Phrase Nets



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NIU

### Words are more than just character sequences

Fed Drapes	
Clark Coolidge	Rhyn
FELLFAR BUT THE BARN (came) up & smacked n	ne Ident
Who're you, bleeding? Fled.	Perfe
Blat in back of a Vistrola Car is sored is such that sun	
fell in the rushes & pen bear appear	Semi
the white wrong numeral on the wall	Sylla
can't take if off with the clock	
down with the clock it	Cons
way on the board - couch with brass, kindergarten clenc backed violet rip into the gas valve	bjoints Vowe
it hemmed & snowed	Damas
	Parai
the wrong way	Eye F
remnant face	2901
rubber	Allite
the pucker	
	Asso

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mes	Phonetic Rhymes	Character Clusters	Levenshtein Distance
ntical R	hyme/Rhyme Riche 🔵		
fect Rhy	AAR AES		
nirhyme	9 • • •		
abic Rh	iyme		
sonant	Slant Rhyme • • • • •		
vel Slan	t Rhyme 🜑 💿 💿 💿	OW1	
arhyme			
Rhyme	9 • • • • • • • • •		
teratior	n • • • • • • • • • • • • • • • • • • •		
onance		0 * * * *	[N. McCurdy et a







### Poemage

- meaning as possible
- Search for poetic devices: affect, imagery, pun, metaphor • Sound and linguistic devices  $\rightarrow$  Rhyming
- - Identical: pare/pair
  - Perfect: picky/tricky
  - Assonance & consonance: blue/estuaries, shell/chiffon
  - Eye rhyme: cough/bough
- Support exploration: scholars do not want computers to "solve" poems

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### Support close reading—in-depth reading to generate as much productive









### Interface

Note:     Note:     Note:     Note:     Note:       Solid::::::::::::::::::::::::::::::::::::		Poemage_v01	
SUNCE RUYANES   Ldentical Rhyme/Rhyme Riche   Perfect Masculine   AET   Perfect Feminine   Perfect Dackylic   Seminhyme   Seminhyme   Syllabic Rhyme   Syllabic Rhyme   K   Voorel Slant Rhyme   K   Syllabic Rhyme   Syllabic Rhyme   Syllabic Rhyme   K   Syllabic Rhyme   Sylla	Poemage v 0.1		Modes: 1 2 3 shuffle nodes
SOUC REMARKS	Set View	Poem View	Path View
Identical Rhyme Rithe       AIT         Perfect Masculine       AIT         Perfect Masculine       AIT         Perfect Feminine       Groupwate green         Perfect Dactylic       Groupmate science         Seminhyme       Groupmate science         Syllabic Rhyme       Groupmate science         Syllabic Rhyme       Mill have to hurry Action and Group science         Vowel Stant Rhyme       Groupmate science         Syllabic Rhyme       Mill have to hurry Action and Group science         Syllabic 2 Rhyme       Milleration         Alliteration       Sw         Alliteration       Sw         Alliteration       Sw         Consonance       Sw         Consonance       Sw         Alliteration       Sw         Alliteration       Sw         Consonance       Sw         Consonance       Sw         Sw       Sellew window gring up on 1 repeat my offer food list in iron flakes         Consonance       Sw         Alliteration       Sw         Alliteration       Sw         Consonance       Sw         Consonance       Sw         Sw       Sellew window gring up on 1 repeat my offer food list in ir	SONIC RHYMES		Machinations Calcite
Perfect Masculine	Identical Rhyme/Rhyme Riche	Clark Coolidge	
Perfect Dactylic Perfect Dactylic Semirhyme Syllabic Rhyme Consonant Slant Rhyme Syllabic 2 Rhyme Alliteration Syllabic 2 Rhyme Syllabic 2 Rhyme Cli SW Cli SW Char beautiful mess Herry meldoles drol on <u>chambo</u> we lead star tool ray meldoles drol on <u>chambo</u> we word <u>spanze</u> fun hard pinks & sponge breath many for ram drift Roller window going up on 1 repeat my offer food list in iron flakes <b>show words show context</b> [ <b>Hintersecting path</b> ]			
Perfect Dactylic Semithyme Semithyme Syllabic Rhyme Consonant Slant Rhyme K Vowel Slant Rhyme Syllabic 2 Rhyme Alliteration Syllabic 2 Rhyme Consonance SH C	Perfect Feminine	muchwet green	
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Syllabic Rhyme       a lot of yellow(troppeds)         Consonant Slant Rhyme       k         K       agate inked         merry melodies drool on financof we lead star tool       crayon & sands         length of granite@tropped       length of granite@tropped         Syllabic 2 Rhyme       active interped on the provide on the parade on the parameter of the paramet	Semirhyme	weaving candle turn on computer cigarette, paper wall tarheels & balance	
Consonant Slant Rhyme   Vowel Slant Rhyme     Pararhyme     Pararhyme     Syllabic 2 Rhyme     Alliteration     SW     Alliteration     SW     Alliteration     SW     Consonance     SH   Consonance     SH   Consonance     SH   Consonance     SH   Consonance     SH   Consonance     Now word        Image: beautiful mess        Now word        Alliteration     SH   Consonance           Image: beautiful mess        Now word           Now word           Image: beautiful mess <td>Syllabic Rhyme</td> <td>He'll have to hurry &amp; carry away, to my blue friend hustling bringing</td> <td>carry hustling</td>	Syllabic Rhyme	He'll have to hurry & carry away, to my blue friend hustling bringing	carry hustling
Vowel Slant Rhyme metry metodies droot on <u>Changeori wet lead star tool</u> crayon & <u>Sands</u> length of granite <u>Drice</u> drill It's sucking up the strand, his crystal flag, & the eels tube for <u>Changeori</u> wet <u>is ucking</u> splinter dry -ice spazzetike- ing ace supper at <u>Church</u> hard pinks & sponge breath many forarms drift Roller window going up on I repeat my offer food list in iron flakes consonance <u>SH</u> <u>CH</u> SK hover word show uncertainty custom set hover word show uncertainty custom set Show words show context fill intersecting paths			
Pararhyme Syllabic 2 Rhyme Alliteration Assonance Consonance Cear beautiful mess back back ing up the strand, his crystal flag, & the eels tube for char. their parade wizzle fun their parade wizzle fun	Vowel Slant Rhyme	crayon & sands	sands
Alliteration SW Assonance SH Consonance CH SK leautiful mess beautiful mess be	Pararhyme	It's sucking up the strand, his crystal flag, & the eels tube for that.	
Alliteration Assonance Consonance CH SK beautiful mess beautiful		arcticouck	
Assonance SH Consonance CH SK Roller window going up on I repeat my offer food list in iron flakes clear beautiful mess hover word show uncertainty custom set show context fill intersecting paths		hard pinks & sponge breath	
Consonance CH   CH SK   clear beautiful mess hover word show uncertainty custom set show words show context fill intersecting paths			
	Consonance CH SK		
	clear beautiful mess	hover word show uncertainty custom set	

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## Comparing Documents

- Word choice/usage
- Relationships
- Phrasing





# Tag Cloud (Two Documents)

act afghanistan allie american attack best budge camps children Citizens coalitie **CONGRESS** continue CORPS COUNTRY created danger depend destruction develop economy encoura enemies evil extend fight free freedom government health help history home homeland hope increase islamic JODS join lives ma military moment months nation opportuni peace people police power protect rebu regimes resolve retirement Securit states tax terro terrorists thank thousan together tonight training true unite War ways Weapons wome work workers World

President Bush, January 29, 2002

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### State of the Union Address, 2002 vs. 2011

es	afghan ago already american behind
et	believe best better building business
tion	Care century challenge chance change child children clean
eate	college company compete congress COUNTRY
rage	create cuts deficit democrats different don done
n	dream economy education energy family
nd	future generation give goal
nass	government health help home idea
nity	innovation internet invest JODS laughter law
ouild	life live money nation passed
y	people percent possible projects race reform
ŕ	republicans research responsibility schools
nds	spending states step students success
	support sure <b>tax</b> teachers <b>technology</b> things together
ed	tonight troops willing win Work workers
en	worldyears
	wond years

President Obama, January 25, 2011







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# Parallel Tag Clouds (Multiple Documents)



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bargaining emissions explanatory pipelines proposed regulations rulemaking transmission

[Collins et al., 2009]







### Jigsaw (Multiple Documents)

### Visual Analytics Support for Intelligence Analysis Case Study: The 9/11 Report

Carsten Görg Youn-ah Kang Zhicheng Liu John Stasko

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### Information Interfaces Group Georgia Institute of Technology

[http://www.cc.gatech.edu/gvu/ii/jigsaw/]







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