Data Visualization: What is it good for?

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Overview

- Introduction to Visualization
- Applications
  - Biology
  - Physics
  - Computational Fluid Dynamics
  - Modern Languages and Digital Humanities

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Who is Bob?

- July 2006: Joined Computer Science Department at Swansea University
- 2001-2006: worked at VRVis Research Center (VRVis.at)–the bridge between academia and industry in Austria
- 2005: PhD, Computer Science, Vienna University of Technology (Gruess Gott TUWien)
- 2000: Msc., Computer Science, University of New Hampshire, Durham, NH
- 1997: BSc., Physics, University of Massachusetts (ZooMass), Amherst, MA
- Research in
  - Data visualization
  - Software Engineering
  - Human-computer interaction

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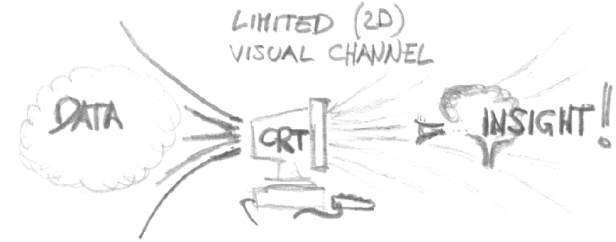
Visualization: What is it?

"The purpose of computing is insight, not numbers"
[Richard W. Hamming, 1962]



Visualization:

- 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 [Oxford English Dictionary, 1989]
- A tool that allows user to gain insight into data.
- The non-fiction version of computer graphics

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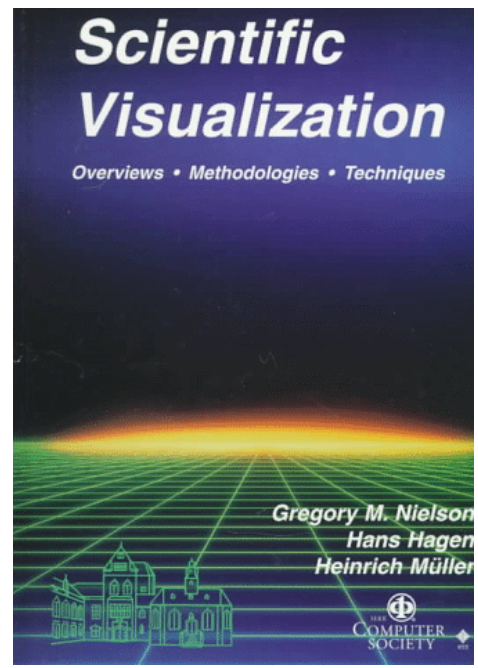
Visualization – Background

- Visualization is very old
- Often an intuitive step to make

phenomena clearer, e.g., a graph

- Our ability to collect and store data exceeds our ability to derive knowledge from it.
- Data set sizes are ever-increasing making a graphical approach necessary
- Classical (easy) approaches known from business graphics (Excel, etc.)
- Visualization = its own scientific discipline since ~1987

1997:



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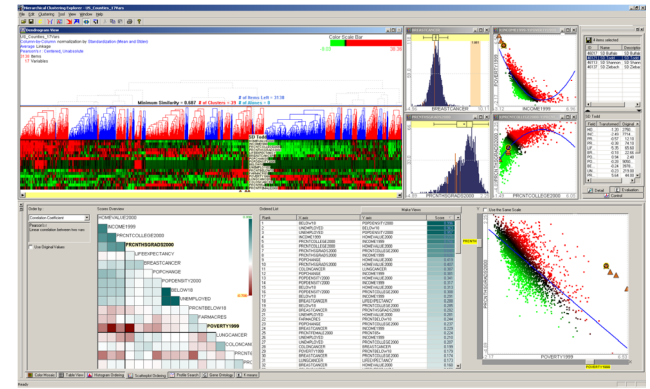
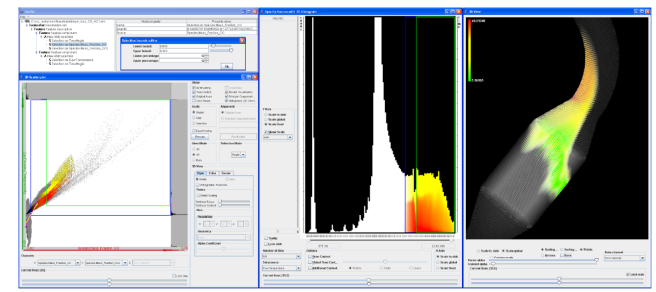
Useful Visualization Tasks

Visualization is good for:

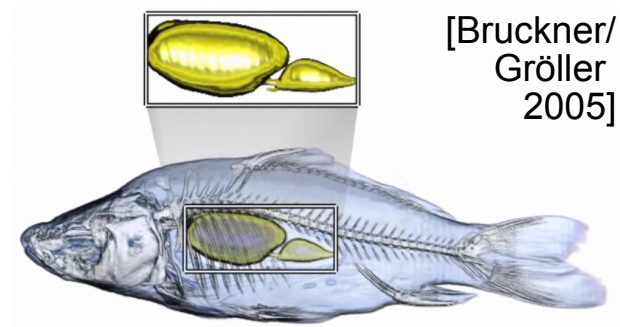
- **exploration**
  - find the unknown, unexpected
  - hypothesis generation
- **analysis**
  - confirm or reject hypotheses
  - information drill-down
- **presentation**
  - communicate/disseminate results



[Seo/Shneiderman 2004]



[Doleisch et al., 2003]



[Bruckner/ Gröller 2005]

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Biology Application: Visualisation of Sensor Data from Animal Movement

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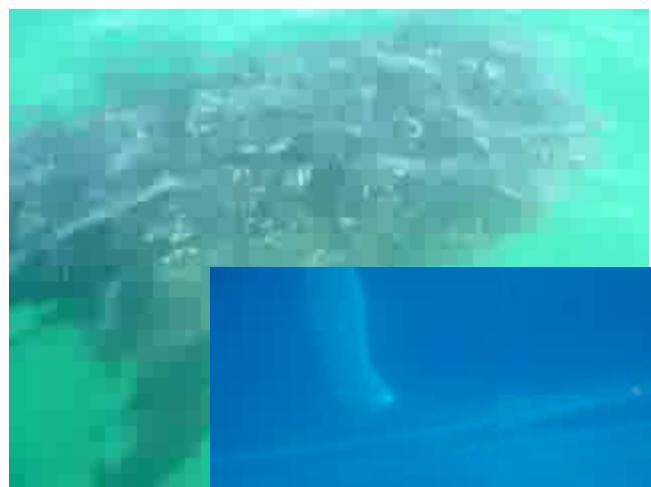
Visual Computing Group

Rory P. Wilson
Emily L.C. Shepard

Institute of Environmental Sustainability



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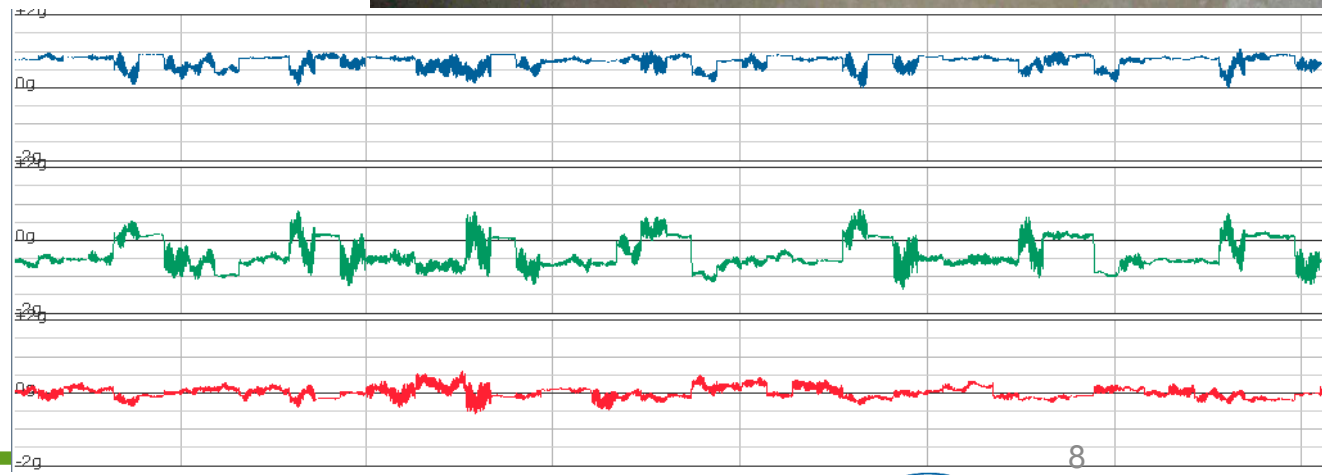
Background

Biologists at Swansea have attached sensors...

...to animals in the wild...

To gather data on:

- acceleration,
- temperature,
- pressure,
- etc



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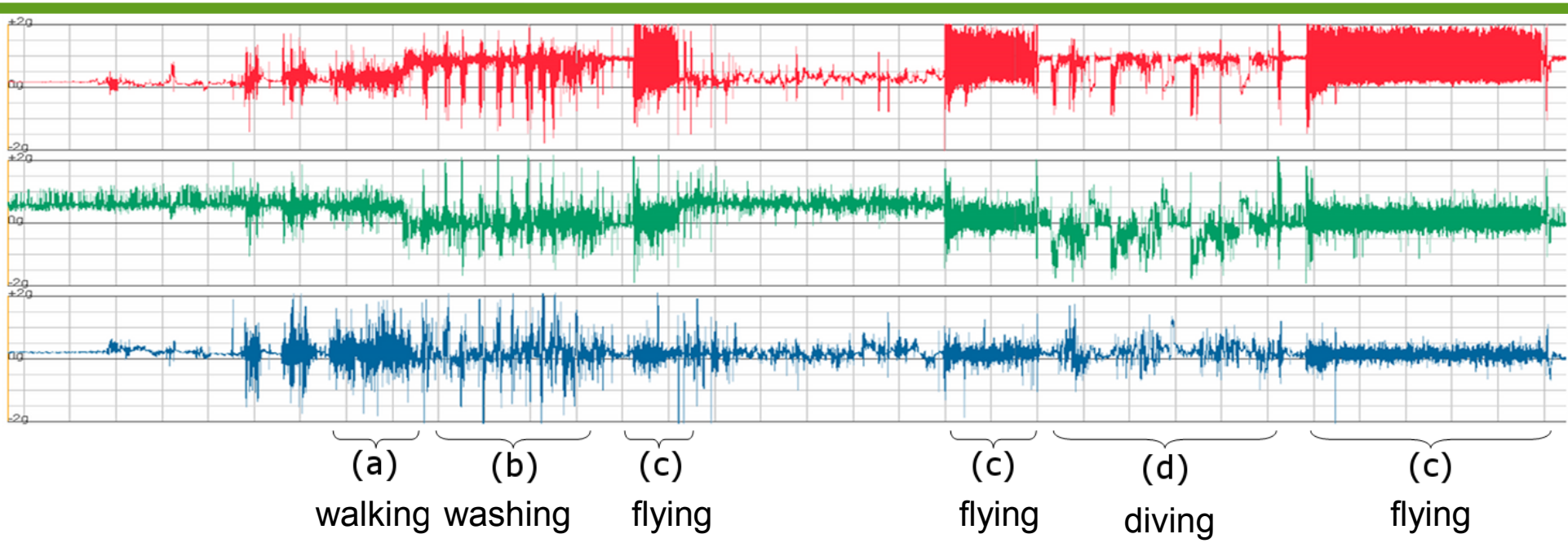
Standard Visualization Technique



2D line plots of the acceleration data is difficult to interpret,

- Large time domain makes relating different periods difficult
- Three channels (possibly more) need to be correlated mentally by user
- Relating intensity plots to orientation or movement is difficult

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Objectives

Given accelerometry data, it is useful to:

- Identify extraordinary events,
- Identify similarity,
- Relate to other attributes to form hypotheses
- Identify commonly adopted postures

While reducing cognitive effort required to interpret line plots.

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Results: Animal Tracking Video

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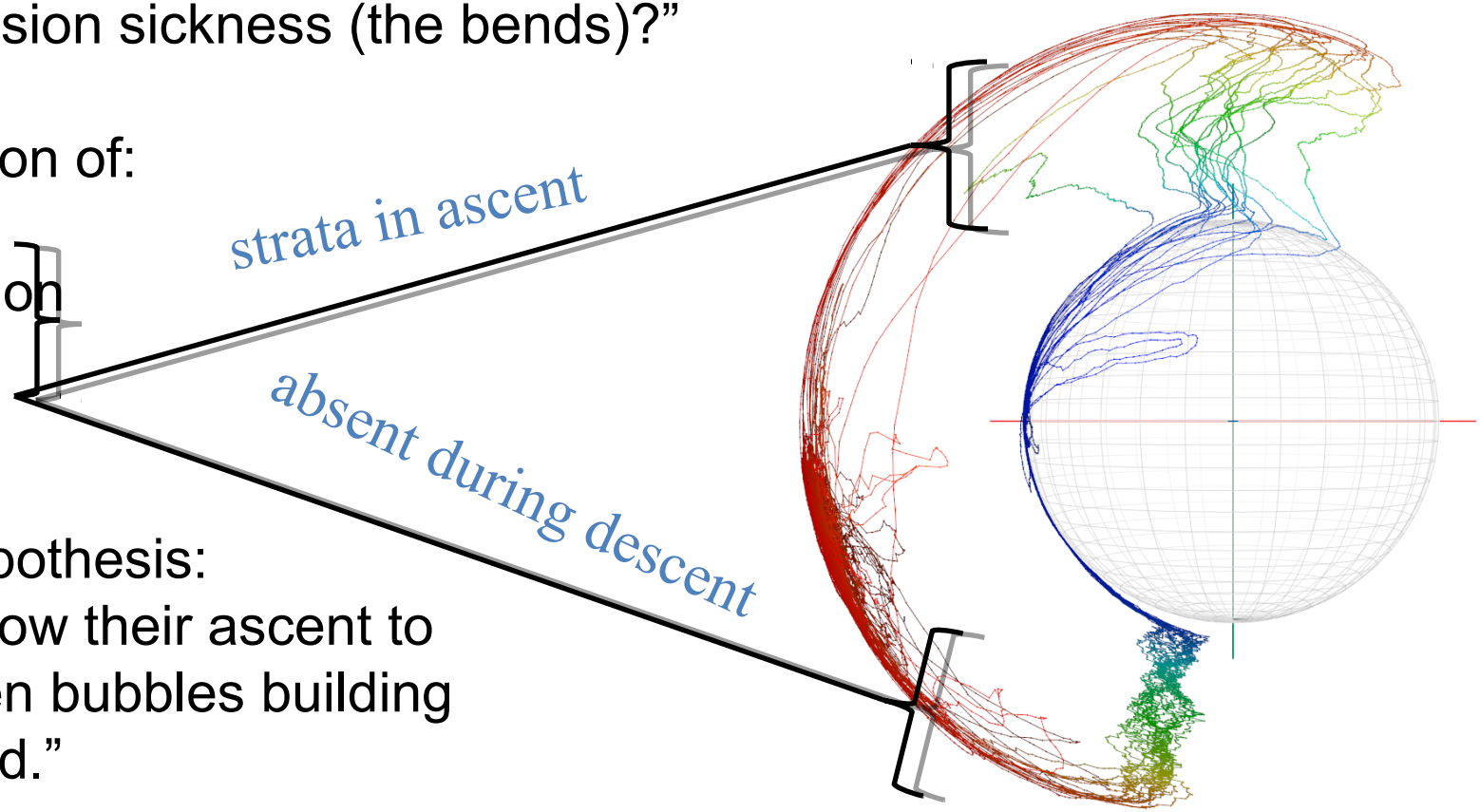
Domain Expert Review

Scatterplot and overlay are valuable tools for both exploration and communication of results.

Open research problem in marine biology: “Why don’t diving birds get decompression sickness (the bends)?”

Visual correlation of:

- Acceleration
- Pressure



Resulted in hypothesis:
“Diving birds slow their ascent to prevent nitrogen bubbles building up in their blood.”

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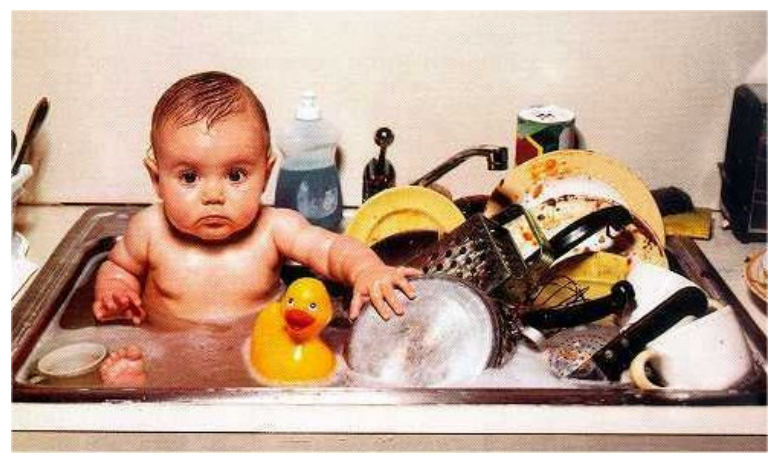
Physics Application: Why Study Foam?

Fire Safety

Cleansing

Displaces oil from porous media

Mineral flotation and separation



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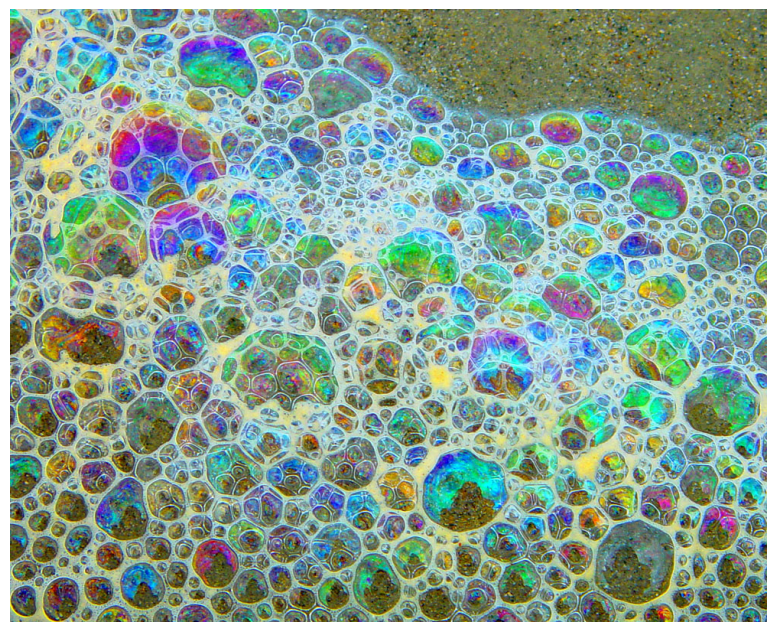
Physics Application: Foam

Two-phase material: liquid and gas

Complex behavior:

- **Elastic solid** at low stress
- **Plastic solid** as stress increases
- **Liquid** at high stress



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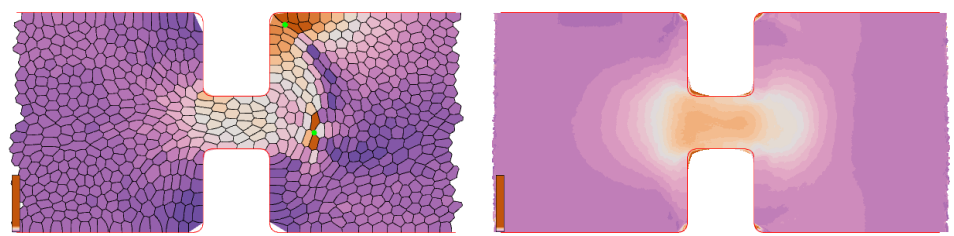
Bubble Scale Research Challenges

Triggers of various foam behaviors are difficult to infer.

Multiple attributes: position, size, pressure, velocity, topology

Difficult to visualize general foam behavior:

- Time-dependent
- Large fluctuations in attribute values caused by dynamic topology of film network.



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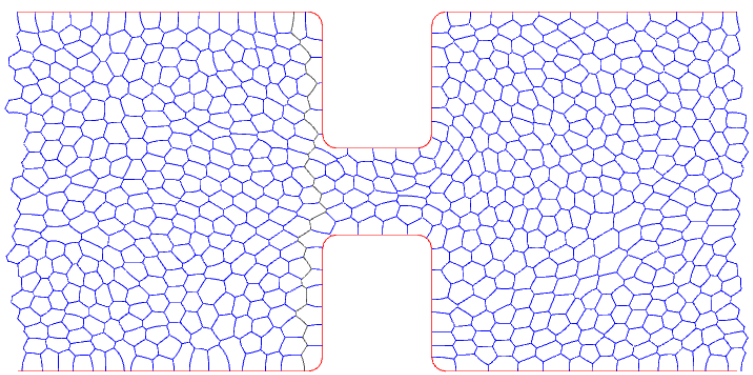
Standard Foam Visualizations

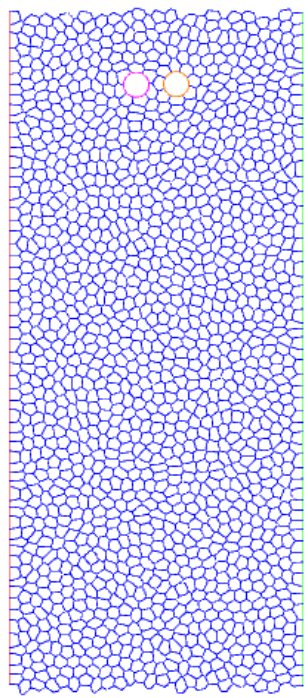
Require modification of simulation code for computation of derived data.

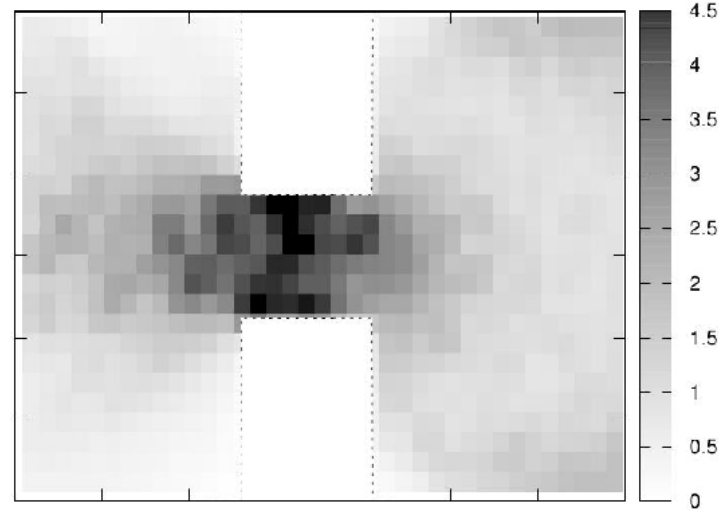
Lack ability to explore and analyze data through interaction.

Slow, coarse level of detail

Univariate







Constriction simulation: average velocity over all time steps

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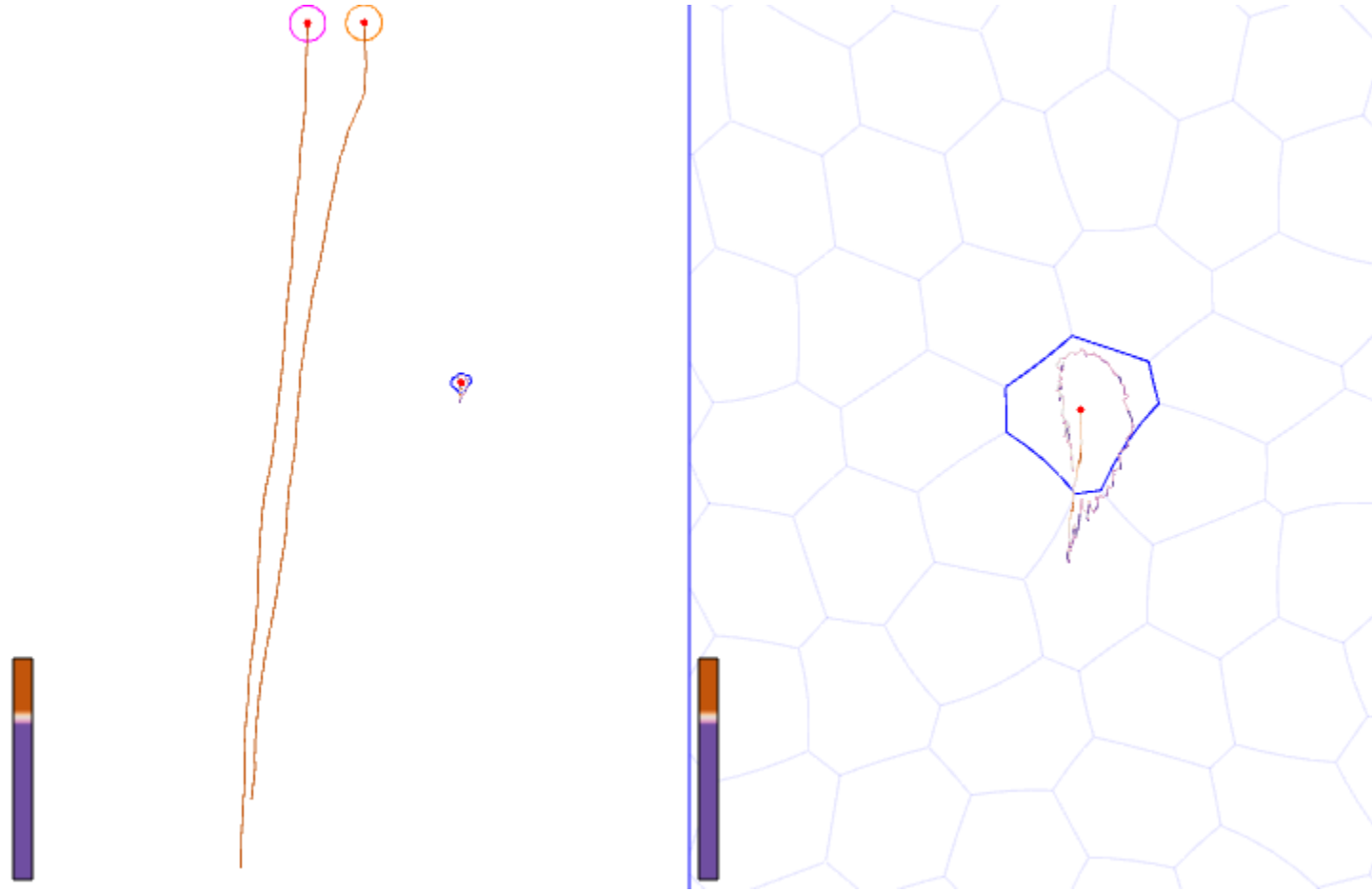
Why Do Bubbles Traverse Loops?



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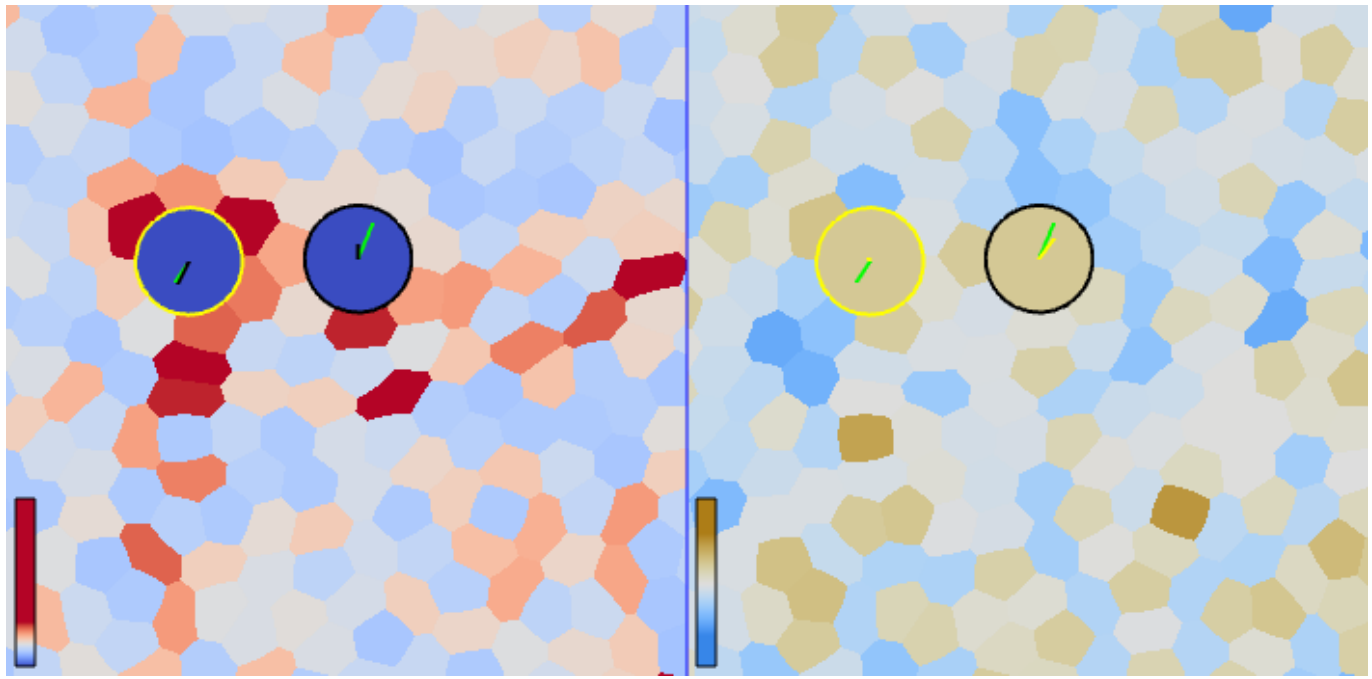
Why does one disc descend more quickly?



Simulation of Sedimenting Discs (t=0)
Elongation → blue-red
Pressure → blue-tan
Network force → black
Pressure force → yellow
Resultant force → green

The network force - contacting soap films pull normal to circumference with the force of surface tension.
The pressure force - adjacent bubbles push against disc with pressure force.

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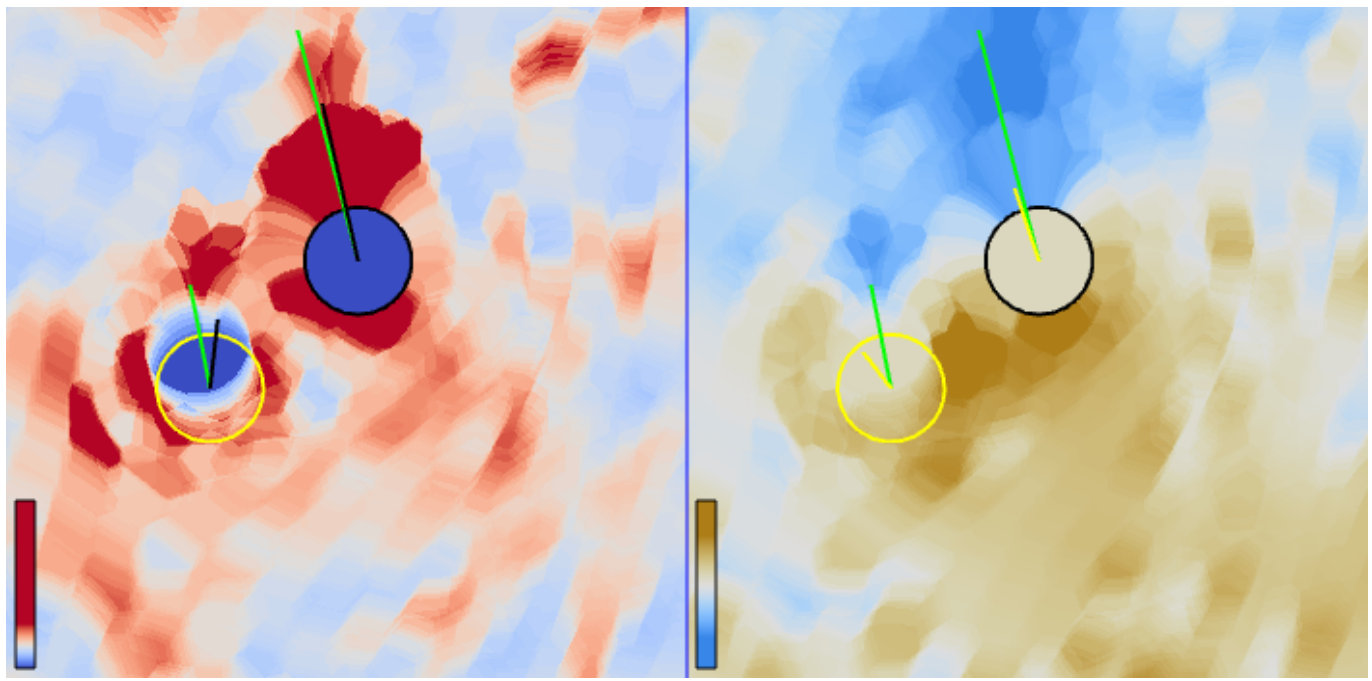
Results: Why do discs drift laterally as they sediment?

Simulation of Sedimenting Discs (t=43)

Elongation → blue-red
Pressure → blue-tan
time window → 10 iterations
Network force → black
Pressure force → yellow
Resultant force → green



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Physics Application: Visualization of Foam (Video)

Elongation → blue-red
Pressure → blue-tan
time window → 10 iterations
Network force → black
Pressure force → yellow
Resultant force → green

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What is Flow Visualization?

- a classic topic within scientific visualization
- depiction of vector quantities (as opposed to scalar quantities)
- applications include: automotive design, aerodynamics, astronomy, engineering, fluid mechanics, meteorology, oceanography, medicine, simulation, turbomachinery,

Challenges:

1. to effectively visualize both *magnitude* + *direction* often simultaneously
2. large data sets
3. time-dependent data
4. What should be visualized? (data filtering/feature extraction)

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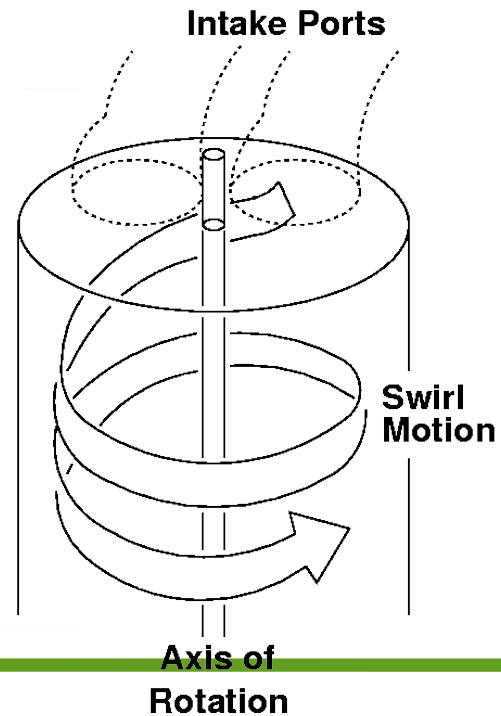
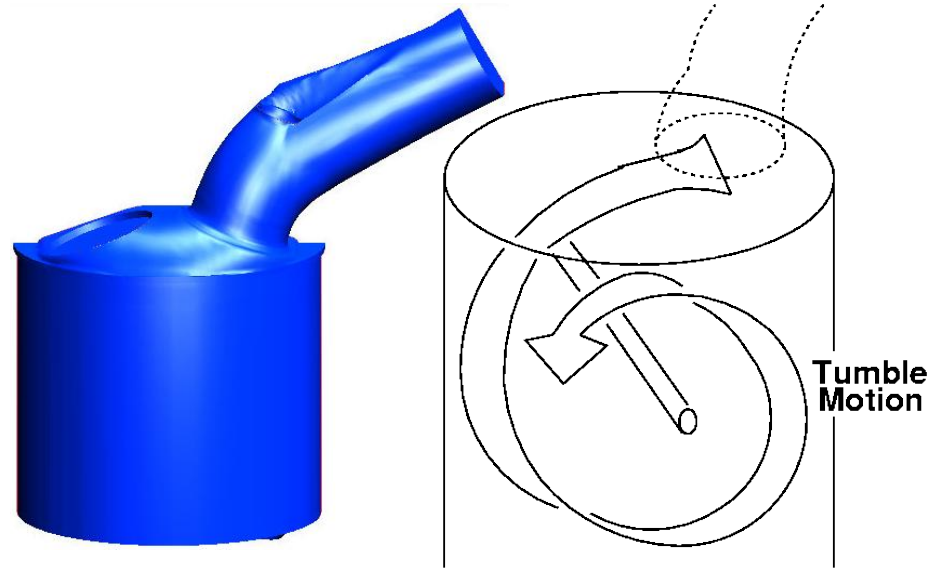
Computational Fluid Dynamics and Flow Visualization

- **swirl motion:** characterized by motion about cylinder-aligned axis
- more stable (easier)





- **tumble motion:** characterized by motion about axis orthogonal to cylinder
- unstable, more difficult

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Computational Fluid Dynamics and Flow Visualization

Achieving ideal patterns of motion leads to optimal mixing (of air and fuel) conditions

- e.g., higher exhaust/gas ratio (EGR)
- decrease in fuel consumption
- lower emissions

1. Can visualization provide insight into or verify characteristic shape/behavior of flow?
2. What tools help to visualize swirl/tumble motion?
3. Where (in the combustion chamber) are ideal ideal flow pattern ***not*** being realized?

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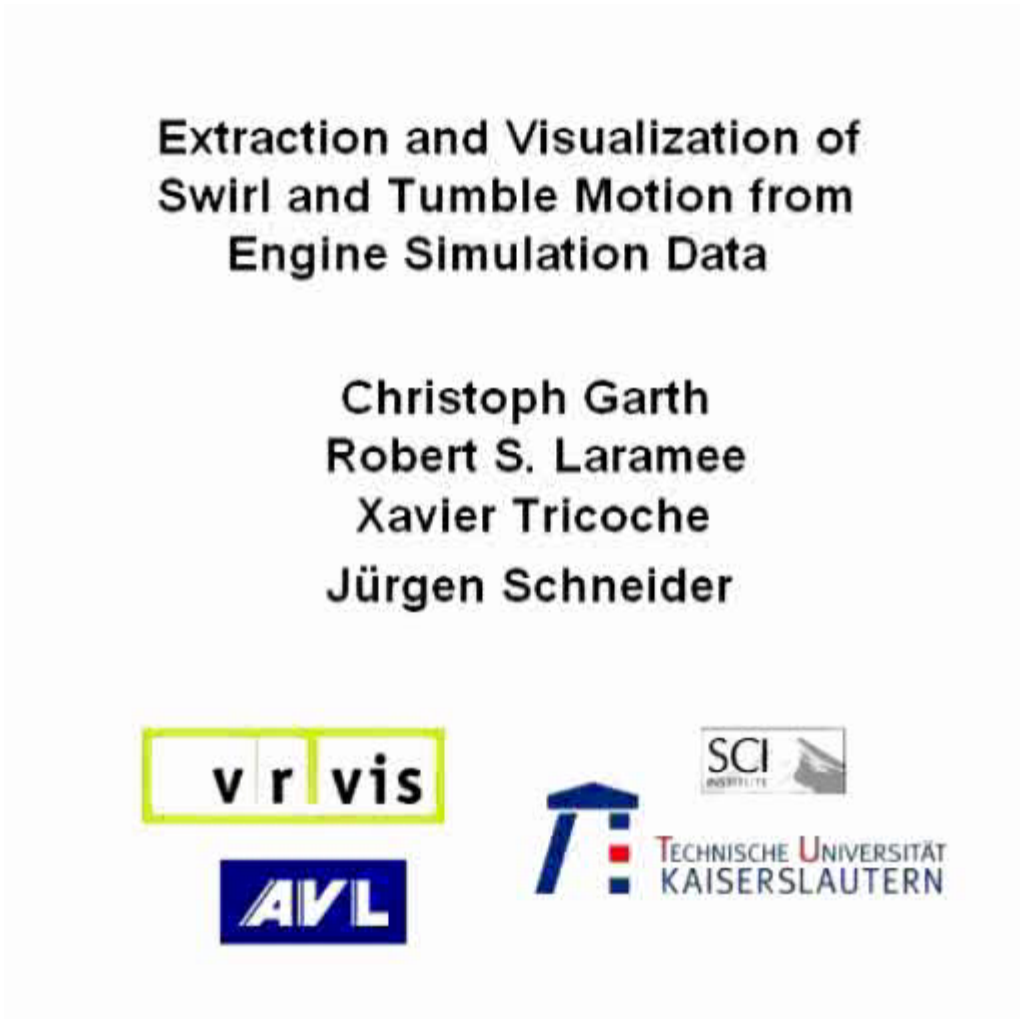
Computational Fluid Dynamics and Flow Visualization



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Computational Fluid Dynamics and Flow Visualization

(Video: Mesh-Driven Vector Field Clustering: An Image-Based Approach)

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Application: Modern Languages

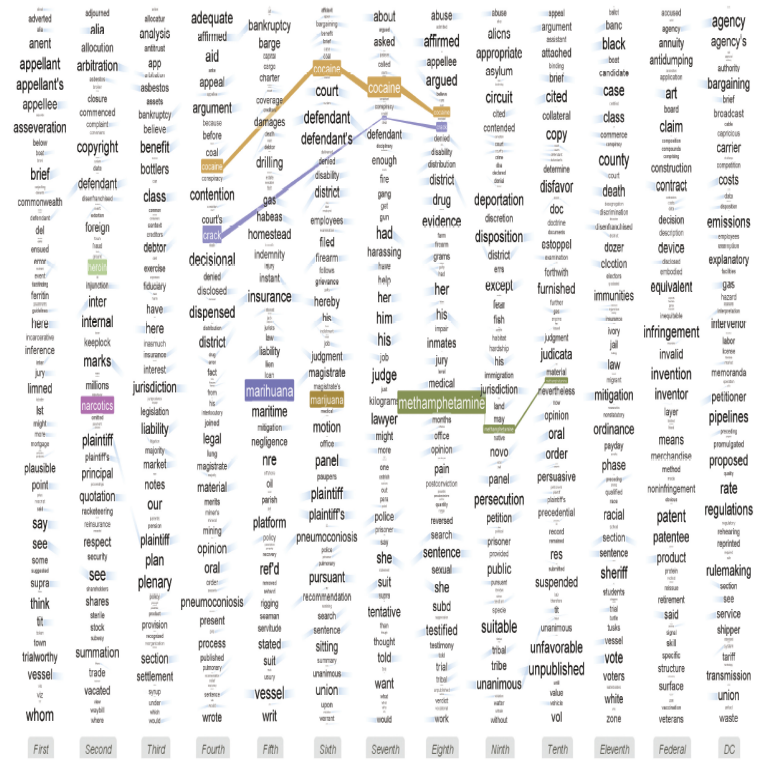
Shakespeare's plays have been translated into dozens of languages for about 300 years

Every translation is a different interpretation

Reflect changing culture or express individual thought by authors

Connecting different regions and reveal a retrospective view of their histories

Researchers from Modern Languages, Swansea University, collect a large number of German translations of Shakespeare's play, *Othello*



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Text Visualization: Challenges and Goals

Challenges

Complex Multi-Dimensional Data Set (translation, author, place, year, popularity)

Where, when, into which languages has Othello been translated?

How have translators **influenced** one another?

How do versions **vary** globally / locally?

Which translation is more **similar** to the original play?

Goals of Visualization

Present different facets of the data

Analyze the data in detail

Explore the relationships and patterns to make new hypotheses

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- Othello (black) has secretly married Brabantio's daughter.
- Brabantio is unhappy.
- Duke of Venice points out that Othello is a good man

If virtue no delighted beauty lack,
Your son-in-law is far more fair than black.
W. Shakespeare (*Othello*, c.1607)

- Duke insults black people, but praises Othello.
- It is not clear if this is said publically, privately, seriously or jokingly. Translations vary.

Blue = German. Red/Green = back-translation to English. Green = terms unique to that version

Wenn es der Tugend nicht an lichter Schönheit fehlt,
Ist vielmehr blond als schwarz, den euer Kind gewählt

1826

If virtue does not lack bright-lit beauty, He is far more blond than black, whom your child has chosen

J.W.O.Benda (during period of nation building)
- never performed or reprinted (less popular)
- frames it as a crude joke

Leiht Tugend ihre Farbe dem Gesicht,
Ist Euer Eidam weiß, ein Schwarzer nicht.

1920

If virtue lends its colour to the face,
Your son-in-law is white, not a black man

M.Wolff (during the Weimar Republic)
- first to be explicitly racist
- best selling translation at time

Wenn nie der Tugend lichte Schönheit fehlt,
Ist Eure Tochter hell, nicht schwarz, vermählt.

1941

If virtue never lacks bright-lit beauty,
Your daughter is brightly, not blackly, married.

H.Schwarz (Germany under Hitler)
- woman translator – focuses on relationship
- Never performed or reprinted (less popular)

Zählte bei Menschen nur der innre Schein,
würden wir dunkler als Othello sein.

1956

If people's inward appearance were all that counted,
We would be darker than Othello.

H.Rothe (persecuted during WW2) (West Germany)
- converted to a moralistic lesson (social war-guilt)
- Successful print but rarely performed

Wenn man die Tugend muß als schön erkennen,
Dürft Ihr nicht häßlich Euren Eidam nennen.

1832

If one must recognise virtue as beautiful,
You may not call your son-in-law ugly.

W.Baudissin (cultural nation-building)
- most famous German version
- authoritative German leadership tone (no joke)

Spricht man von Tugend, als von einem Licht,
Scheint Euer Eidam mir so dunkel nicht.

1939

If one speaks of virtue as of a light,
Your son-in-law seems not so dark to me

E.Engel (Germany under Hitler)
- use of 'dark' and centred on 'me': typical of fascism
- renowned production in Berlin

Wenn Mannesmut nicht Reiz und Glanz entbehrt,
So ist er, wenn auch schwarz, höchst schätzenswert.

1941

If manly courage is not without charm and glory,
Then he is, even if black, highly estimable.

T.Von Zeynek (Austria under Hitler)
- Reflects fascist male-dominated racist, and offensive
- Wasn't performed until the 1960s (reflectively)

Wenn Ihr der Tugend nicht Schönheit absprechen wollt,
Ist Euer Schwiegersohn nicht dunkel, sondern Gold!

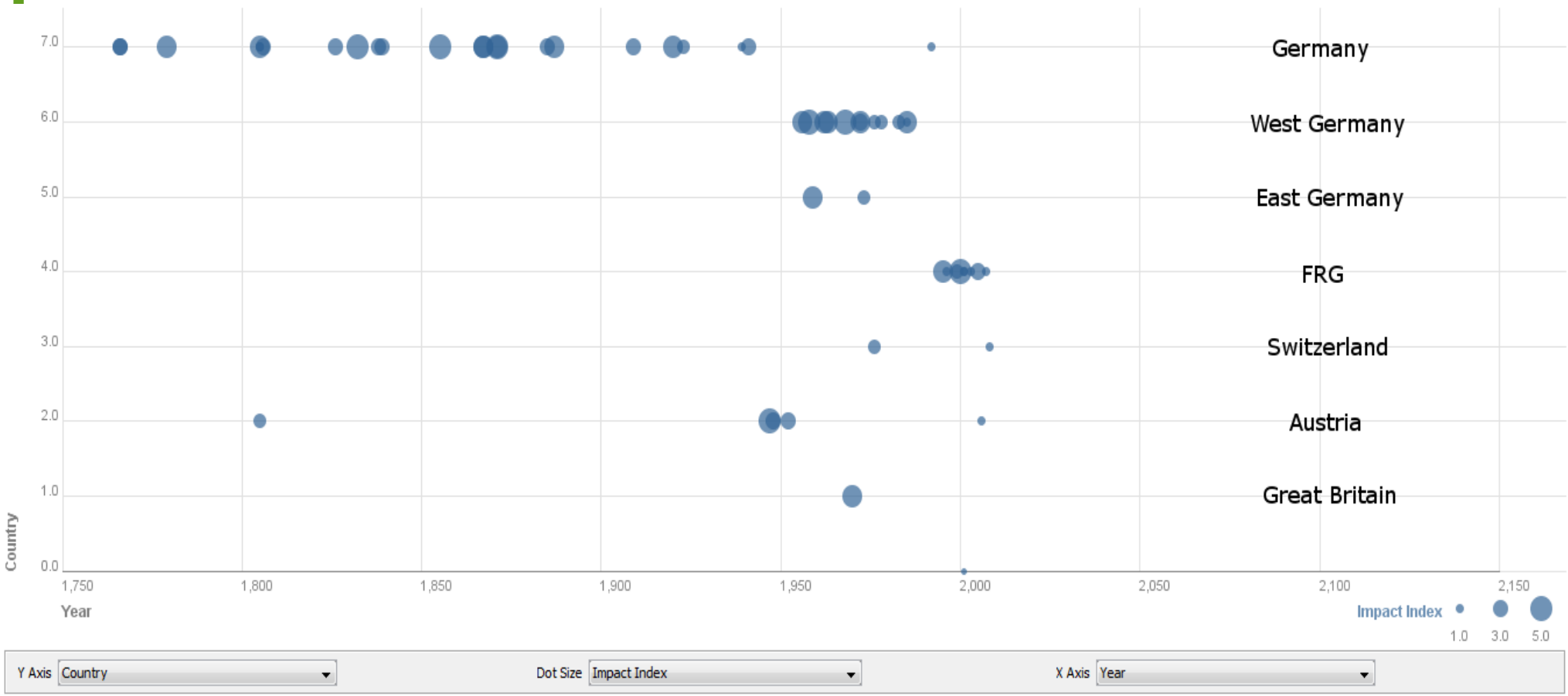
1970

If you do not wish to deny beauty to virtue,
Your son-in-law is not dark but gold!

E.Fried (in London, self-exiled from post-war Germany)
- Famous radical leftist poet – polysemic metaphor

Background of Translation Data

57 translations of *Othello* from 7 various countries, ranging from 1766 to 2006



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Text (Pre-)Processing

Document Collection
Document Standardization
Scanned and stored in ASCII format

Tokenization
Break the stream of characters into words or tokens

Remove articles: e.g., a, the (die, der, das, ein, etc.)

Language dependent

Lemmatization
Convert to root form, e.g., play, (-ing, -er, -s etc.)

Concordance
Tokens + Frequency

Vector Generation (LSI Model)

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Visualizing Translation Variation: Othello Video

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More Visualization Applications

- Visualization of Higher Education (HE) in Wales (Strategic Planning Unit)
- Visualization of Questionnaire Data (Criminology)
- Visualization of EEG Data (Psychology)
- Visualization of Tensor Field Data (Engineering)

Many more examples on Bob's web page:
http://cs.swan.ac.uk/~csbob/

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References

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Acknowledgements

- Thank you for your attention!
- Any Questions?

Thanks to the following people:

Mohammed Alharbi, Ken Brakke, Tom Cheesman, Nick Croft, Helmut Doleisch, Matthew Edmunds, Alison Ehrmann, Zhao Geng, Christoph Garth, Edward Grundy, Markus Hadwiger, Helwig Hauser, Mark W Jones, Robert Kosara, Dan Lipsa, Rami Malki, Ian Masters, Tony McLoughlin, Lukas Mroz, Zhenmin Peng, Juergen Schneider, Emily Shepard, Xavier Tricoche, Ferdinand Vesely, Rory P Wilson, Bo Xia

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