ItoLab.

Flow Visualization in Real and Time Spaces

Takayuki Itoh

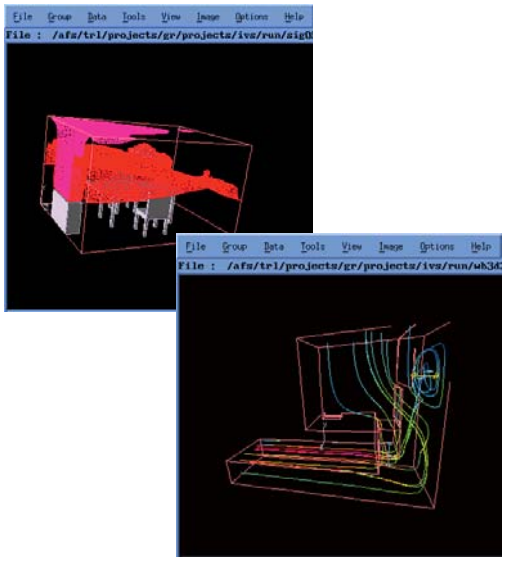
Department of Information Sciences
Ochanomizu University

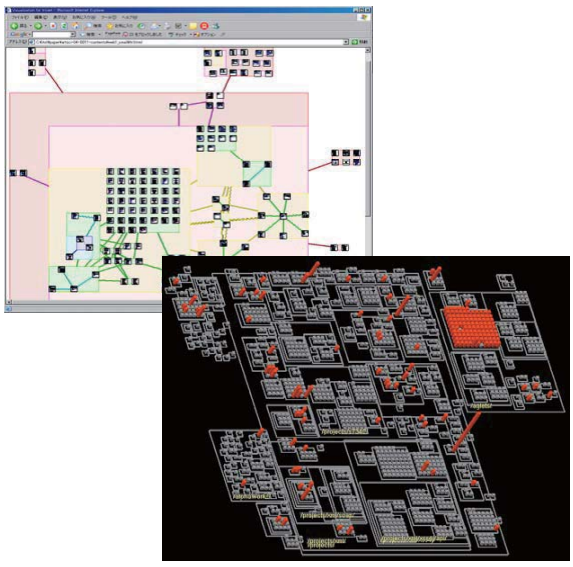
1

ItoLab.

Various visualization

- Scientific Visualization
  - Mainly scientific data
  - Mainly physical spaces
- Information Visualization
  - Various data
  - Mainly non-physical spaces





This document is provided by JAXA.

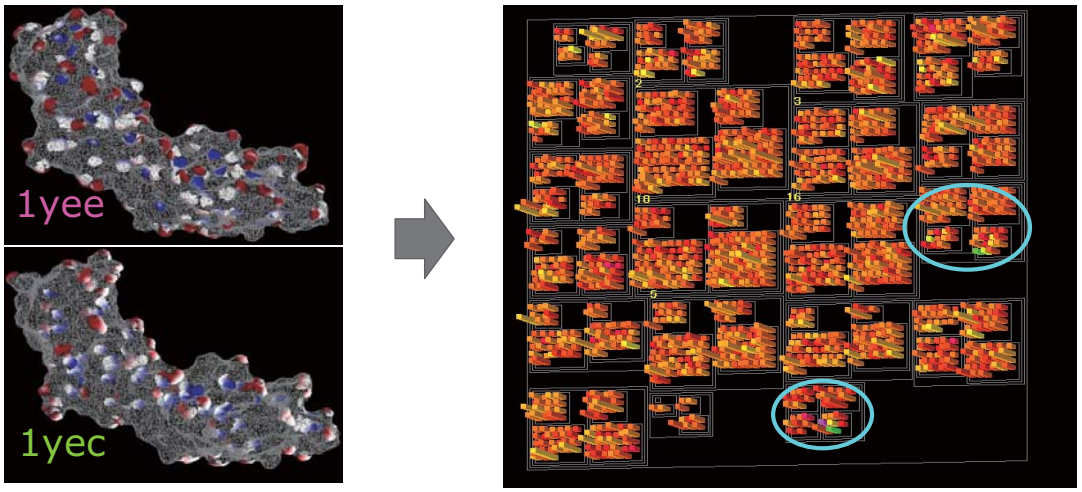
ItoLab.

Typical topic in Itoh lab.
(1) Protein surface analysis

- Retrieval and comparison of similarly shaped protein surfaces

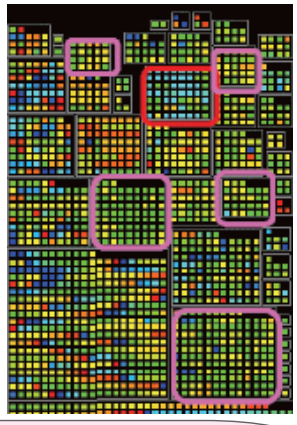
Very similar, but partially different proteins

Chemical properties are also partially different

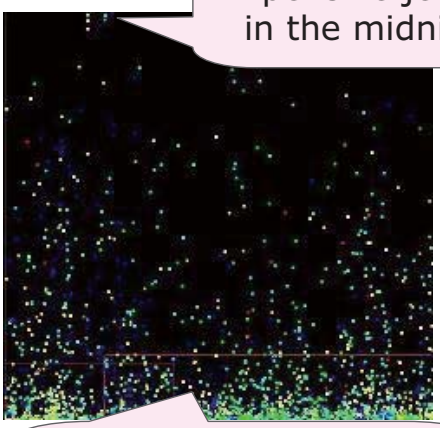


Typical topic in Itoh lab.
(2) Credit card fraud analysis

- Discovery of trend and correlation among attributes of malicious transactions



Many of transportation-related frauds are in the morning



Expensive jewelry in the midnight

Many abnormal refunds from specific shops

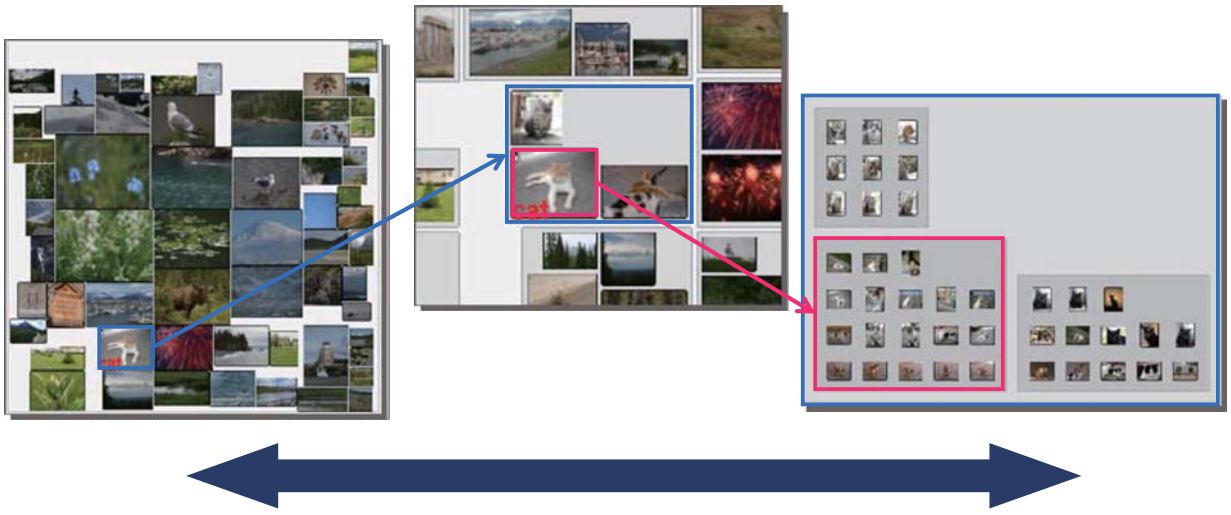
This document is provided by JAXA.

ItoLab.

Typical topic in Itoh lab.

(3) Browser for many images

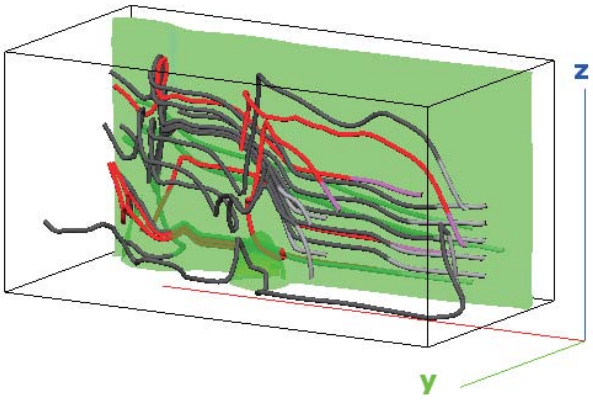
- Zooming user interface for clusters of images

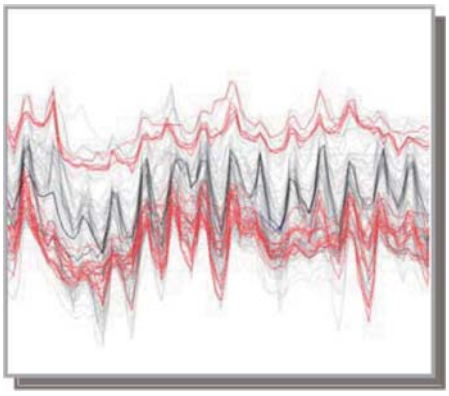


ItoLab.

Today's topic

- Real space visualization
  - Integrated scalar & vector visualization
- Time space visualization
  - Level-of-detail control for polyline charts





- Towards integrated EFD/CFD visualization

This document is provided by JAXA.

ItoLab.

Let me go to other charts ...

A Streamline Selection Technique for Integrated Scalar & Vector Visualization

Takayuki Itoh, Shiho Furuya

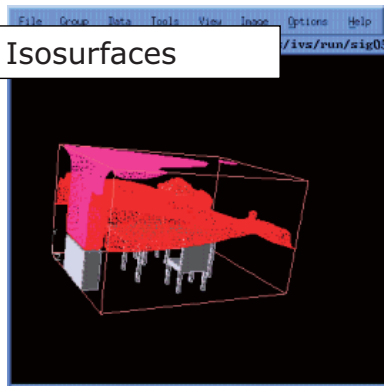
Ochanomizu University

This document is provided by JAXA.

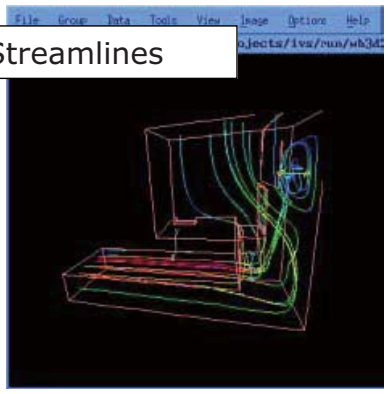
Background
… Scalar and vector visualization

Scalar field	Vector field
2D ■ Contour lines 3D ■ Isosurface ■ Volume rendering	2D ■ Arrow plots 3D ■ Streamline ■ Line integral convolution

Isosurfaces



Streamlines

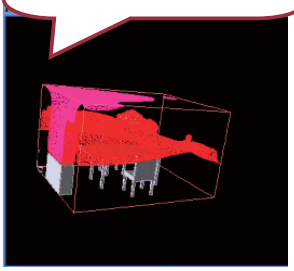


Background
Integrated scalar & vector data

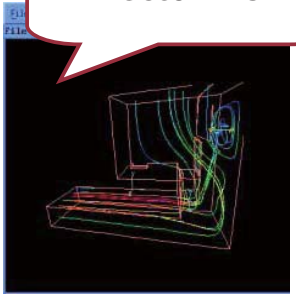
Ex. Weather simulation data
- Pressure, temperature, air flow…etc

Needs of integrated visualization to understand relationships between scalar and vector fields

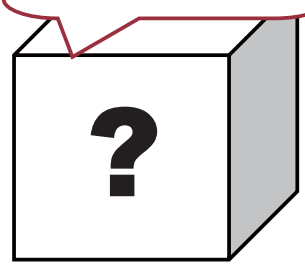
Scalar vis.



Vector vis.



Integrated

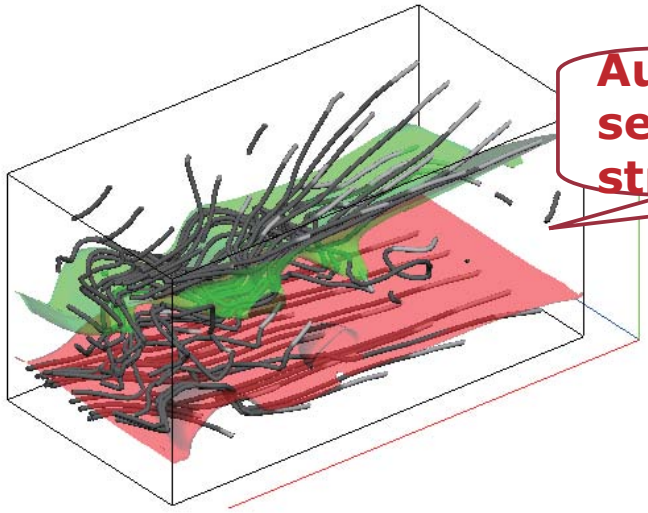


This document is provided by JAXA.

Target of this study:

Integrated 3D scalar & vector visualization

- Isosurfaces for scalar
- Streamlines for vector



Processing flow

STEP1: Generate many streamlines temporarily, and calculate their information entropy

↓

STEP2: Check if they go through critical points

↓

STEP3: Check if they are occluded by isosurfaces

↓

Select the good streamlines according to the 3-step evaluation

This document is provided by JAXA.

Processing flow

STEP1: Generate many streamlines temporarily, and calculate their information entropy

STEP2: Check if they go through critical points

STEP3: Check if they are occluded by isosurfaces

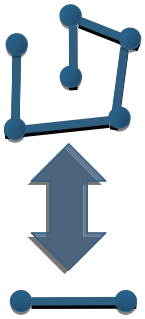
Select the good streamlines
according to the 3-step evaluation

STEP1: Information entropy

$$E = -\frac{1}{\log_2(m+1)} \sum_{j=0}^{m} \frac{D_j}{L} \log_2 \frac{D_j}{L}$$

L : Length of a streamline in 3D space
D_j : Length of j-th segment in 2D display space
m : Number of segments of the streamline

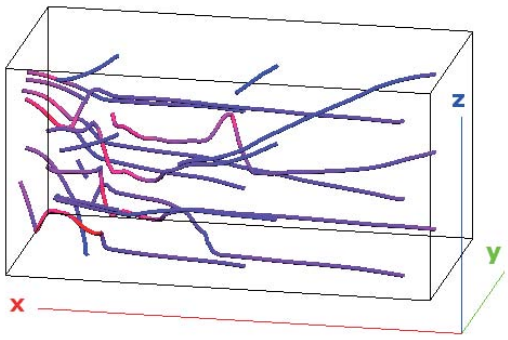
- Calculation for each streamline
- Higher information entropy
  = Uniformly long segments in 2D display space
- **To select "*informative*" streamlines**



This document is provided by JAXA.

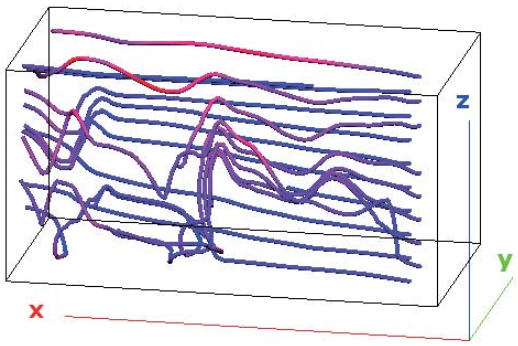
STEP1: Information Entropy

Streamlines just uniformly generated



- Too short, less informative

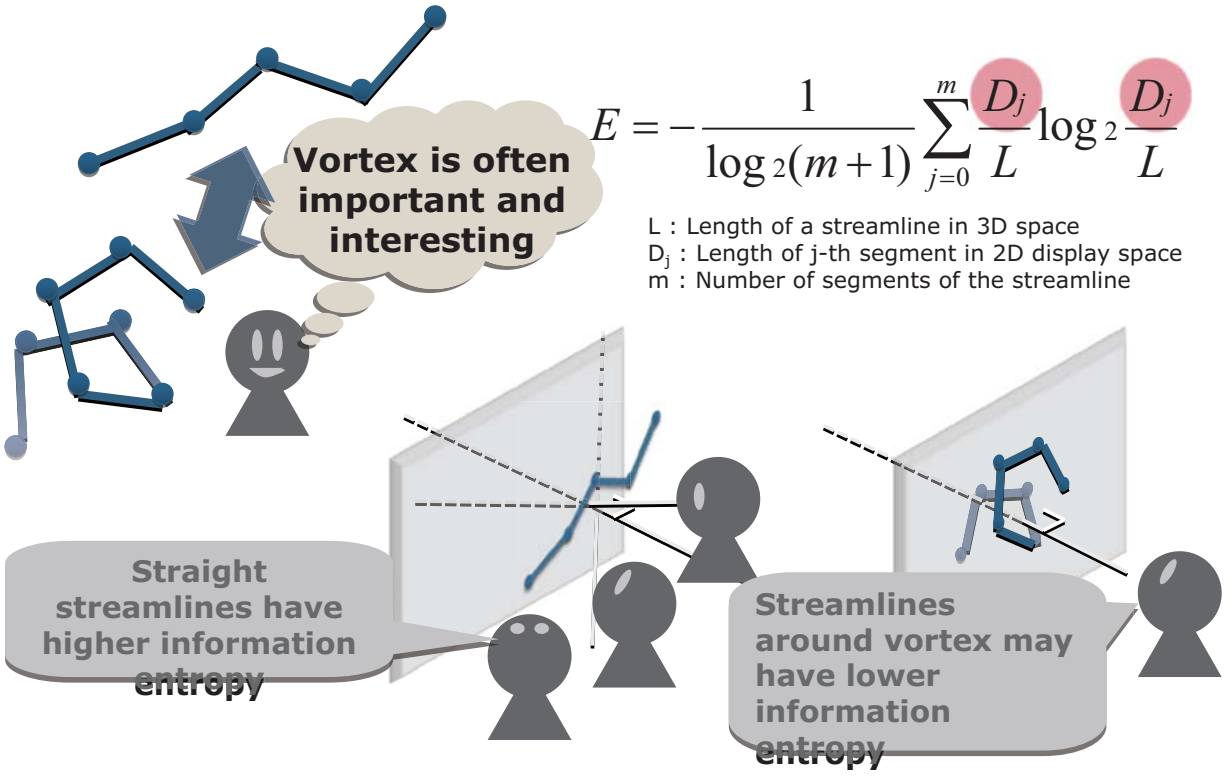
Streamline selected by information entropy



- Globally visualized by informative streamlines

Air flow by a weather simulation

STEP1: Information Entropy



$$E = -\frac{1}{\log_2(m+1)} \sum_{j=0}^{m} \frac{D_j}{L} \log_2 \frac{D_j}{L}$$

L : Length of a streamline in 3D space
D_j : Length of j-th segment in 2D display space
m : Number of segments of the streamline

This document is provided by JAXA.

Processing flow

STEP1: Generate many streamlines temporarily, and calculate their information entropy

STEP2: Check if they go through critical points

STEP3: Check if they are occluded by isosurfaces

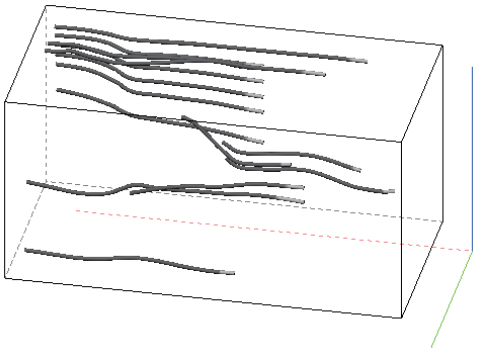
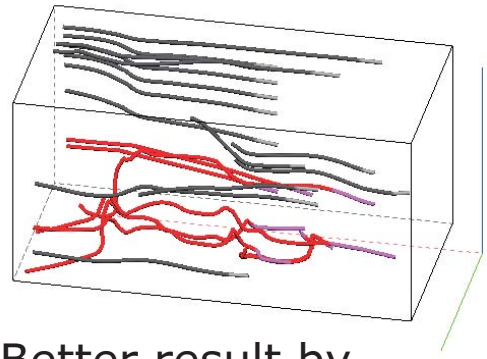
Select the good streamlines according to the 3-step evaluation

STEP2: Critical points

- Where is a critical point?
  - Vector: velocity is zero
  - Scalar: local minimum/maximum, saddle
- The technique divides streamlines
  - Going around critical points
  - Others

This document is provided by JAXA.

STEP2: Critical points

WITHOUT STEP2	WITH STEP2
	
▫ Local interesting features around critical points are missing	▫ Better result by aggressively selecting streamlines around critical points

Red: around critical points Black: others

Processing flow

STEP1: Generate many streamlines temporarily, and calculate their information entropy

STEP2: Check if they go through critical points

STEP3: Check if they are occluded by isosurfaces

Select the good streamlines according to the 3-step evaluation

This document is provided by JAXA.

STEP3: Occlusion by isosurfaces

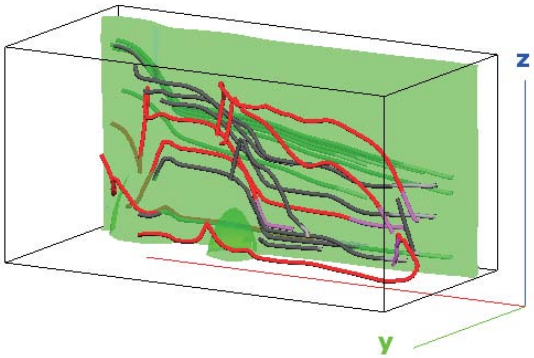
- Visually unnatural if many streamlines “behind” isosurfaces are selected
- Aggressively select “near” streamlines
  - By assigning penalties to occluded streamlines

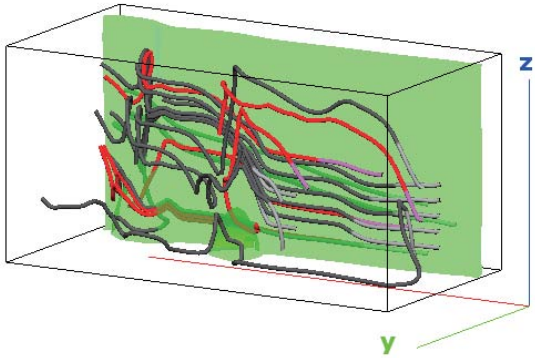
$$E' = (1 - \frac{m}{M})E + (\frac{m}{M})(1 - \alpha)E$$

New entropy: E’
Original entropy :E
Num. of segments :M
Num. of occluded segments: m
Opacity of isosurface: α

STEP3: Occlusion by isosurfaces

WITHOUT STEP3	WITH STEP3





- Many invisible streamlines behind the isosurface
- More number of visible streamlines are selected

This document is provided by JAXA.

Conclusion & Future works

- Conclusion
  - Automated streamline selection for integrated scalar and vector visualization
    - Higher information entropy
    - Around critical points
    - Less occlusion by isosurfaces
- Future works
  - Selection of important critical points
  - Seamless visualization of time-varying data

FRUITS TIME: AN INTERACTIVE VISUALIZATION TECHNIQUE FOR TIME-VARYING DATA

Takayuki ITOH, Yumiko UCHIDA
Ochanomizu University

This document is provided by JAXA.

TARGET: LARGE TIME-VARYING DATA

- Various data in our daily life
  - Stock prices, Weather measurements, Simulation results, etc.

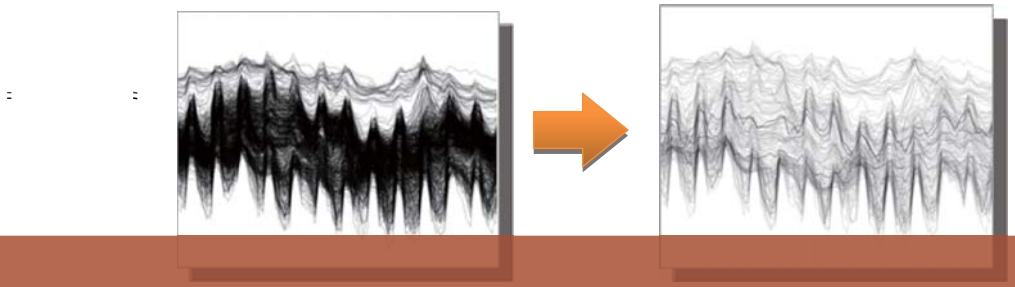
**Difficult to read large time-varying data,
if it is simply drawn as polylines in a single chart space**

Level-of-detail (LOD) control **and** ***interactive query***
for polyline-based large time-varying data visualization

- **Easily discover features from large data**
- **Interactively extract interesting part of the data**

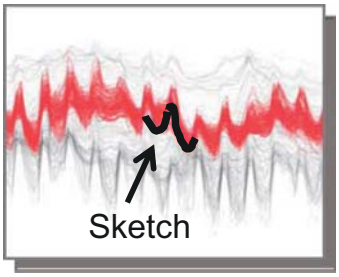
OVERVIEW OF "FRUITS TIME"

- **Level-of-Detail Control of Polylines**
  - Cluster similarly-shaped polylines, and remain representative polylines



- **Overview while finding local interesting features**
- **Interactive resetting of level-of-detail control**

- **Sketch-based query of polylines**
  - Highlight representative polylines
  - Highlight non-representative polylines

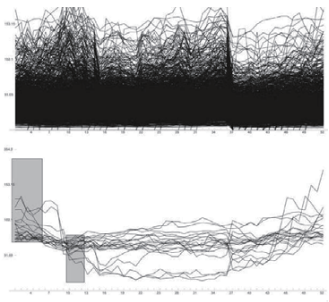


This document is provided by JAXA.

RELATED WORKS

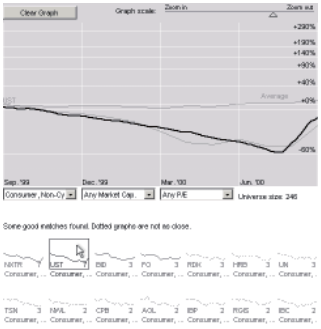
- Problems for visualizing large amount of time-varying data
  - Cluttering among polylines
  - Missing interesting features

Improved techniques for polyline-based visualization



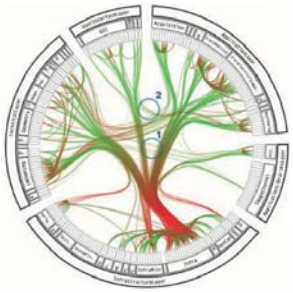
Range-based query of time-varying data

[H. Hochheiser 2004]



Sketch-based query of time-varying data

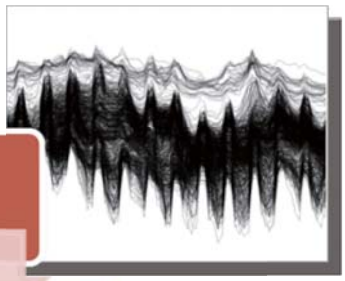
[M. Wattenberg 2001]



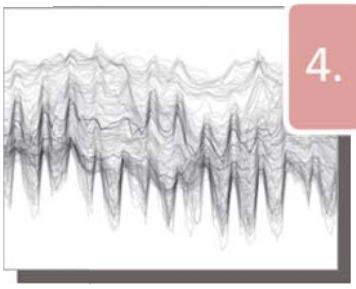
Hierarchical edge bundling

[D. Holten 2006]

FEATURE 1: LEVEL-OF-DETAIL CONTROL



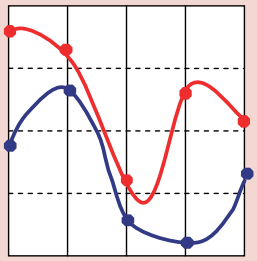
1. Sampling & Quantization
2. Clustering
3. Representative selection
4. Display representatives



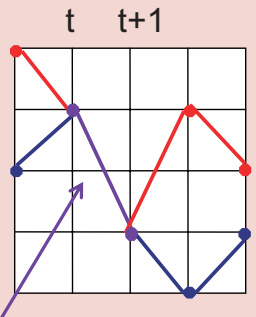
This document is provided by JAXA.

SAMPLING, QUANTIZATION, AND GROUPING

1. Sample time steps



2. Quantize values
3. Group polylines



Belong to the same group if:
quantized values at t-th and (t+1)-th values are equal

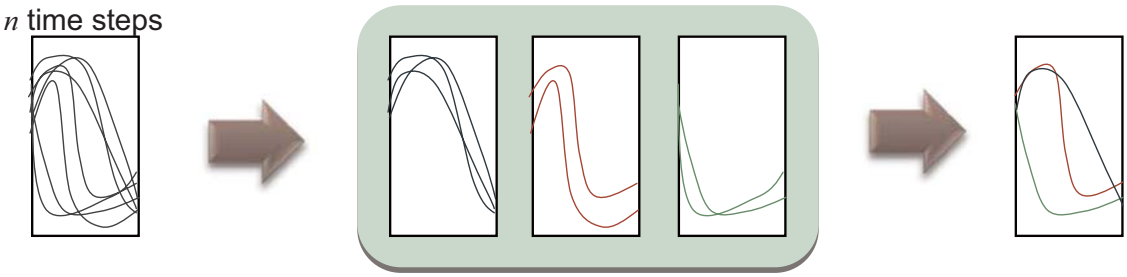
CLUSTERING AND REPRESENTATIVE SELECTION

Clustering of polylines in the groups based on original shapes

- n time steps in a grid subspace
- n-dimensional vector from the y-coordinate values
- Clustering of the n-dimensional vectors

Representative selection for each cluster

- Select the polyline that is closest to the center of a cluster
- Level-of-detail control by displaying only representative polylines
  - Adjust the opacity of the polylines based on numbers of polylines in the clusters



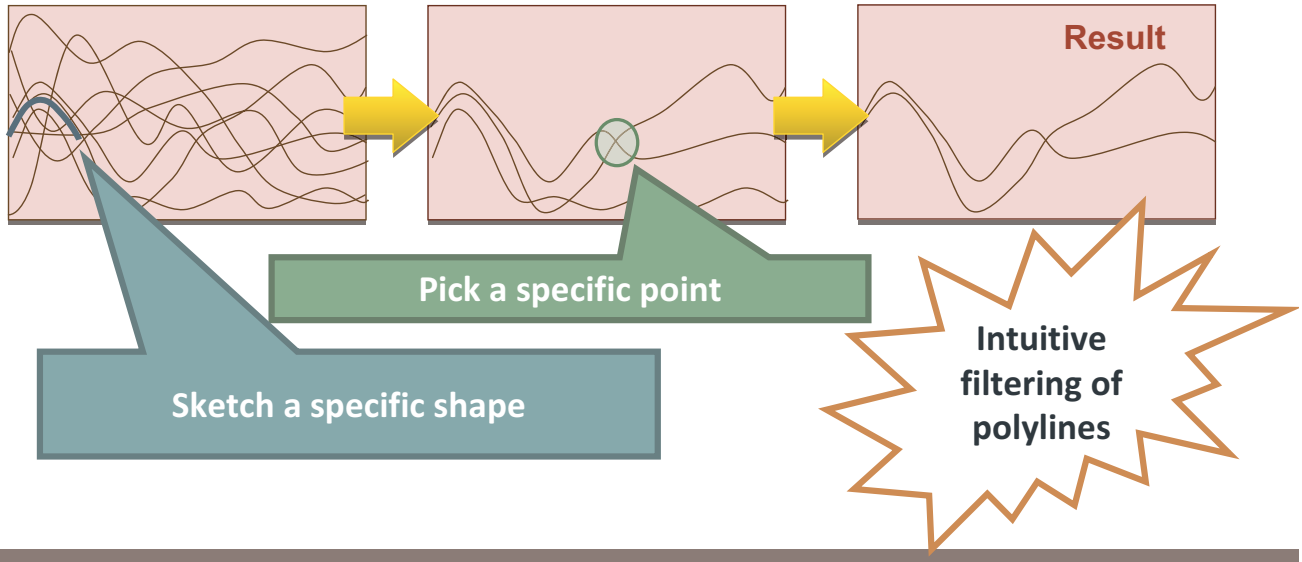
This document is provided by JAXA.

FEATURE 2: SKETCH-BASED QUERY INTERFACE

- Extract specific polylines which drastically change at specific time

Shape-based query system is required

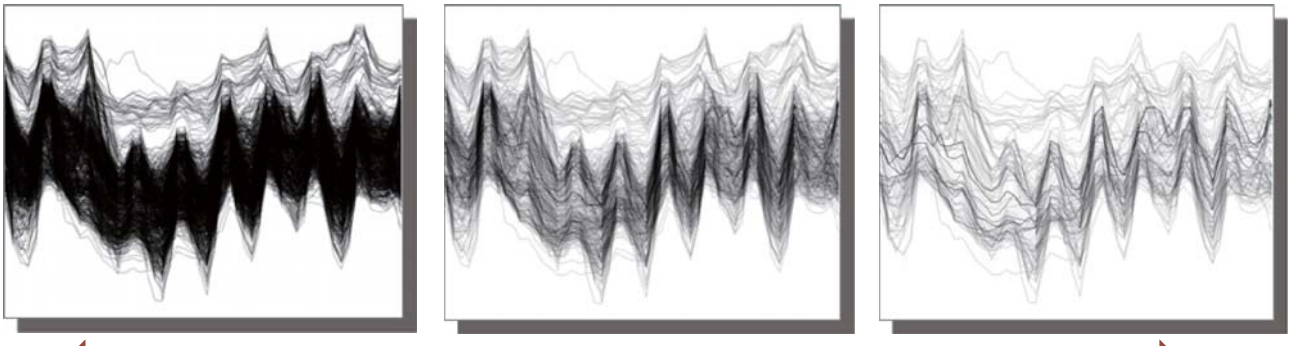
Interactive query & filtering of polylines by:
- Sketching specific shapes
- Picking specific points



RESULT 1: LEVEL-OF-DETAIL CONTROL

- Interactive control of resolution of sampling/quantization with GUI

Ex: Temperature measurement at various places in Japan



More (916) **Number of polylines** Few (273)

Flexible control of level-of-detail

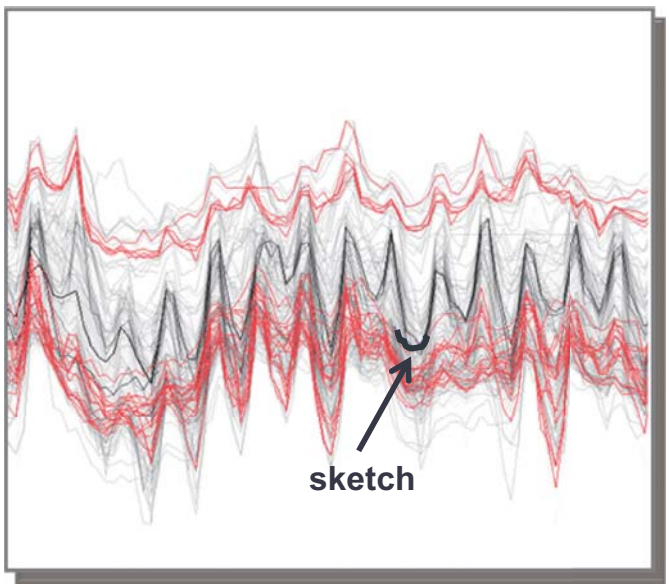
This document is provided by JAXA.

RESULT 2: SKETCH INTERFACE (MOVIE)

- Filtering by multiple query
- Simultaneous display of multiple query results
- User-specified coloring of the query results

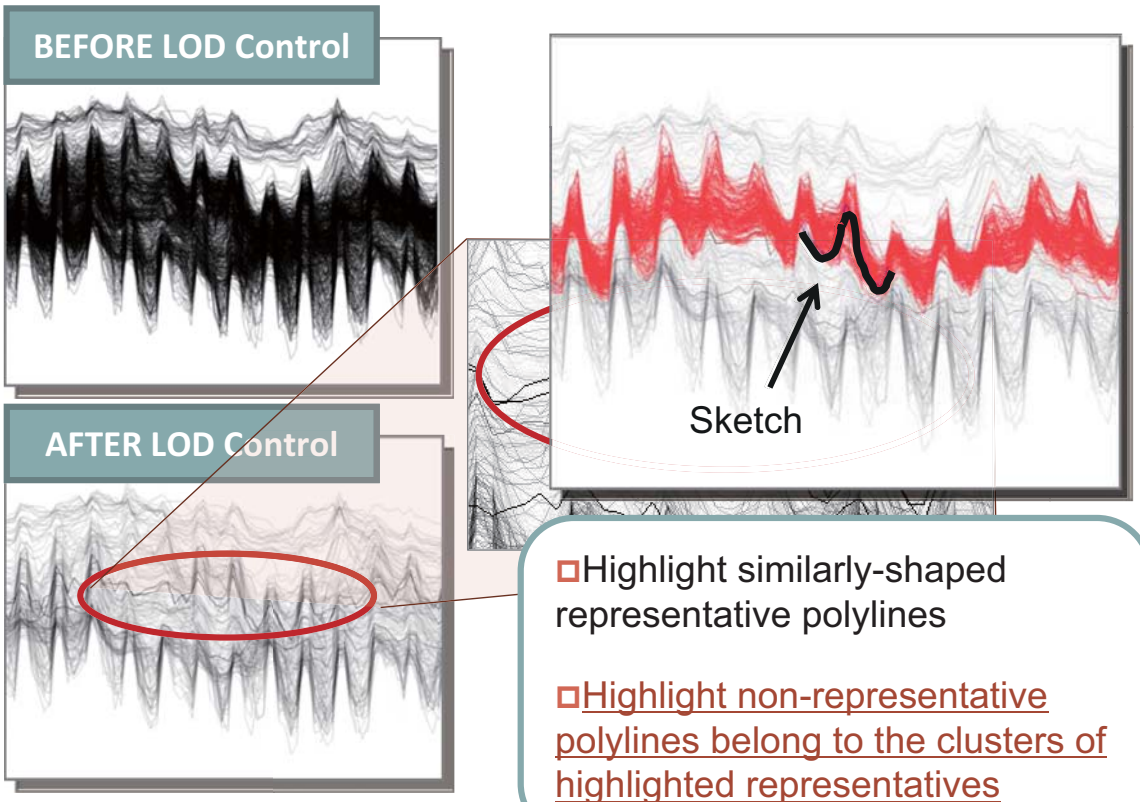
RESULT 3: POSITION-IGNORANT QUERY

- Highlight polylines which
  "similarly-shaped, but away from sketched position"



This document is provided by JAXA.

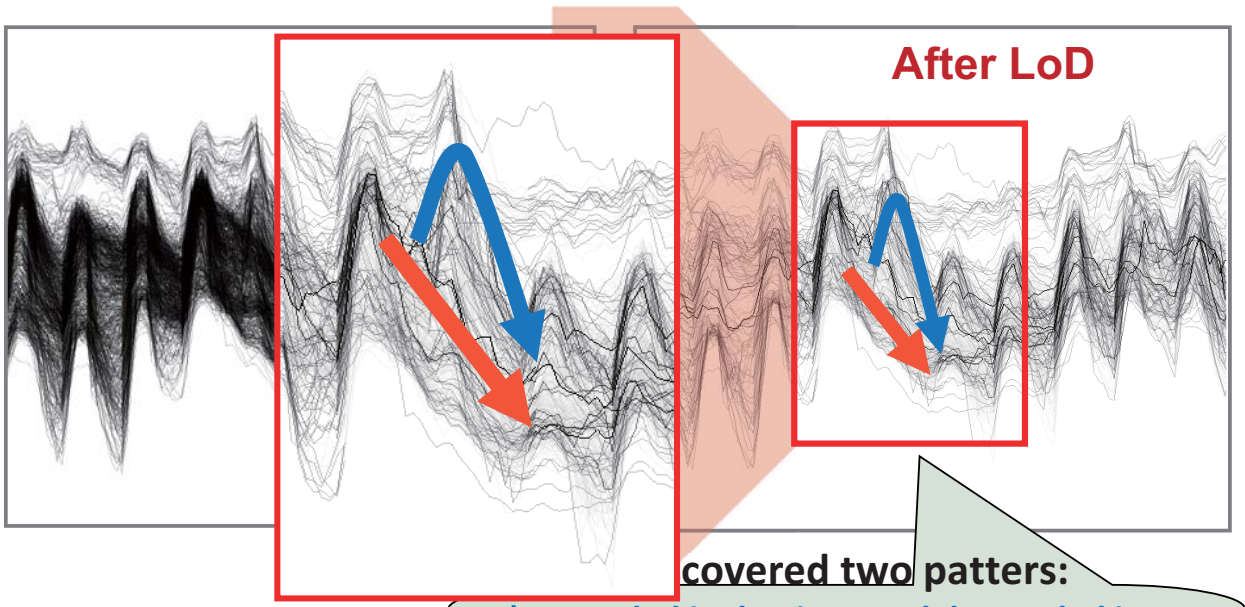
RESULT 4: RESETTING LOD OF HIGHLIGHTING POLYLINES



- Highlight similarly-shaped representative polylines
- Highlight non-representative polylines belong to the clusters of highlighted representatives

APPLICATION TO WEATHER DATA

Temperature measured at 913 points by AMeDAS



covered two patters:

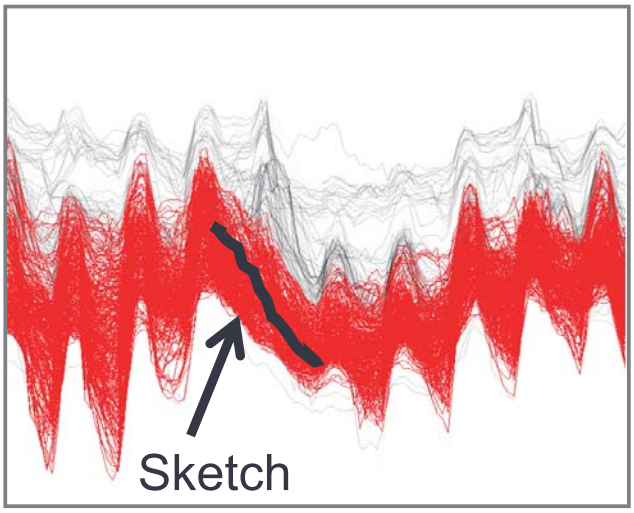
1) Ascended in daytime, and descended in night

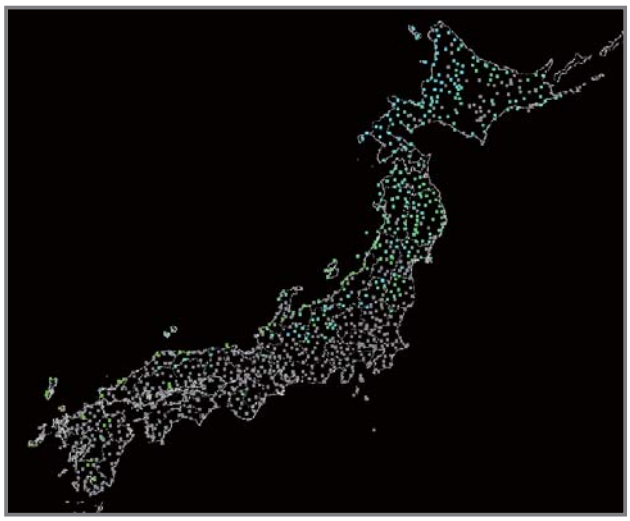
2) Not Ascended in daytime, but just descended

This document is provided by JAXA.

APPLICATION TO WEATHER DATA

- Sketched polylines simply descended
- Highlighted corresponding points on the Japan map



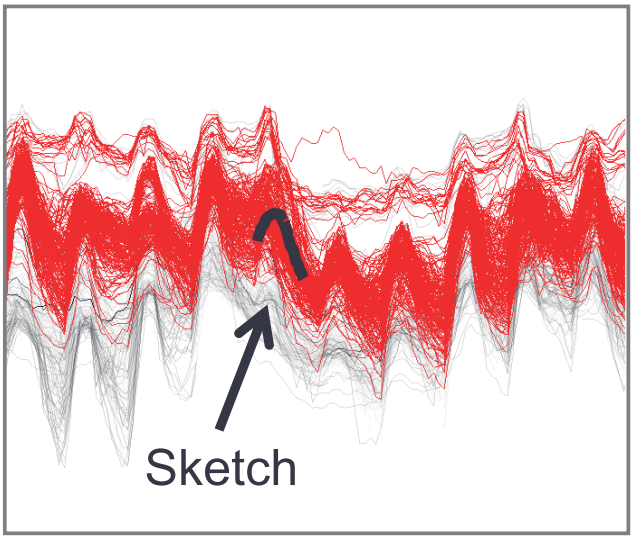


Weather did not ascend in daytime

Bad weather along Japan Sea

APPLICATION TO WEATHER DATA

- Sketched polylines ascended in daytime
- Highlighted corresponding points on the Japan map



Temperature ascended in daytime

Fine weather along Pacific Ocean

This document is provided by JAXA.

SUMMARY & FUTURE WORKS

- Summary: FRUITS Time
  - A polyline-based time-varying data visualization
  - [Feature 1] LOD Control of polylines
  - [Feature 2] Sketch-based query & partial resetting of LOD
- Future works
  - More case study with real data
  - User evaluation
  - Coordinate view with other visualization techniques
    - Volume visualization? Multi-dimensional visualization?
  - Improvement of clustering process
  - 3D techniques
  - Scalability test

Towards integrated EFD/CFD visualization

- Real space
  - Integrated **EFD-scalar and CFD-vector** visualization
  - Integrated **EFD-vector and CFD-scalar** visualization
  - **Difference-based** visualization between EFD/CFD
- Time space
  - **Similarity/Difference-based** visualization mixing EFD and CFD
  - Sketch interface **from EFD to CFD**
  - Sketch interface **from CFD to EFD**

ItoLab.

This document is provided by JAXA.

ItoLab.

Conclusion

- Introduction of Itoh lab.
- Topic 1 (Real space):
  Integrated scalar & vector visualization
- Topic 2 (Time space):
  LoD-control for polyline charts
- Towards integrated EFD/CFD visualization

ItoLab.

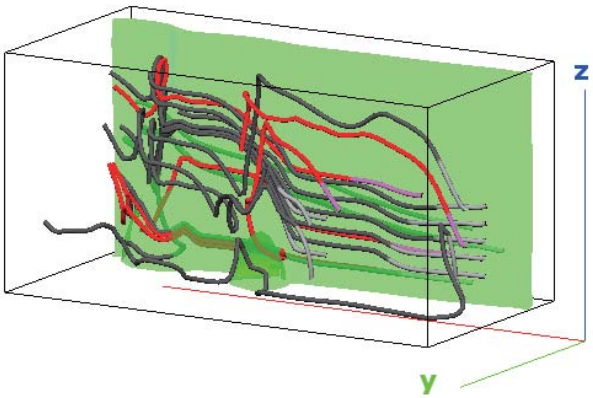
Future works

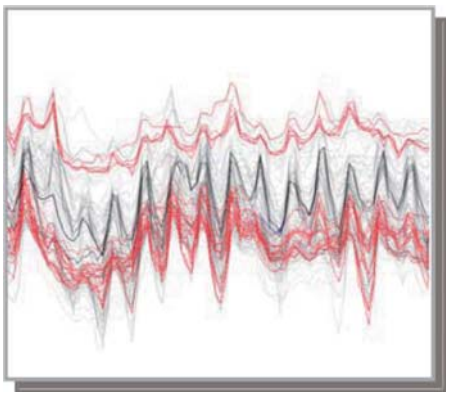
- Train successors!!
  - Both works are done by graduating M2 students
- More test cases
- More experiments with EFD
- Scalable algorithm development
  - Our test data is very small
- “Really” integrated system development
  - Real, time, and other visualization techniques
  - EFD, CFD, and other data sources

This document is provided by JAXA.

ItoLab.

Thanks you, and any questions?





This document is provided by JAXA.