

Expressive Flow Field Exploration

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Outline

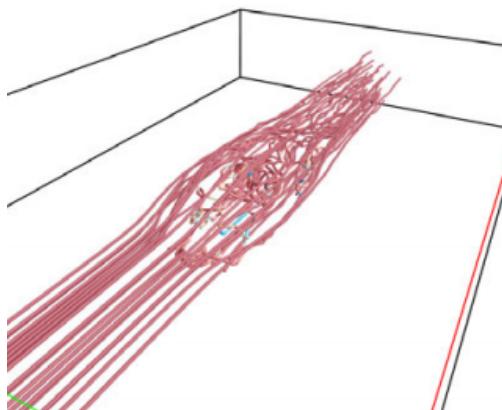
- Motivation
 - Example: a unified approach to streamline and viewpoint selection
 - A traditional streamline selection approach
- Interactive Exploration
 - Example 1: a deformation framework
 - An approach that directly interacts with flow fields
 - Example 2: FlowString
 - An interface composed of patterns in flow fields
 - Example 3: FlowGraph
 - An abstract representation of flow fields
- Conclusion

Motivation

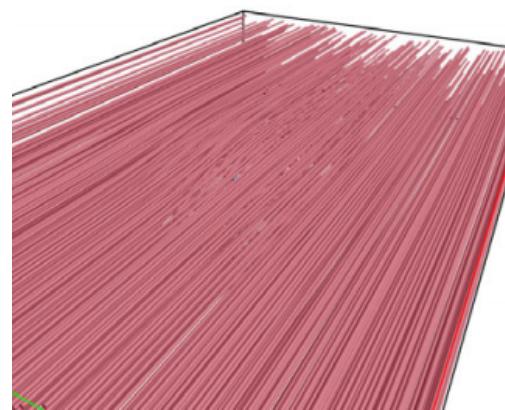
- Traditional streamline visualization
 - Seed placement
 - Streamline selection
- Example: A Unified Approach to **Streamline Selection** and **Viewpoint Selection** for 3D Flow Visualization [5]
 - Solve these two problems simultaneously by building **information channels** between them
- Limitations
 - Why this is not enough?

Example: a unified approach to streamline and viewpoint selection

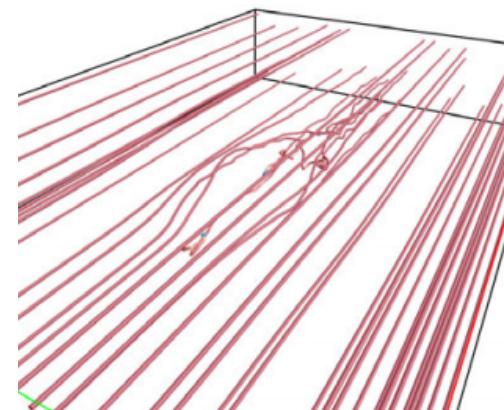
- Streamline selection
 - Different regions require different densities



Appropriate



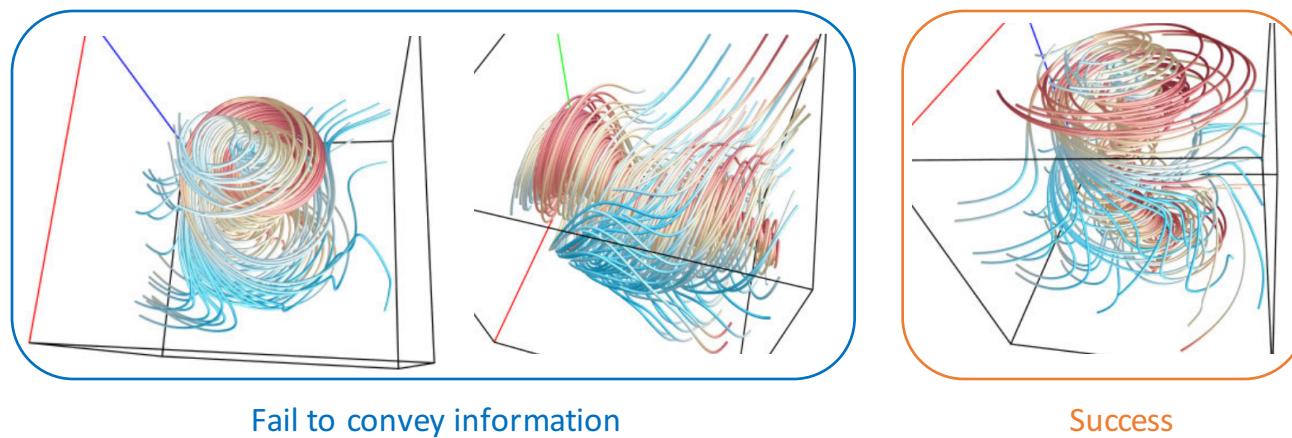
Too dense



Too sparse

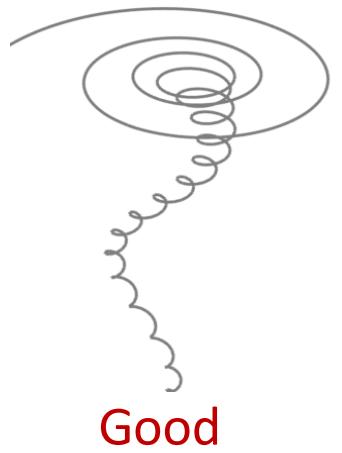
Example: a unified approach to streamline and viewpoint selection

- Viewpoint selection
 - Streamlines need to be observed under appropriate viewpoints

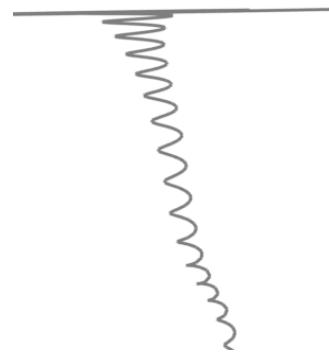


Building connections

- Evaluate the goodness of a streamline under a viewpoint
 - Using **mutual information** between the 3D streamline and its 2D projection
 - Favor informative streamlines under appropriate viewpoint



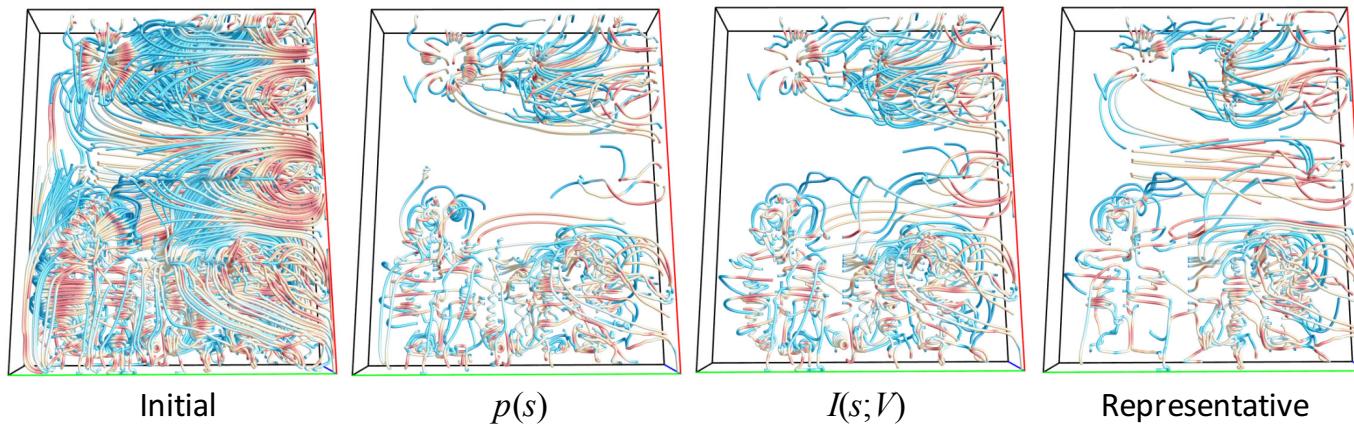
Good



Bad

Results

- Streamline selection based on different criteria



Limitations

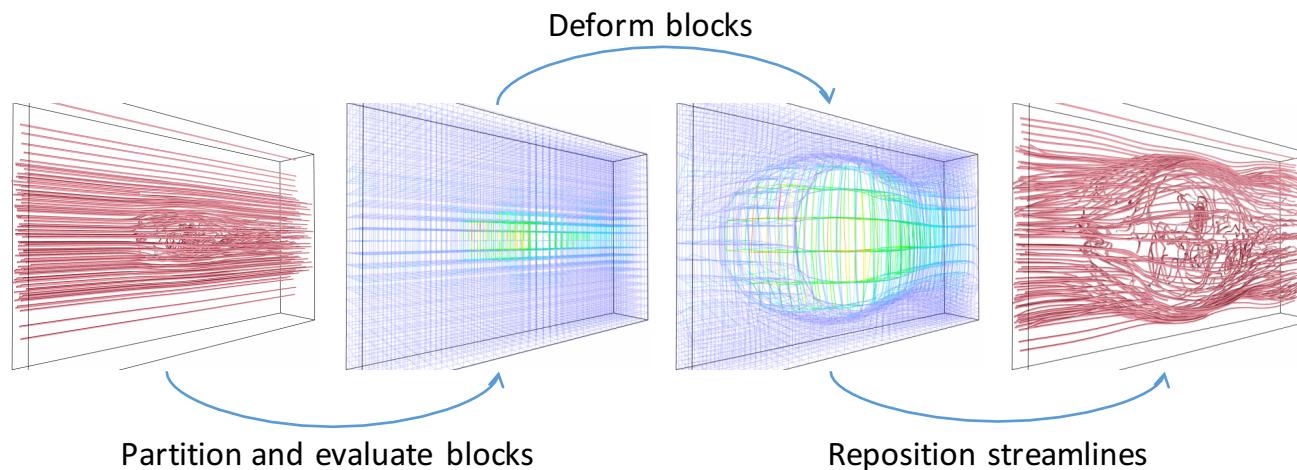
- Lack of discrimination power
 - Mutual information does not distinguish different types of features
- Lack of customization
 - No interaction is involved
- Manipulation granularity
 - A streamline is either displayed or completely ignored

Interactive Exploration: Example 1

- A Deformation Framework for Focus+Context Flow Visualization [4]
 - Flow features can be small
 - Need to magnify those regions
 - Cannot be solved by streamline selection
 - Flow features can be occluded
 - Need to remove occlusion
 - Partially solved by streamline selection
 - Streamlines might pass regions of different importance
 - Streamline selection cannot control the densities of different regions independently

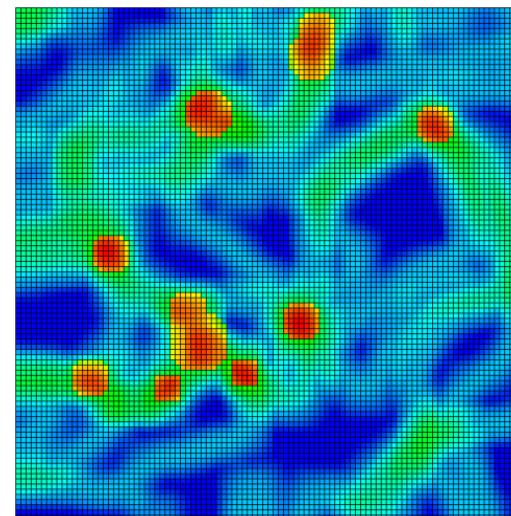
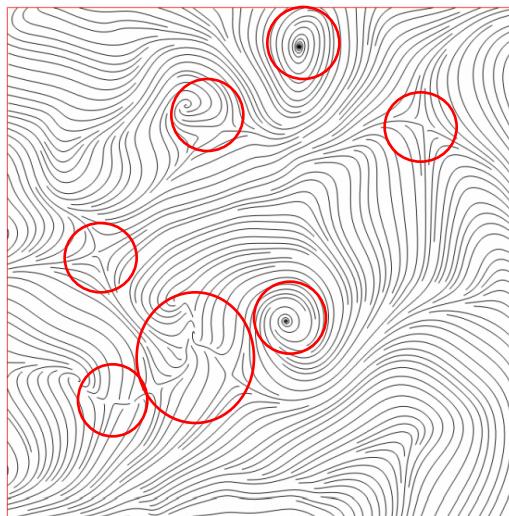
Overview

- Uniformly **partition** the volume into blocks
- **Evaluate** the importance of each block
- **Deform** blocks according to their importance
- **Reposition** streamlines



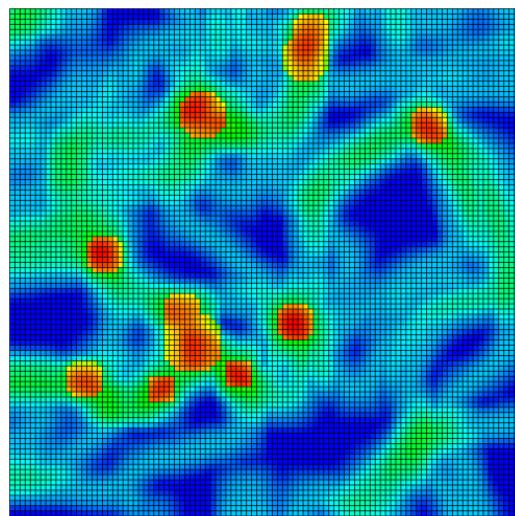
Importance evaluation (1/9)

- Automatic importance evaluation
 - Using [entropy](#) considering both vector direction and magnitude

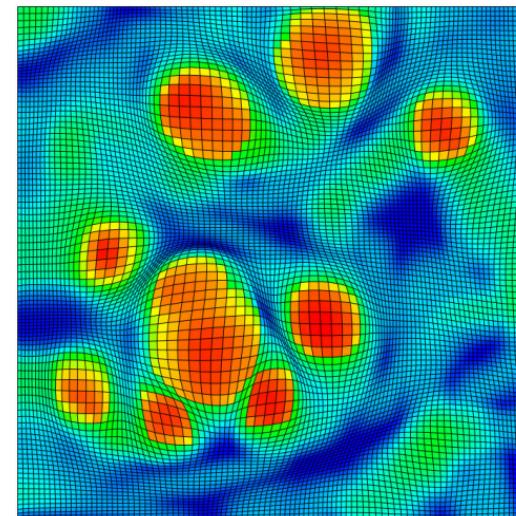


Importance evaluation (2/9)

- Automatic importance evaluation
 - Grid deformation



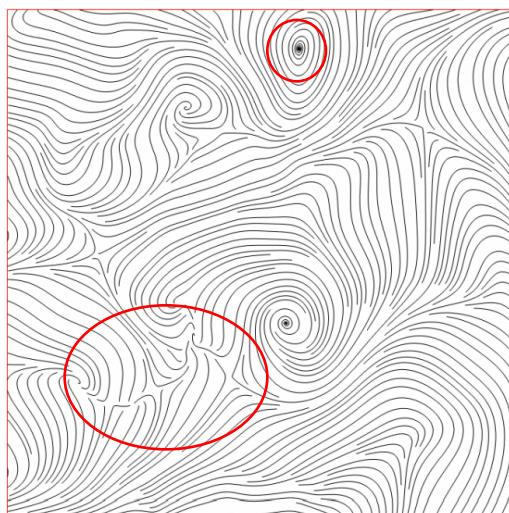
Original



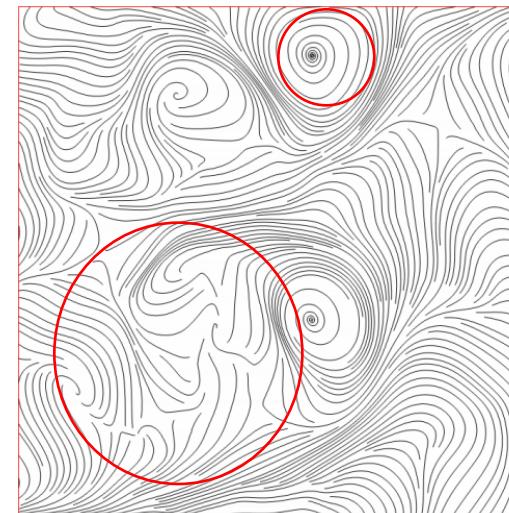
Deformed

Importance evaluation (3/9)

- Automatic importance evaluation
 - Streamline reposition



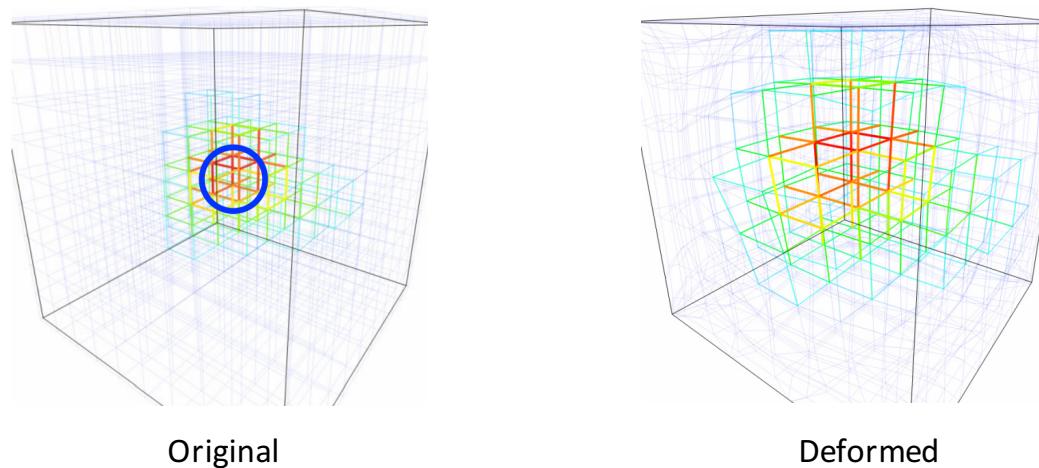
Original



Deformed

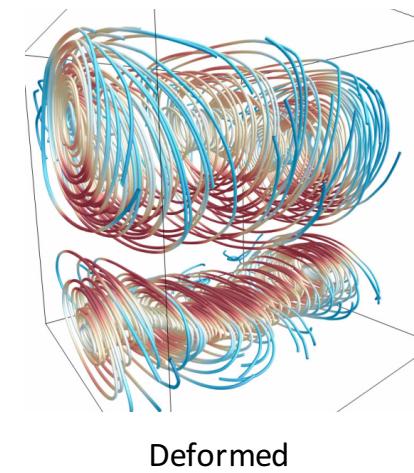
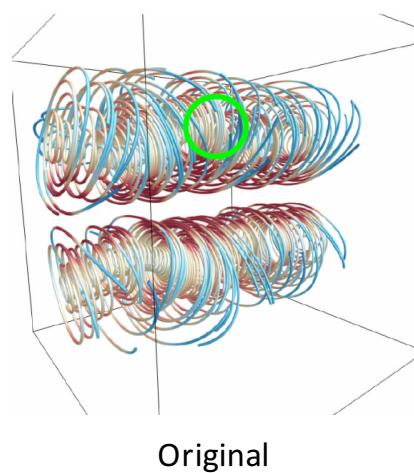
Importance evaluation (4/9)

- User-specified importance: **spherical block focus**
 - Highest importance value at focus block
 - Decrease gradually for blocks further away



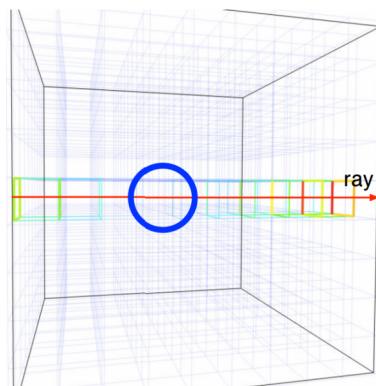
Importance evaluation (5/9)

- User-specified importance: **spherical block focus**
 - Highest importance value at focus block
 - Decrease gradually for blocks further away

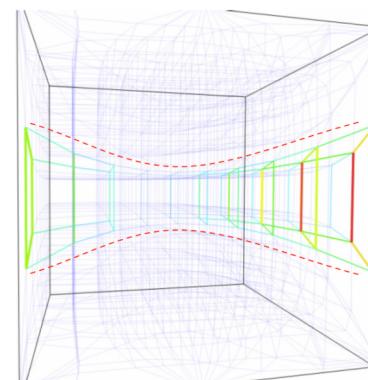


Importance evaluation (6/9)

- User-specified importance: **hourglass block focus**
 - Lowest importance value at focus
 - High importance values for blocks in front and behind



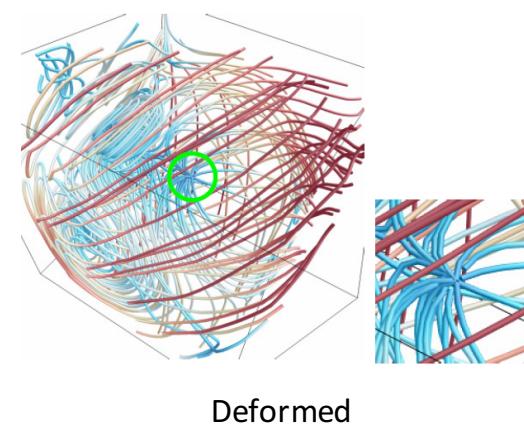
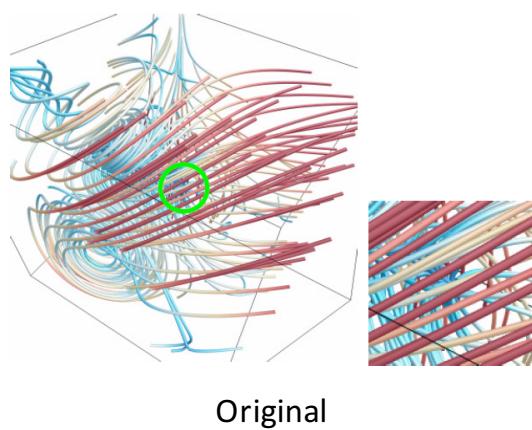
Original



Deformed

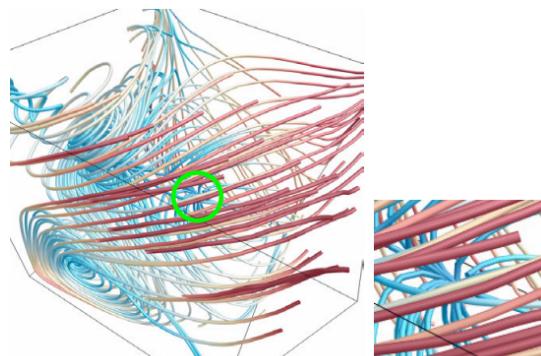
Importance evaluation (7/9)

- User-specified importance: **hourglass block focus**
 - Lowest importance value at focus block
 - High importance values for blocks in front and behind

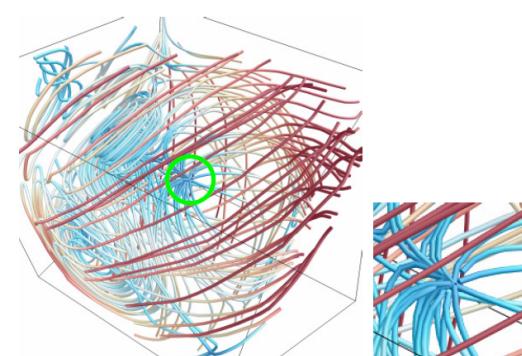


Importance evaluation (8/9)

- User-specified importance: **hourglass block focus**
 - Lowest importance value at focus block
 - High importance values for blocks in front and behind



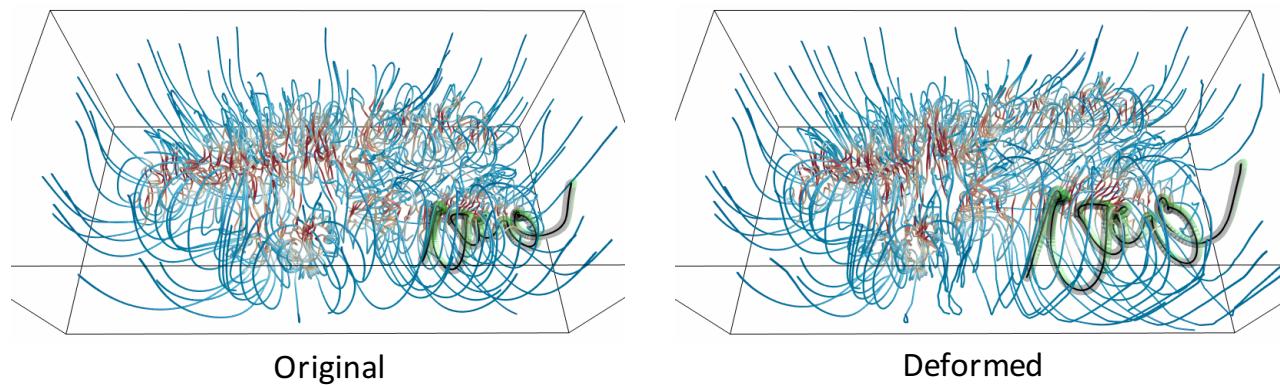
Spherical block focus



Hourglass block focus

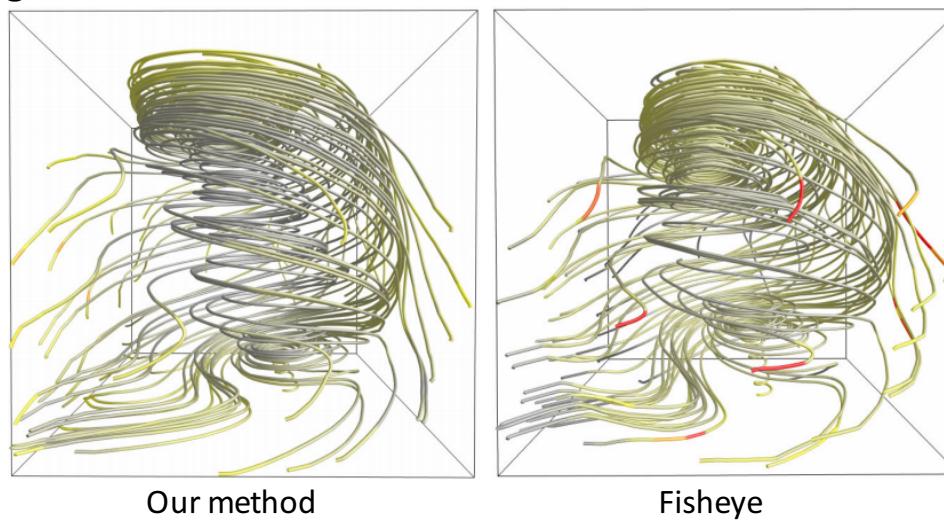
Importance evaluation (9/9)

- User-specified importance: **streamline focus**
 - High importance values for blocks passed by the focus streamline
 - Low importance values for other blocks
 - The same template can be applied on a user-drawn path



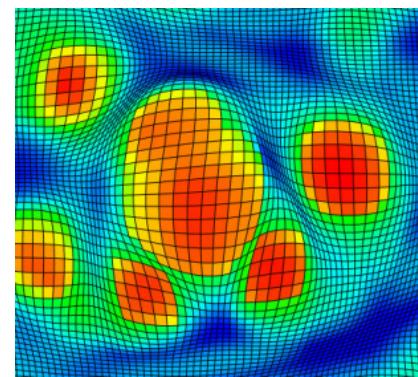
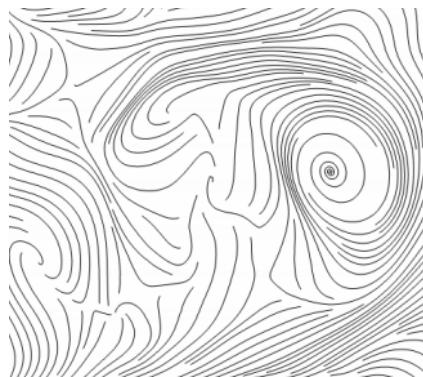
Comparison with fisheye view

- Our deformation framework
 - The **entire space** is used to absorb the distortion
- Fisheye view
 - The distortion is gathered around the **boundary** of the focal region



Discussion

- Users may be interested in different flow patterns
 - Entropy cannot distinguish them
 - Both the spiral and saddles are magnified
- Users may not be aware of the locations of the regions of interest
- Users may not even know what patterns exist in a flow field

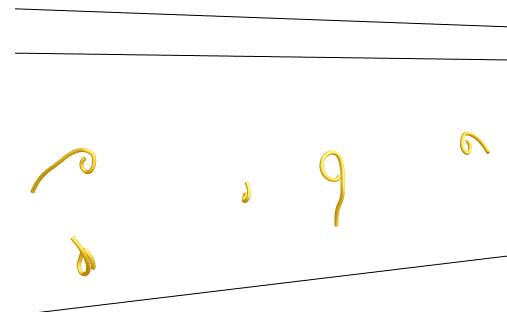
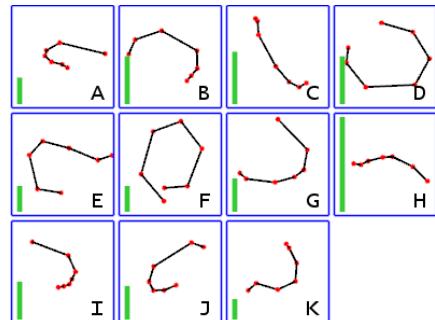


Interactive Exploration: Example 2

- A Vocabulary Approach to Partial Streamline Matching and Exploratory Flow Visualization (FlowString) [1,3]
 - Principal pattern discovery
 - What are the most common flow pattern in a flow field
 - Where are they
 - Query of a specific pattern
 - Partial streamline matching

A Vocabulary Approach

- We encode the streamlines into strings
 - Each **character** represents a **basic shape**
 - Shapes can be queried in a **textual searching manner**
 - A is a hook-like pattern and F is a spiral
 - AF matches a spiral connects to a hook



Overview

- Notation
 - **Character**: a shape primitive
 - **Alphabet**: a set of characters
 - **Word**: a frequently appear pattern (substring)
 - **Vocabulary**: a set of words
- Alphabet generation
 - Resample streamline
 - Cluster similar local shapes of sample points
- Encoding
 - Assign characters to sample points
- String query
 - Use suffix tree for efficiency
 - Support both exact and approximate search

Interface

Streamline query

Query result

Streamline set

Alphabet and vocabulary

Query string

Textual

Visual

Parameters

k-Approx: 0

Frequency: 100

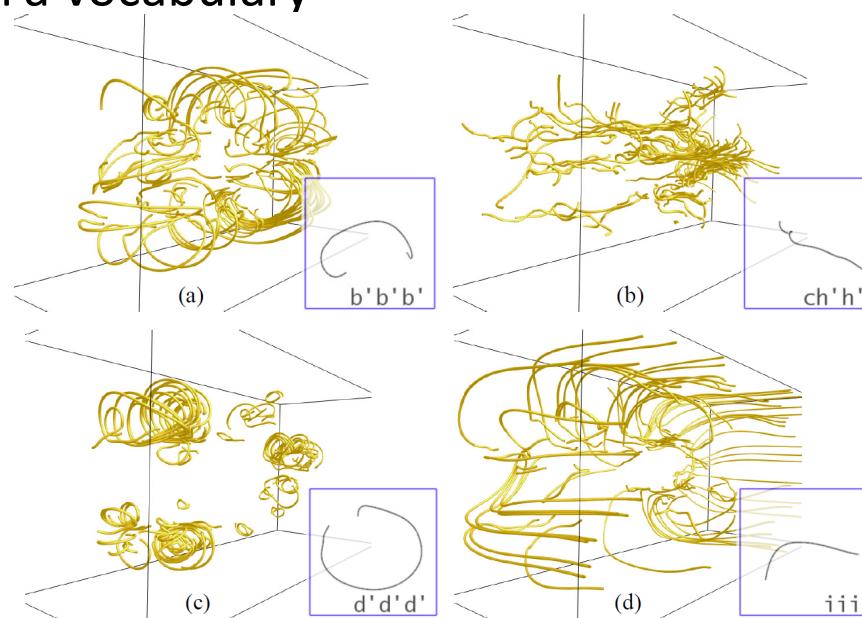
Length: 3

Auto-add +: 0

Prefer User Alphabet

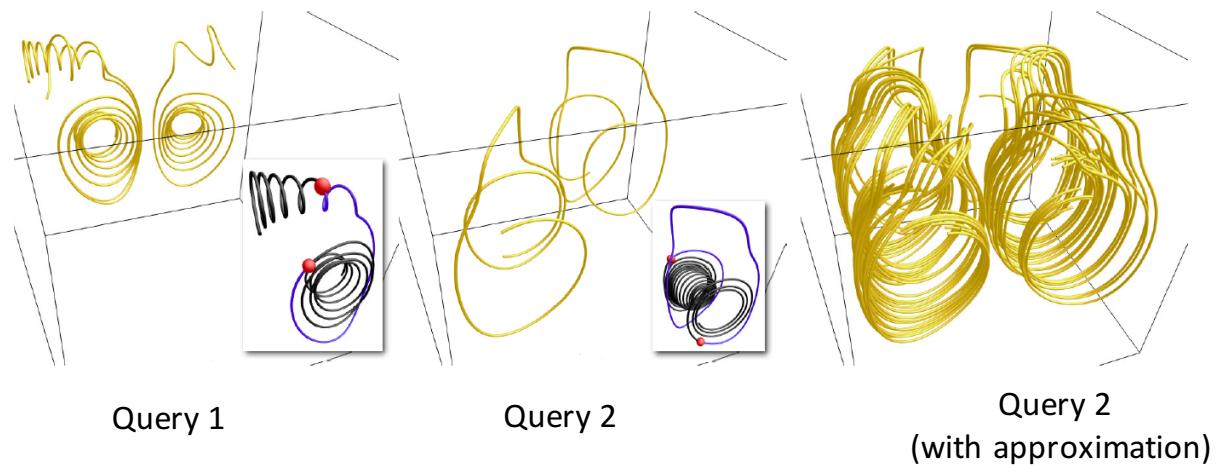
Results (1/3)

- Four words in a vocabulary



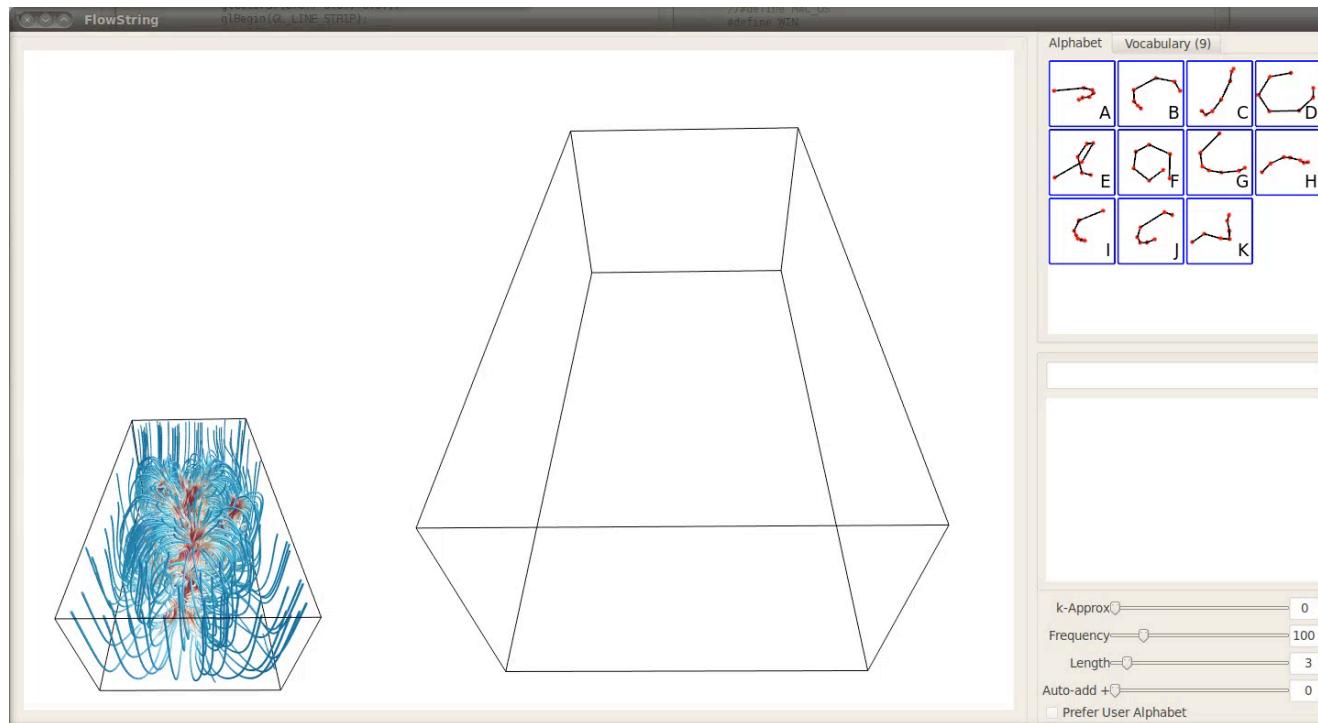
Results (2/3)

- Query of a user-selected streamline segment



Results (3/3)

- Interaction

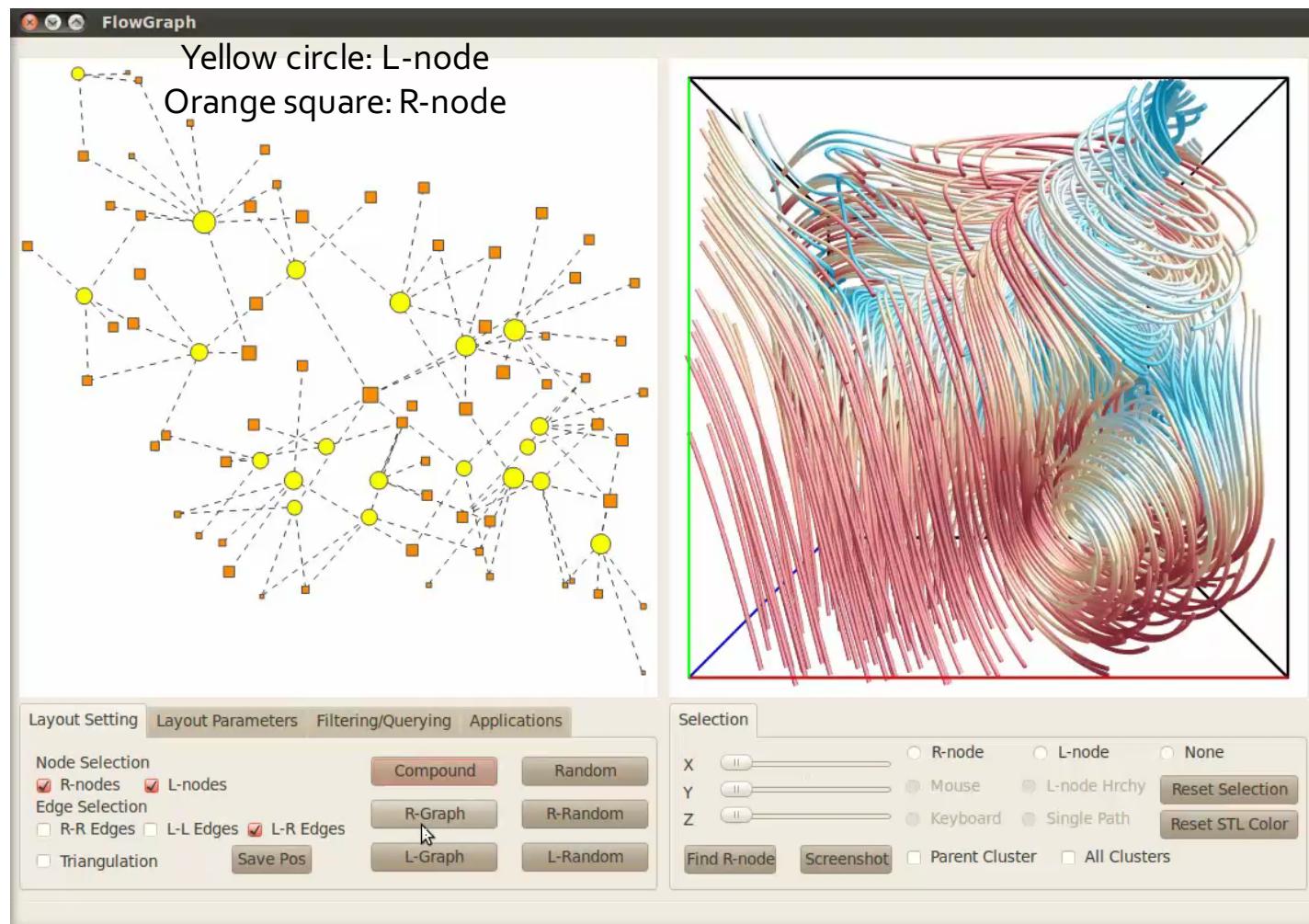


Discussion

- Support queries of specific patterns
- Only distinguish streamline segments with different shapes
 - Other attributes are missing
- Lack of context
 - Only matched streamline segments are displayed

Interactive Exploration: Example 3

- A Graph-Based Interface for Visual Analytics of 3D Streamlines and Pathlines [2,6]
 - A *compound* graph representation
 - Allow full exploration of streamline clusters, spatial regions and their interconnections



FlowGraph definition (1/2)

- Two kinds of nodes
 - **R-nodes (spatial regions)** 
 - Spatial regions partitioned in an octree manner
 - Stop the **top-down** partitioning if the flow entropy is smaller than a given threshold
- **L-nodes (streamline clusters)** 
 - Streamline clusters organized hierarchically
 - Group spatially neighboring and geometrically similar streamlines in a **bottom-up** manner

FlowGraph definition (2/2)

- Three kinds of weighted edges

- **R-R edges**



- Record the number of common streamlines shared between two R-nodes

- **L-L edges**



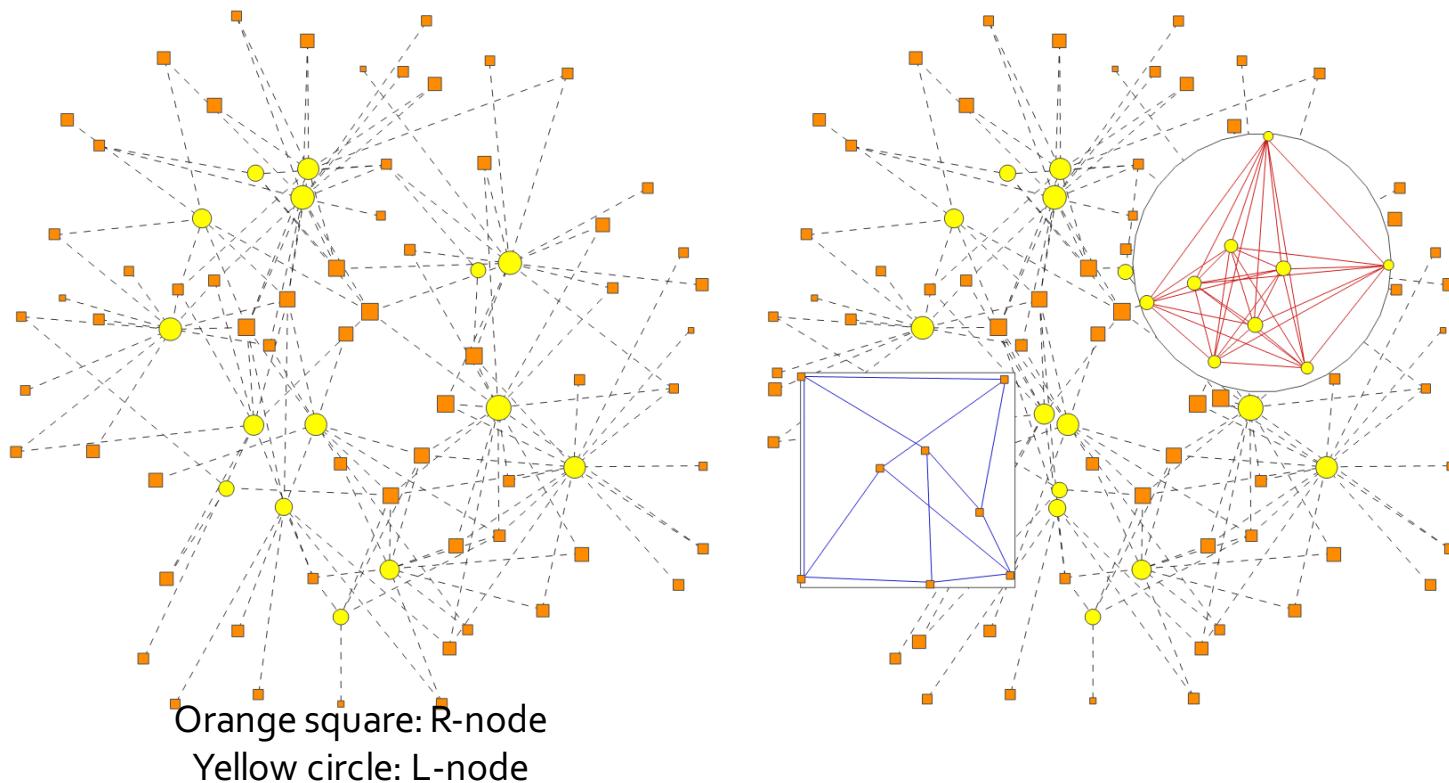
- Record the number of common leaf-level regions traversed in order between two L-nodes

- **L-R edges**



- Record the number of streamlines in the L-node passing through the R-node between an L-node and an R-node

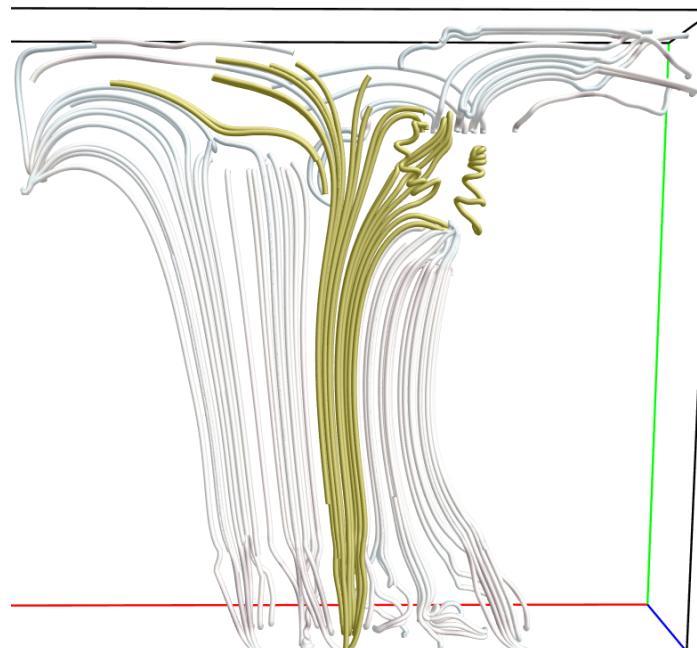
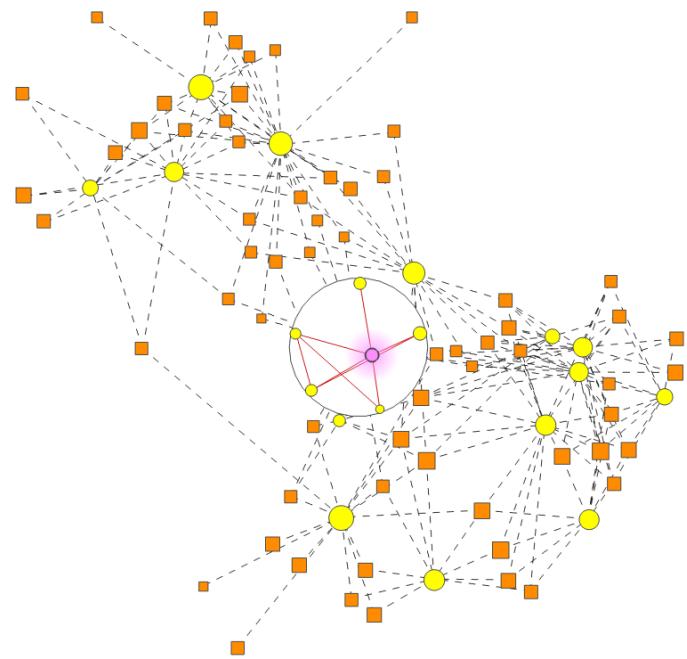
FlowGraph drawing

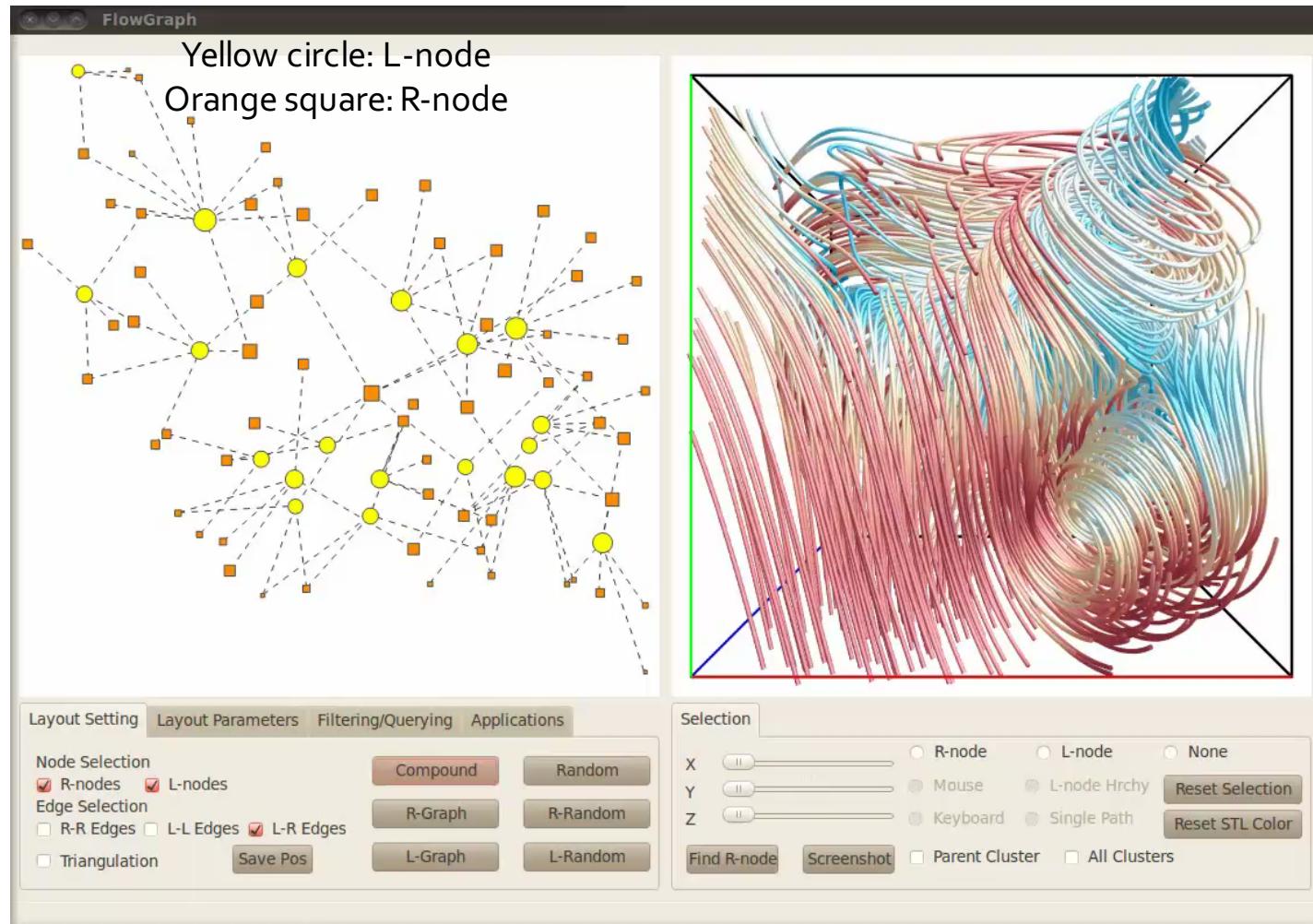


FlowGraph exploration

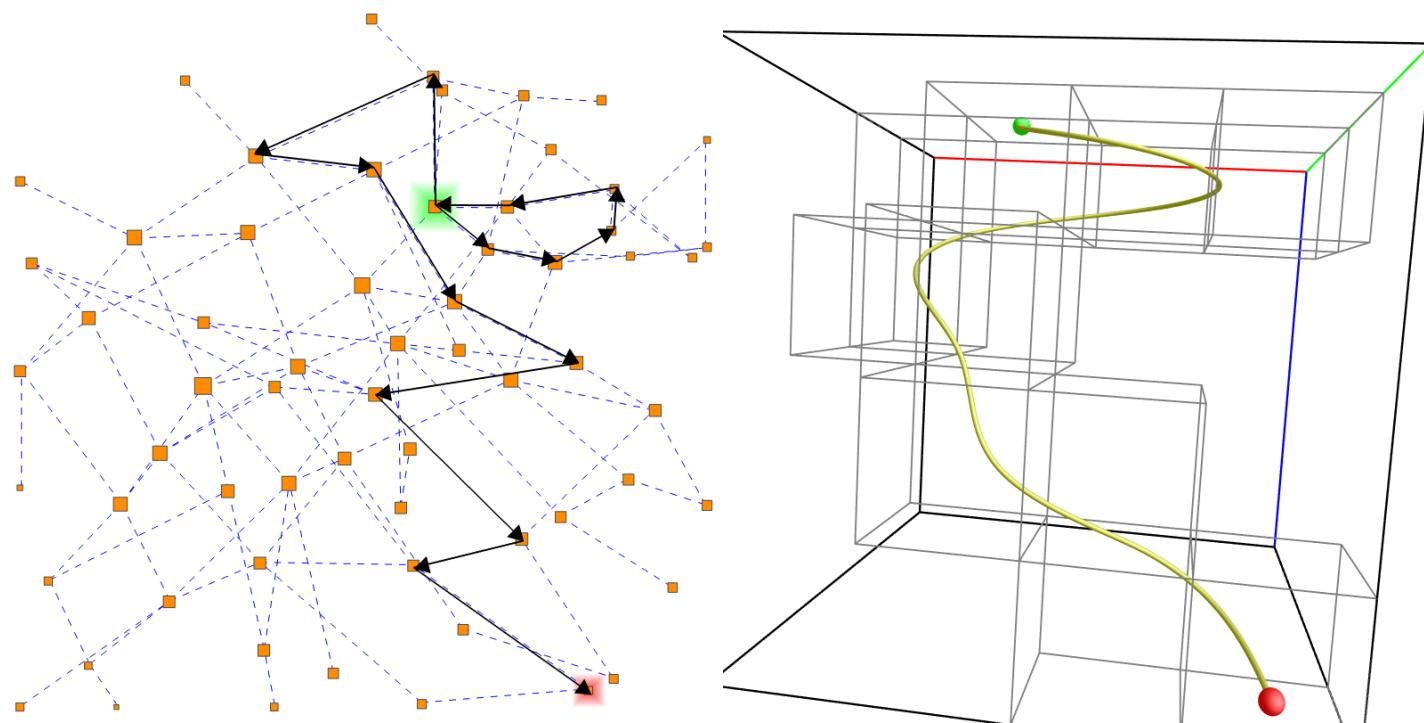
- Standard exploration
 - Hierarchical exploration
 - Brushing and linking
 - Filtering and querying
- Specific to FlowGraph
 - Path comparison
 - Region comparison
 - Graph transition
 - Path illustration

Expanding L-node

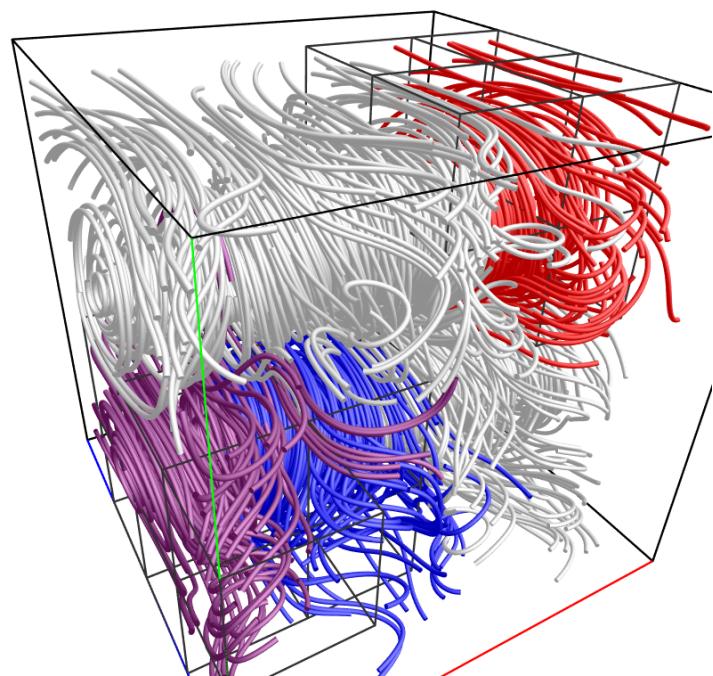
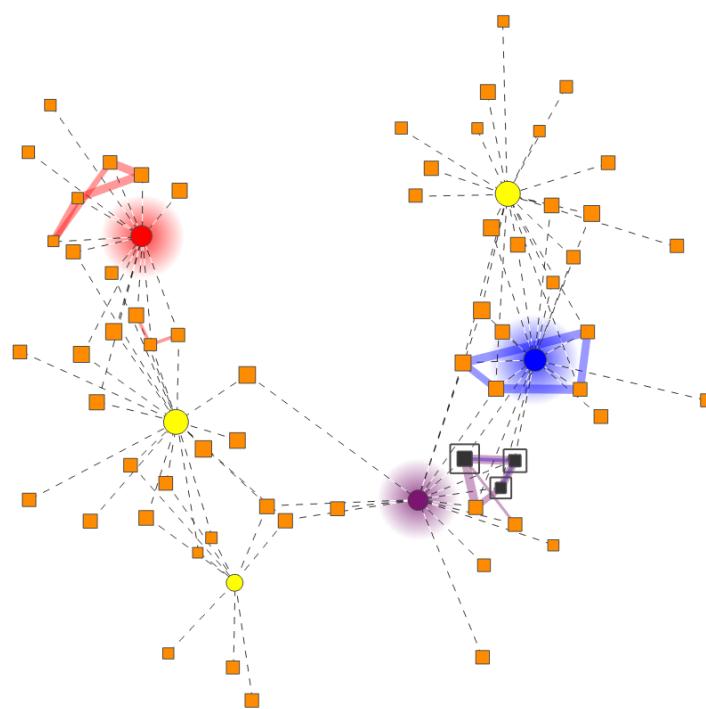


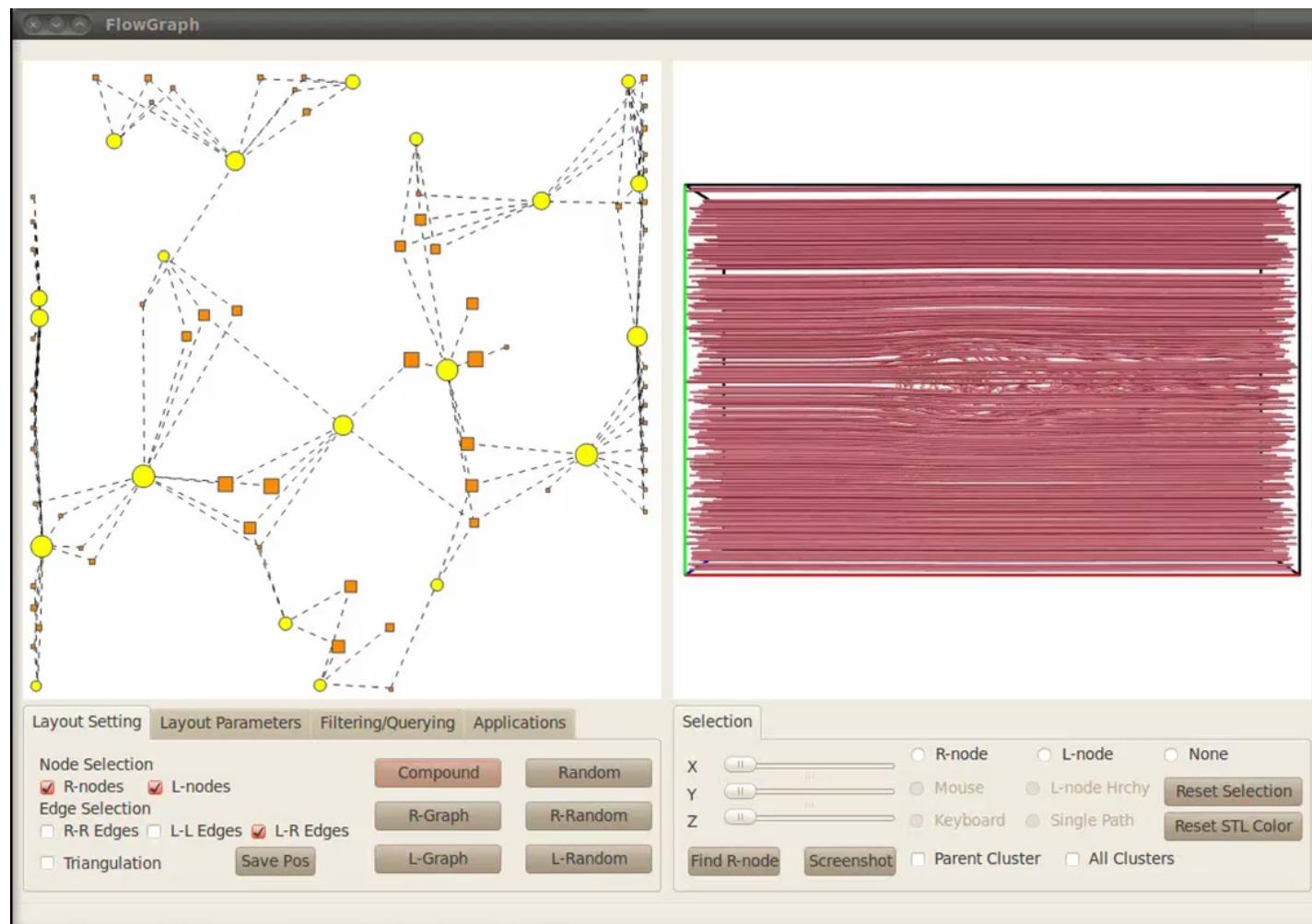


Path illustration



Path comparison





Discussion

- Build connections between streamline clusters and spatial regions
- Some trial-and-error effort is needed
 - Users need to brush the graph to identify a certain type of feature

Conclusion

- Interactive techniques open new pathways to explore flow fields
 - Provide customized visualization results
 - Specify what to display and how to display
 - Allow features to be manually discovered
- Relation to automatic feature detection and classification
 - Interactions allows features to be displayed in a user-specific way
 - Automatic detection provides input to the interactions

Reference

- [1] Jun Tao, Chaoli Wang, Ching-Kuang Shene, and Raymond A. Shaw. A Vocabulary Approach to Partial Streamline Matching and Exploratory Flow Visualization. *IEEE Transactions on Visualization and Computer Graphics*, 22(5):1503-1516, May 2016.
- [2] Jun Ma, Chaoli Wang, Ching-Kuang Shene, and Jingfeng Jiang. A Graph-Based Interface for Visual Analytics of 3D Streamlines and Pathlines. *IEEE Transactions on Visualization and Computer Graphics*, 20(8):1127-1140, Aug 2014.
- [3] Jun Tao, Chaoli Wang, and Ching-Kuang Shene. FlowString: Partial Streamline Matching Using Shape Invariant Similarity Measure for Exploratory Flow Visualization. *Proceedings of IEEE Pacific Visualization Symposium*, Yokohama, Japan, pages 9-16, Mar 2014.
- [4] Jun Tao, Chaoli Wang, Ching-Kuang Shene, and Seung Hyun Kim. A Deformation Framework for Focus+Context Flow Visualization. *IEEE Transactions on Visualization and Computer Graphics*, 20(1):42-55, Jan 2014.
- [5] Jun Tao, Jun Ma, Chaoli Wang, and Ching-Kuang Shene. A Unified Approach to Streamline Selection and Viewpoint Selection for 3D Flow Visualization. *IEEE Transactions on Visualization and Computer Graphics*, 19(3):393-406, Mar 2013.
- [6] Jun Ma, Chaoli Wang, and Ching-Kuang Shene. FlowGraph: A Compound Hierarchical Graph for Flow Field Exploration. *Proceedings of IEEE Pacific Visualization Symposium*, Sydney, Australia, pages 233-240, Feb 2013.

Questions?