# Parallel Computation Of 2D Morse-Smale Complexes

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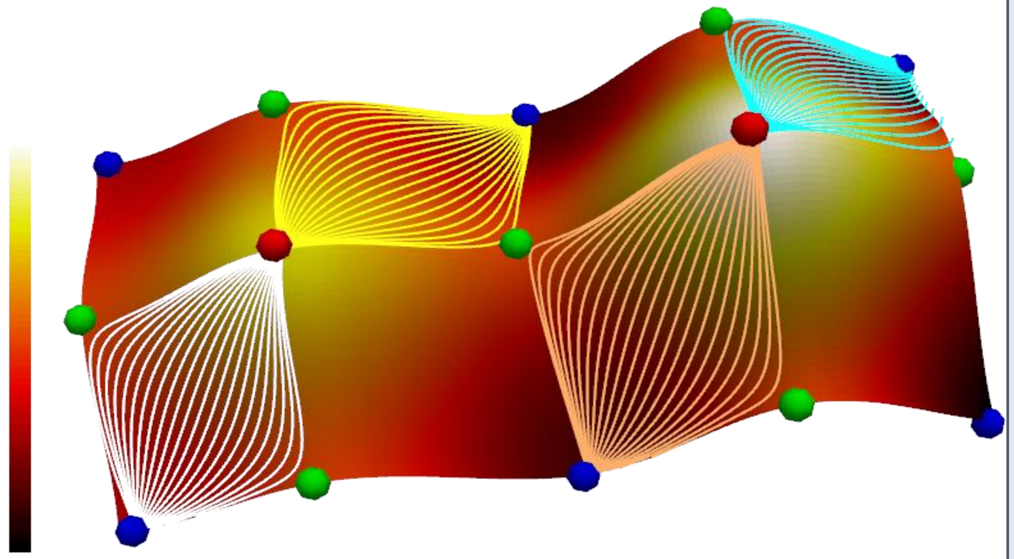
## Objective

Parallel computation of the Morse-Smale complex designed for multi-core and GPU environments.

Computation for datasets that don't fit in Memory.

## The Morse-Smale Complex

**Input:** Scalar (real valued) function Example: 2D plane→ sin(x)+sin(y).



**Gradient curves:** Curves that trace the direction of steepest descent

**Critical Points:** Points of origin/destination of gradient curves

**Morse-Smale complex:** Partition based on origin/destination of gradient curves.

### Reference

Shivashankar, N. Maadaswamy, S. and Natarajan, V., Parallel Computation of 2D Morse-Smale Complexes, *IEEE Transactions on Visualization and Computer Graphics (To Appear).*

### Contact and Acknowledgements

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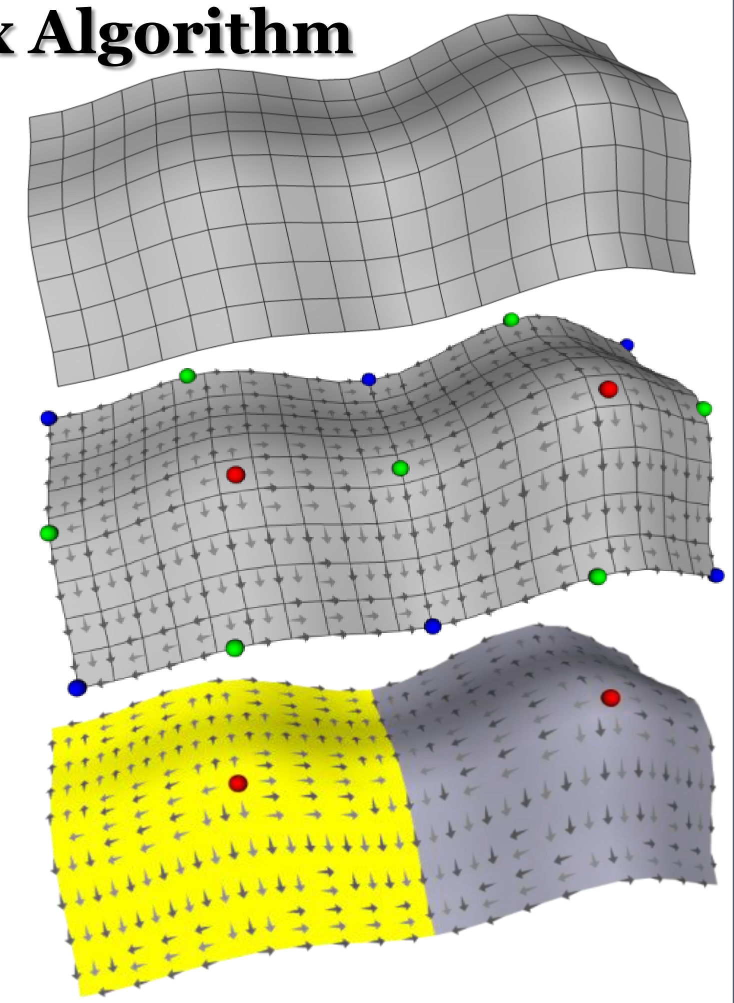
## Parallel Morse-Smale(MS) Complex Algorithm

**INPUT:** Domain as a Cell complex and a scalar function sampled at vertices.

1.Compute discrete gradient

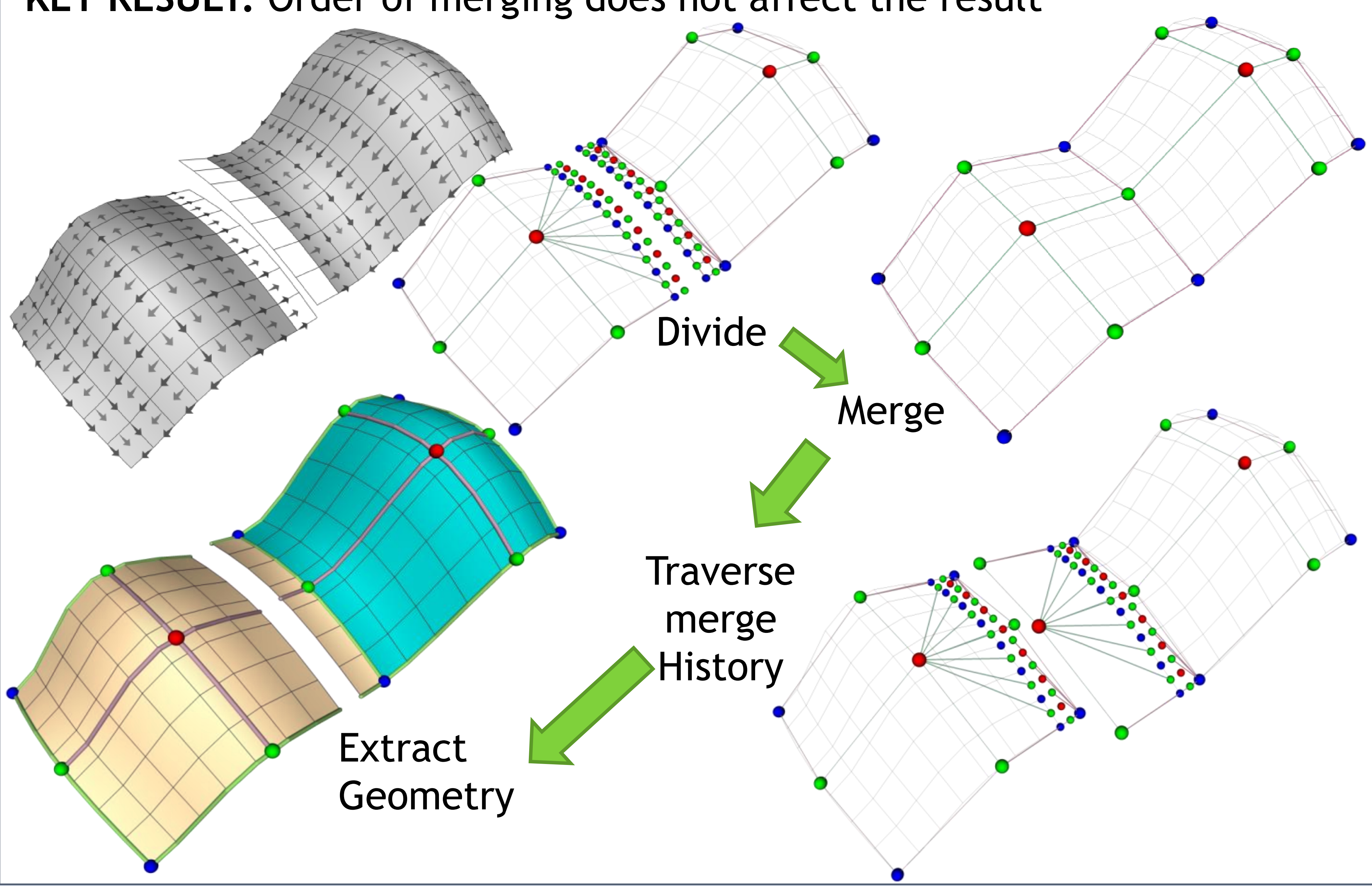
**KEY RESULT**: Computing discrete gradient is independent of order. Can be done in parallel.

2. Traverse the gradient field to compute the MS complex.



## Large Data: Divide and conquer.

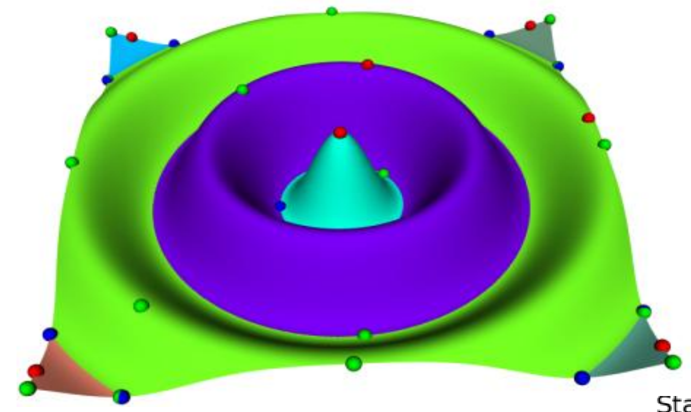
**KEY RESULT:** Order of merging does not affect the result




## Evaluation

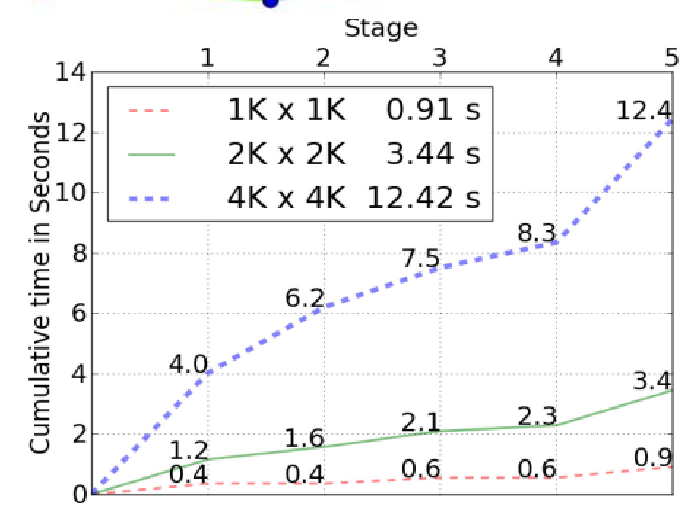
Experiments with synthetic and real world datasets on 2D grids.

Observed near linear scaling with data size and number of cores.

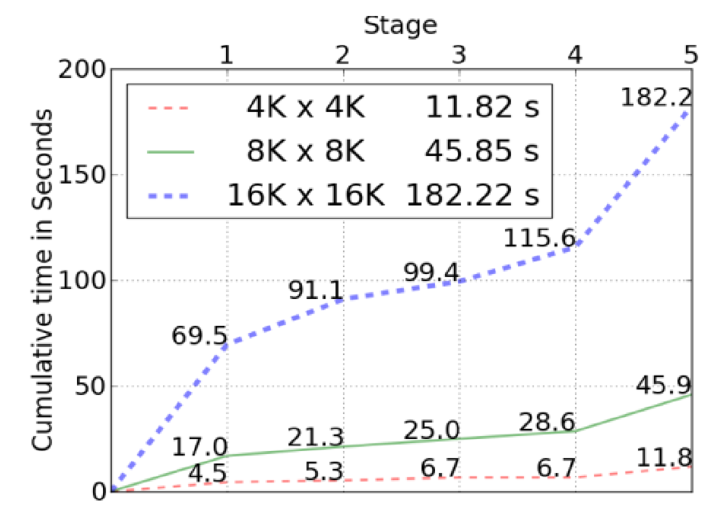


**WGAUSS dataset**

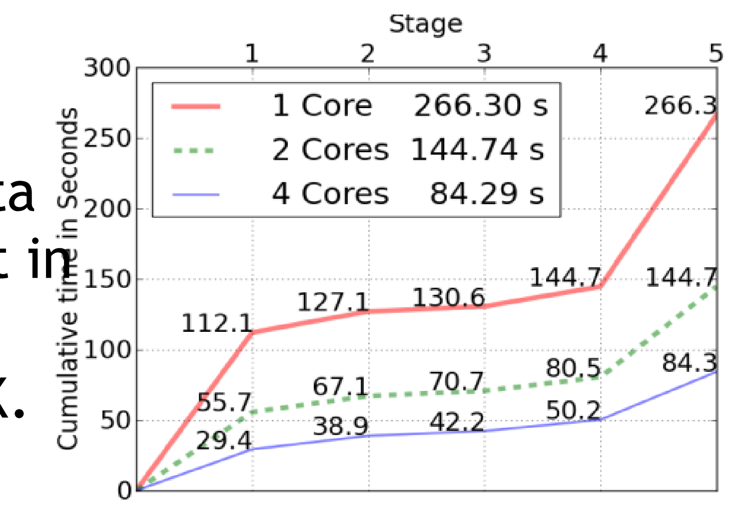
Data fits in CPU but not GPU




Data fits neither in CPU nor GPU.




Computed in CPU. Data does not fit in CPU. Size: 8Kx8K.



# Computing Reeb Graphs as a Union of Contour Trees

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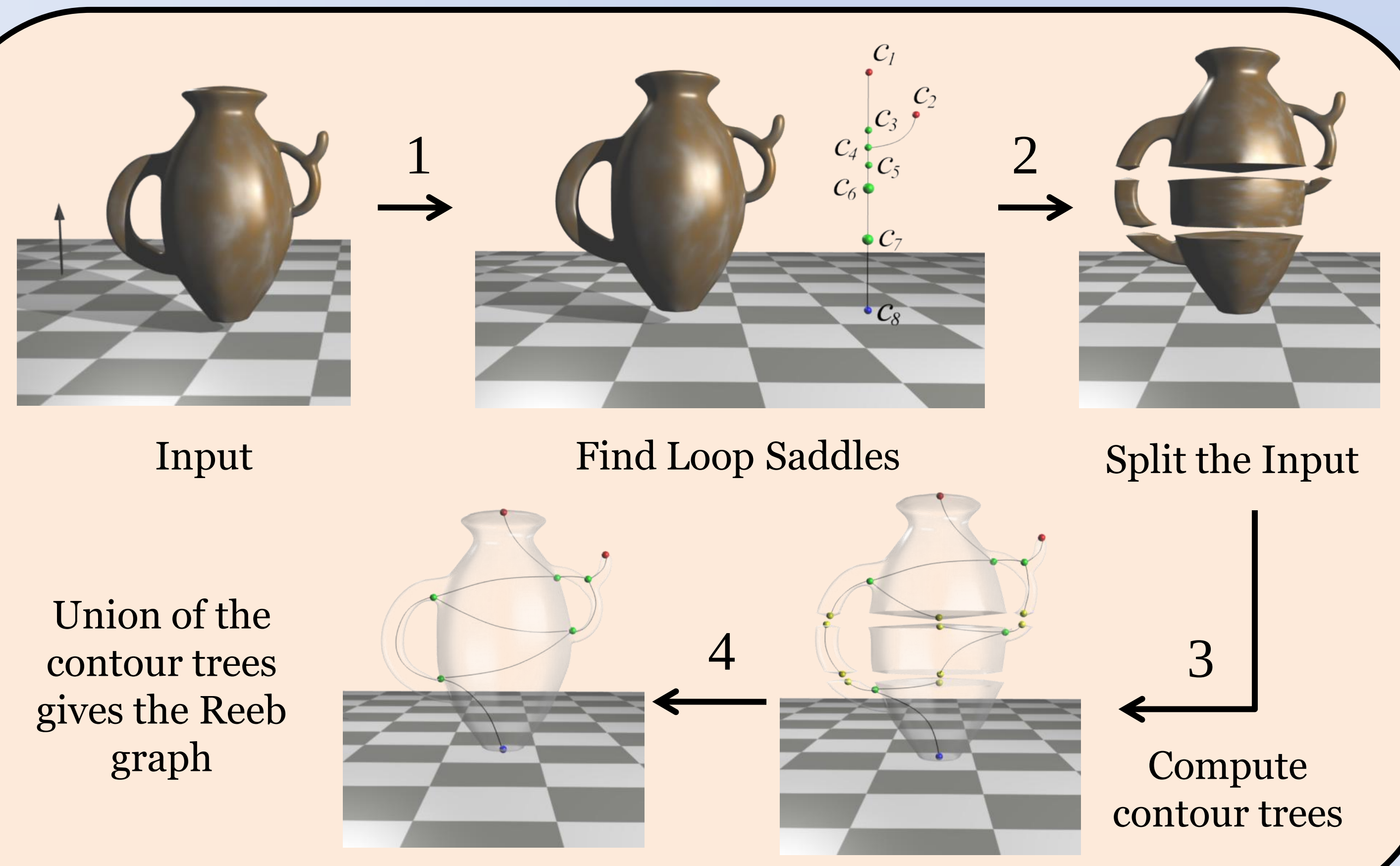
The Reeb graph of a scalar function is obtained by mapping each connected component of its level sets to a point

**Applications**
- Topology based shape matching. *Hilaga et al. SIGGRAPH 2001*
- Transfer function design. *Weber et al. TVCG 2007*
- User Interface. *Bajaj et al. Vis 1997*



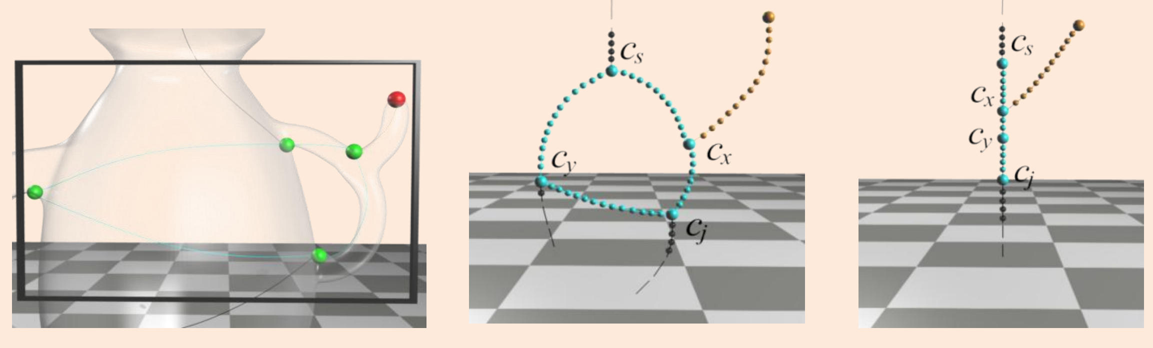

## The ReCon Algorithm

1. Identify the loop saddles of the input
2. Split the input at a function value infinitesimally above that of the loop saddles to obtain a set of simply connected interval volumes
3. Compute the contour trees for each interval volume
4. Construct the Reeb graph by computing the union of these contour trees

## Identifying Loop Saddles

***Lemma***

*Let $G_R$ be the Reeb graph of the given input scalar function **f**. Consider the join tree $T_J$ of **f**. Any join saddle that ends a loop in $G_R$ appears as a degree-2 node in $T_J$.*



Loop in the input Augmented Reeb graph Join Tree

## Properties

1. Efficient: has a running time of $O(n \log n + sn)$
   - $n$ - # triangles
   - $s$ - # saddles
2. Generic: works without any modifications on $d$-manifolds and non-manifolds
3. Easy to implement
4. Handles data that do not fit in memory
5. At least an order of magnitude faster than existing generic algorithms

## Performance for 3D Input

| 3D Model | # Triangles | # Loops | Time taken (sec) | | | |
|---|---|---|---|---|---|---|
| | | | ReCon | LS | OS | Rand |
| Skull | 0.34M | 2 | 0.1 | 0.3 | 3.4 | 2.2 |
| Post | 1.24M | 0 | 0.4 | 0.9 | 13.0 | 14.5 |
| Plasma | 2.64M | 0 | 1.5 | 1.9 | 396.3 | 132.6 |
| SF Earthquake | 4.19M | 0 | 2.4 | 2.8 | 598.1 | 166.9 |

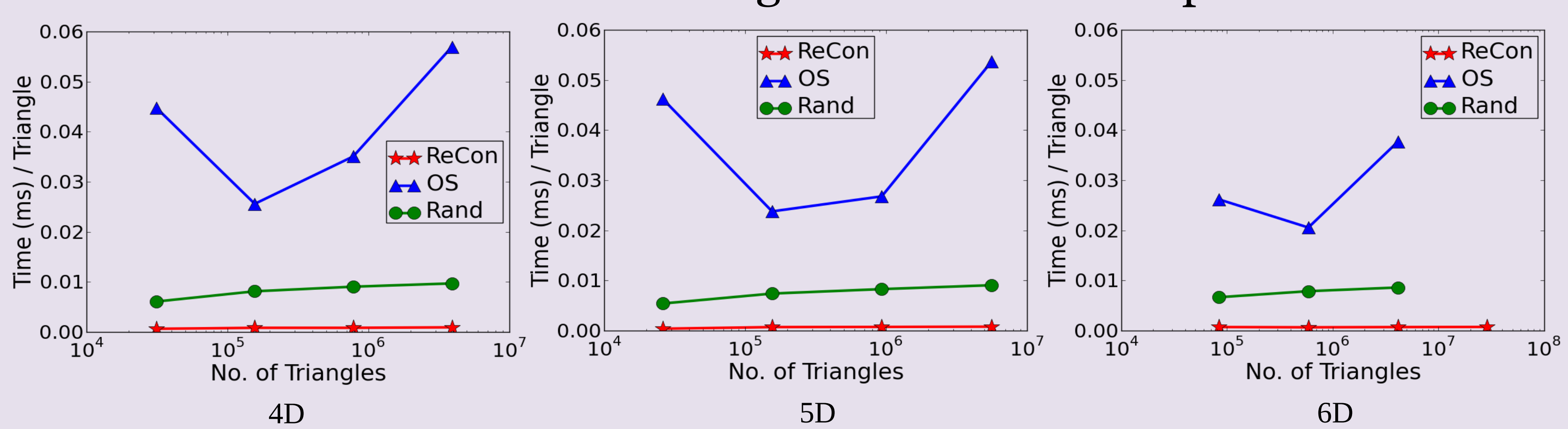
## Performance for 2D Input

| 2D Model | # Triangles | # Loops | Time taken (sec) | | | |
|---|---|---|---|---|---|---|
| | | | ReCon | Online | OS | Rand |
| Awakening | 4M | 1643 | 2.4 | 6.72 | 41.4 | 51.8 |
| Day | 6M | 2161 | 4.3 | 10.3 | 91.3 | 67.5 |
| Dawn | 6.6M | 757 | 4.5 | 11.5 | 73.2 | 71.8 |
| Lucy | 28M | 15 | 34.2 | 60.1 | *Mem* | *Mem* |

## Scalability with increasing loop size

| Model | # Triangles | # Loops | Time taken (sec) |
|---|---|---|---|
| s4d-7 | 0.78M | 1 X $10^5$ | 0.7 |
| s5d-6 | 0.93M | 1 X $10^5$ | 0.7 |
| s4d-8 | 3.9M | 5.8 X $10^5$ | 3.6 |
| s5d-7 | 5.6M | 5.6 X $10^5$ | 4.4 |
| s6d-6 | 4.1M | 2.9 X $10^5$ | 2.9 |
| Lucy | 28.0M | 15 | 34.2 |
| s6d-7 | 28.8M | 2 X $10^6$ | 21.2 |

## Performance for higher dimensional input




Input – 4D, 5D, and 6D Sierpinski simplexes of various sizes

## Handling Large data

| Model | # Triangles | Function | Time taken | |
|---|---|---|---|---|
| | | | ReCon | Online |
| David | 56M | x | 3.6 m | 4.7 m |
| | | y | 3.8 m | 4.8 m |
| | | z | 3.2 m | 16.6 m |
| St. Matthew | 372M | x | 26.9 m | 40 m |
| | | y | 26.7 m | 4.2 hrs |
| | | z | 25.2 m | 41 m |
| Atlas | 507M | x | 41.5 m | * |
| | | y | 38.5 m | * |
| | | z | 42.6 m | * |

## References

- Pascucci et al. *ACM Trans. Graph 2007* (Online)
- Doraiswamy et al. *IEEE TVCG 2011* (OS)
- Tierny et al. *IEEE TVCG 2009* (LS)
- Harvey et al. *SCG 2010* (Rand)

## Contact

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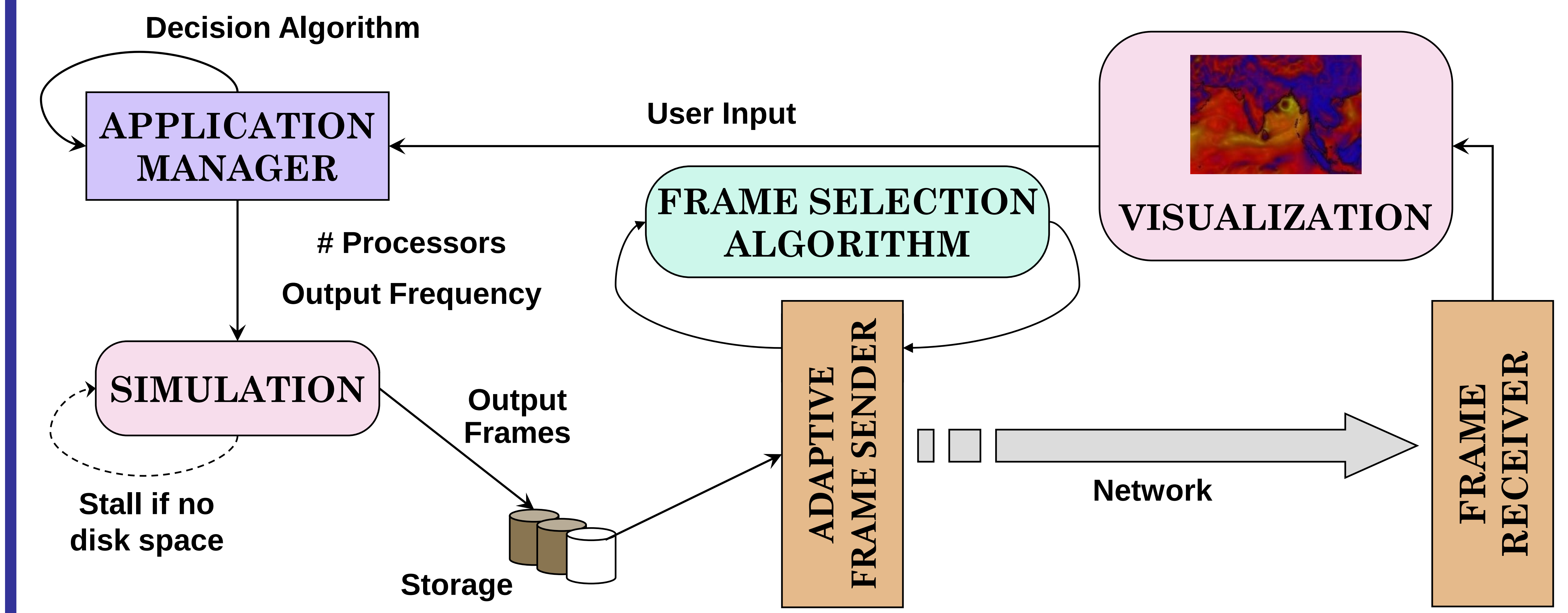
# Efficient Online Visualization and Simulations for Large-scale Applications

## Problem Statement

Develop an adaptive integrated steering framework that

- allows simultaneous simulation and online visualization
- spawns high-resolution simulation dynamically over desired region-of-interest
- supports optimal processor allocation for simulation
- supports optimal frequency of output for visualization

## Framework for Adaptive Simulation and Online Visualization




## Simulation-Visualization Lag

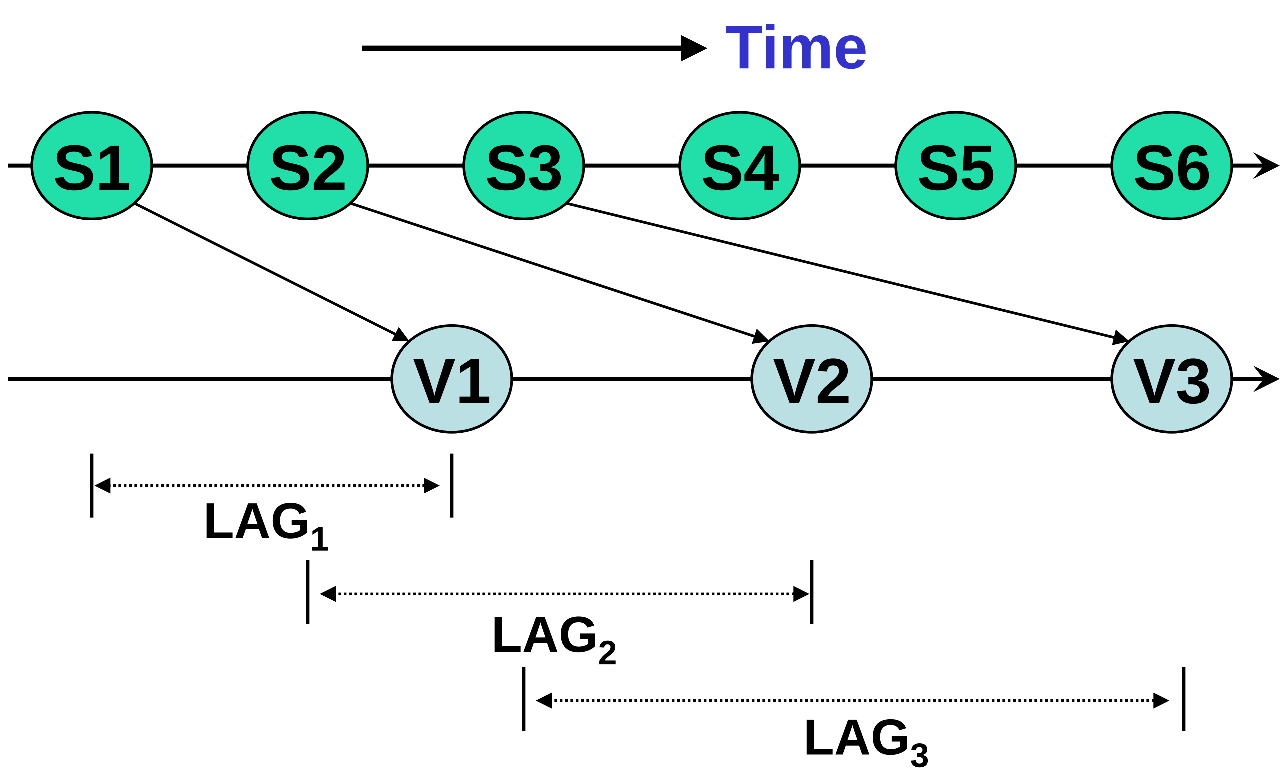
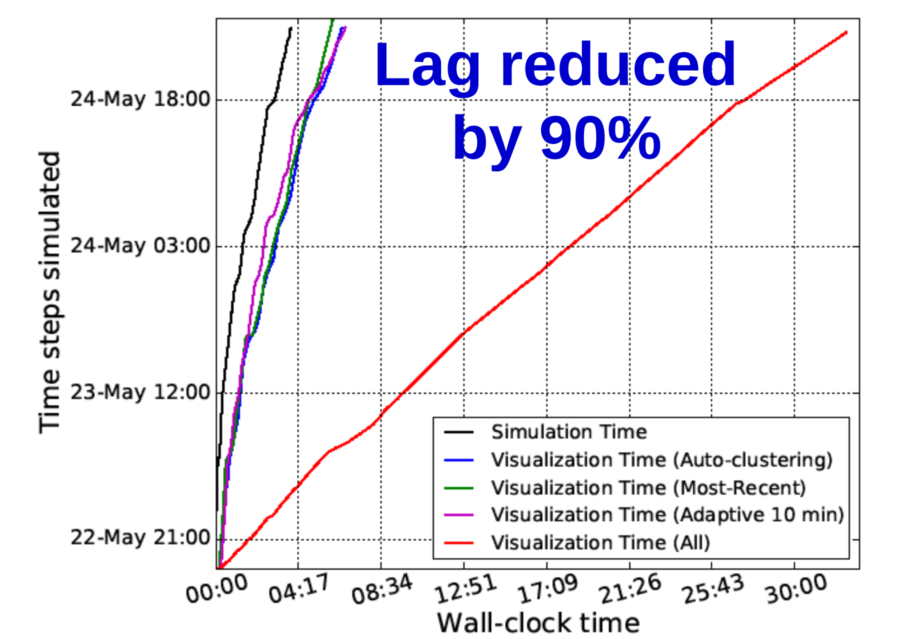



Illustration of increasing visualization lag

## Frame Selection Algorithms

- Most-recent
  - Transfer the most-recently simulated frame
- Auto-clustering
  - Modified k-means for temporal clustering to select the most-representative frames
- Adaptive
  - Transfer full or reduced frames within acceptable lag bound

## Results

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# Symmetry in Scalar Field Topology

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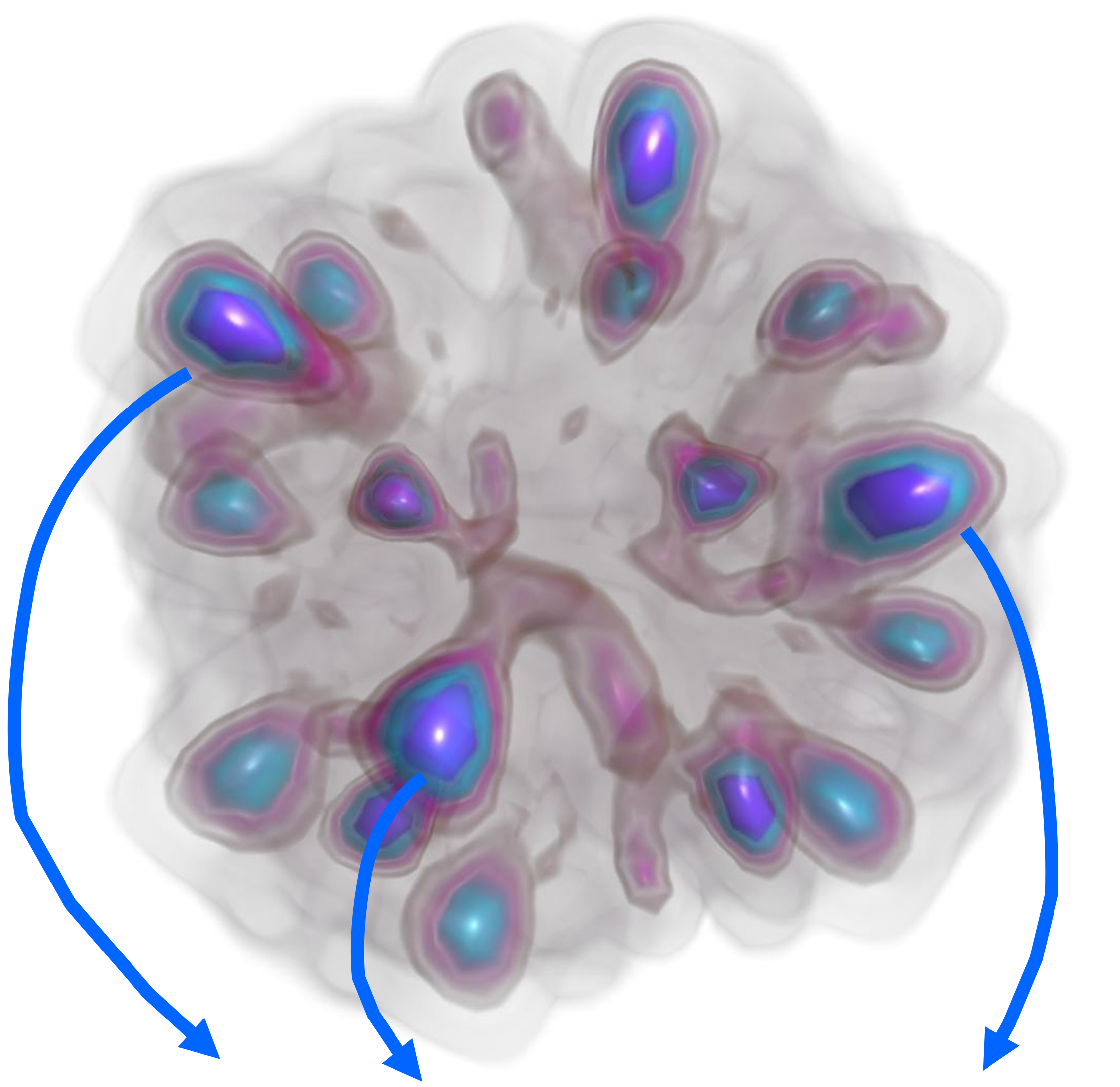
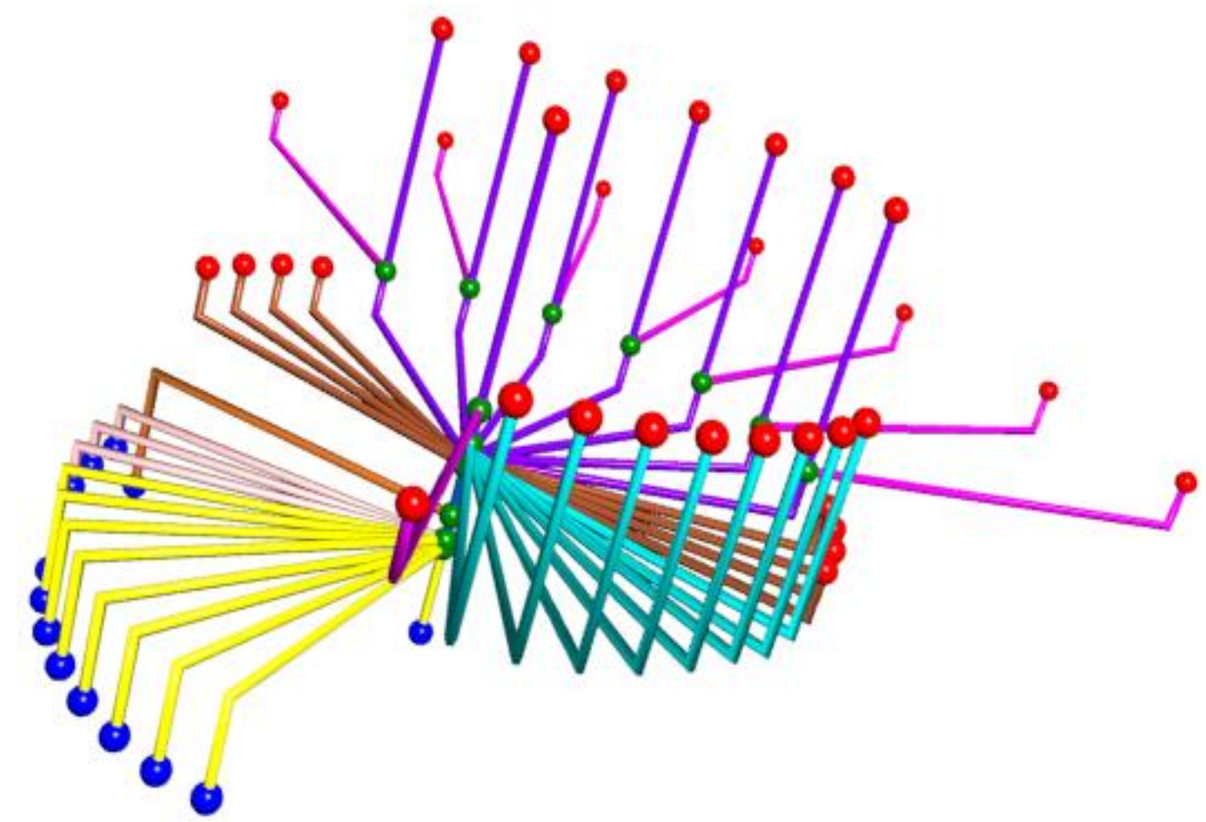


Symmetric structures in EM image of RuBisCO molecule

Four types of symmetric regions identified



Classify subtrees of the contour tree

## Motivation

Scalar fields contain repeating patterns

Provide insights on scientific phenomena

## Technique

Classify subtrees of the contour tree

Similarity measure to compare subtrees

## Applications

Symmetry-aware isosurface extraction

Symmetry-aware transfer function design