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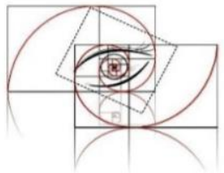

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# Decal-Lenses: Interactive Lenses on Surfaces for Multivariate Visualization

**Allan Rocha**, Julio Daniel Silva, Usman Alim, Sheelagh Carpendale, and Mario Costa Sousa

# Introduction

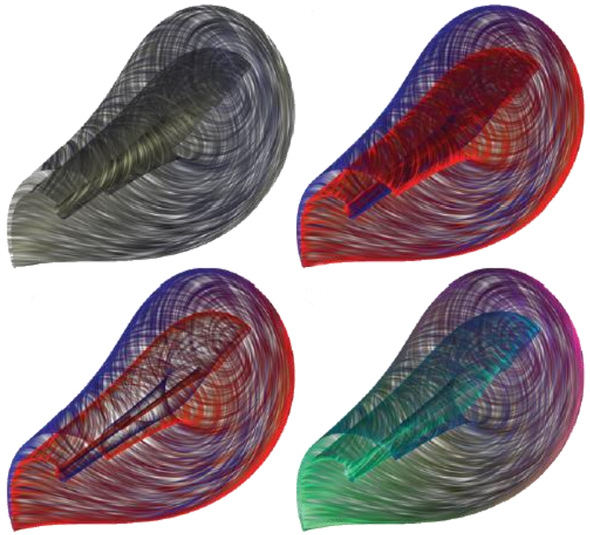
- Multivariate Surface Data
  - Common in several domains: Medicine, Geology, Engineering
  - Experts require to interpret and correlate multiple attributes

- Problem of *how to* visualize multivariate data

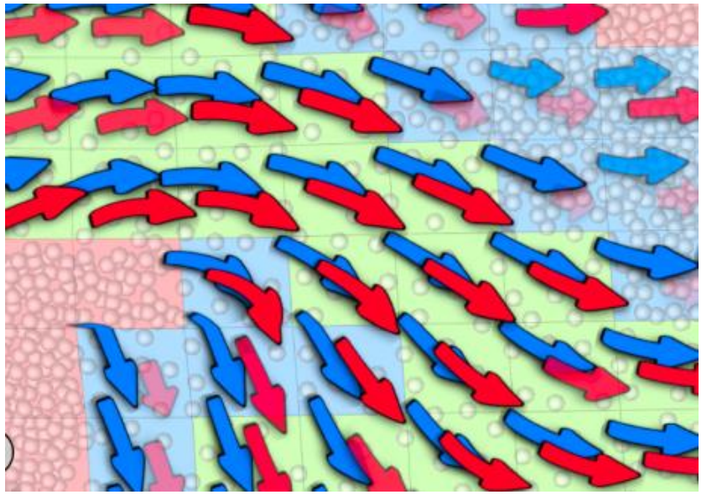
# Introduction

- Multivariate Layered (Superimposed) Visualization on Surfaces

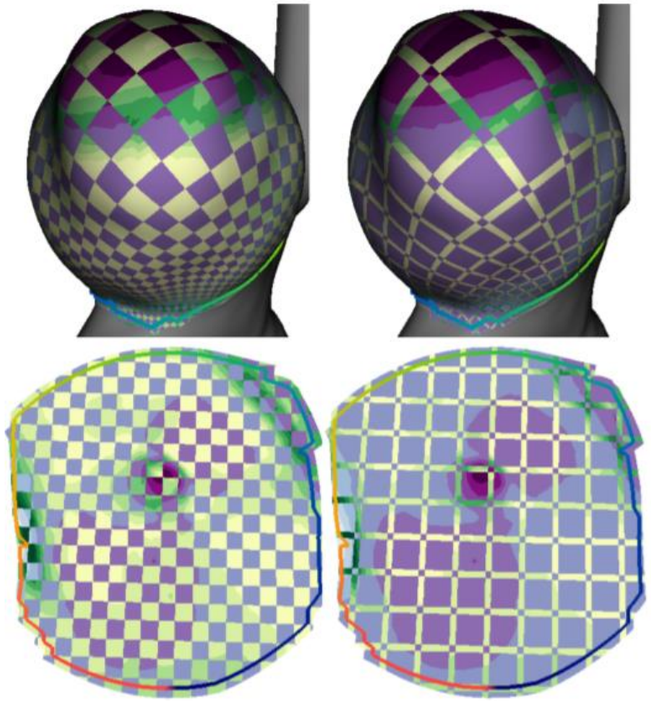
[Chen *et al.*, 2011]



[Carnecky *et al.*, 2012]



[Rocha *et al.*, 2017]



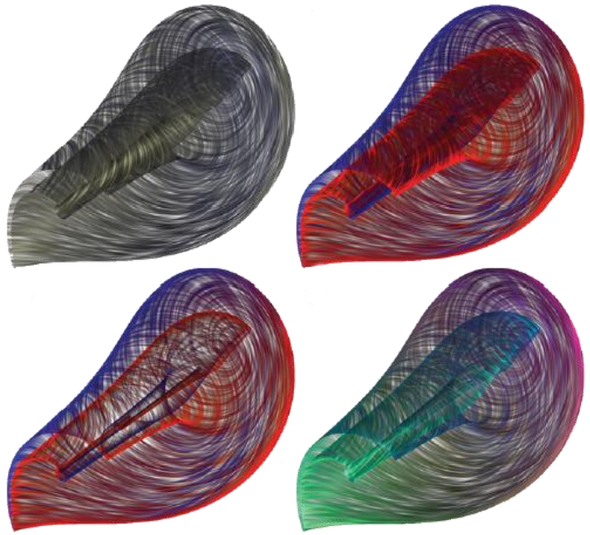
[Meuschke *et al.*, 2018]

# Clutter problem

# Introduction

- Multivariate Layered (Superimposed) Visualization on Surfaces

[Chen *et al.*, 2011]



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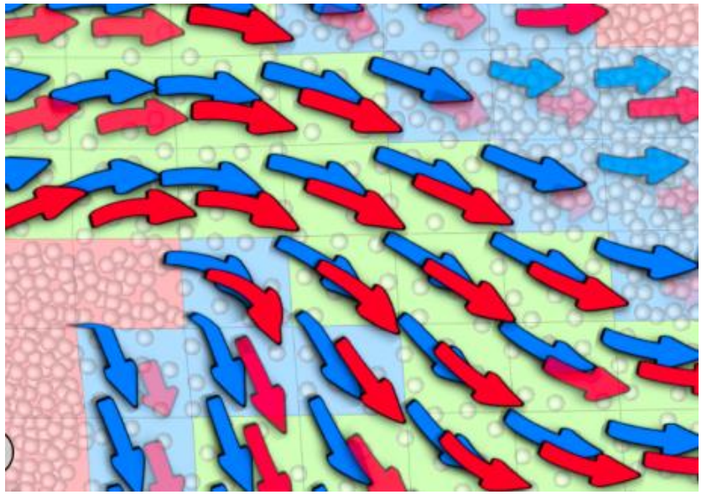

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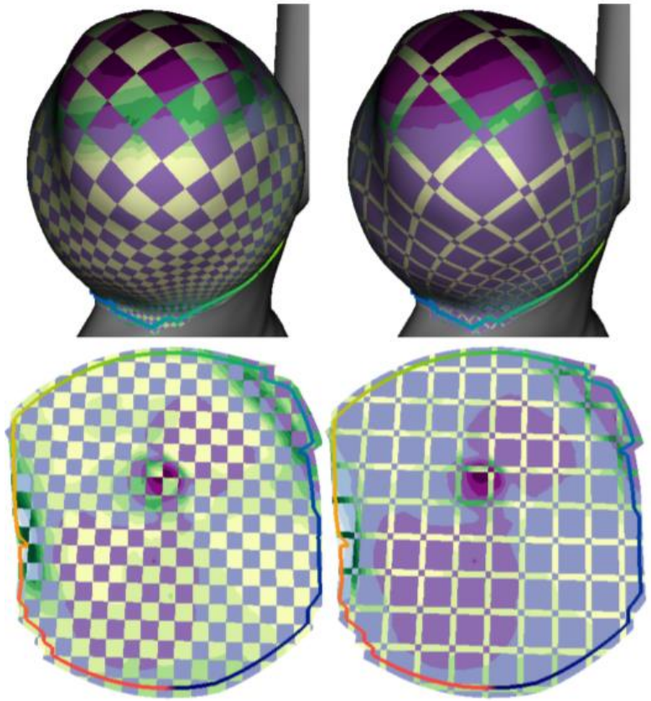


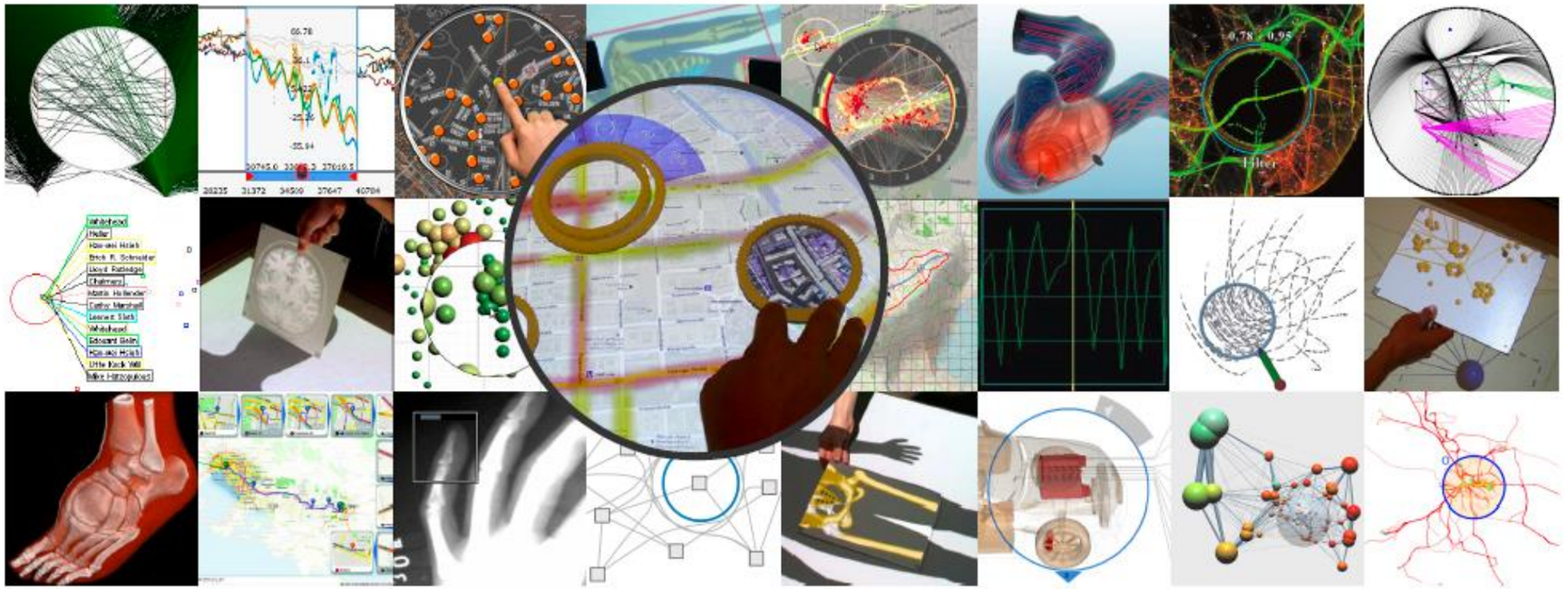
[Meuschke *et al.*, 2018]

How to augment and manage multivariate visualizations on surfaces?

Interaction Techniques

# Introduction

- Interactive Lenses in Visualization

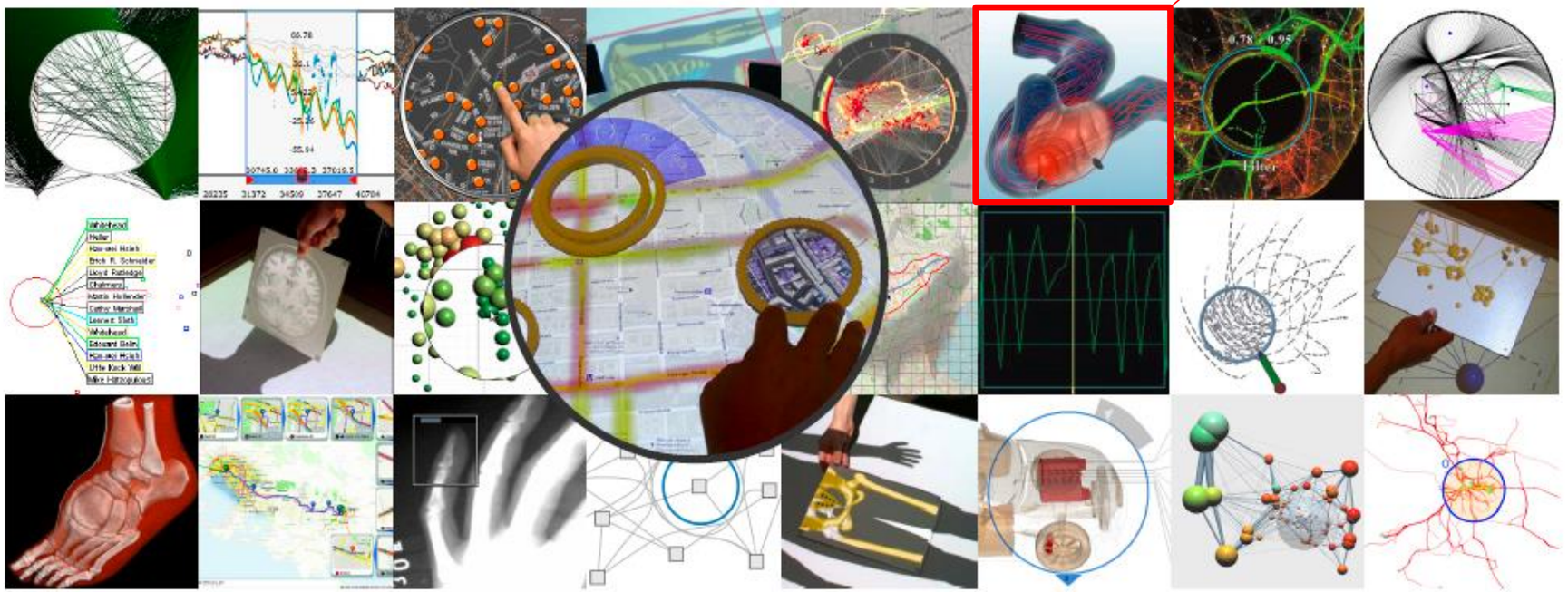


[ Tominski *et al.,* 2014, 2017 ]

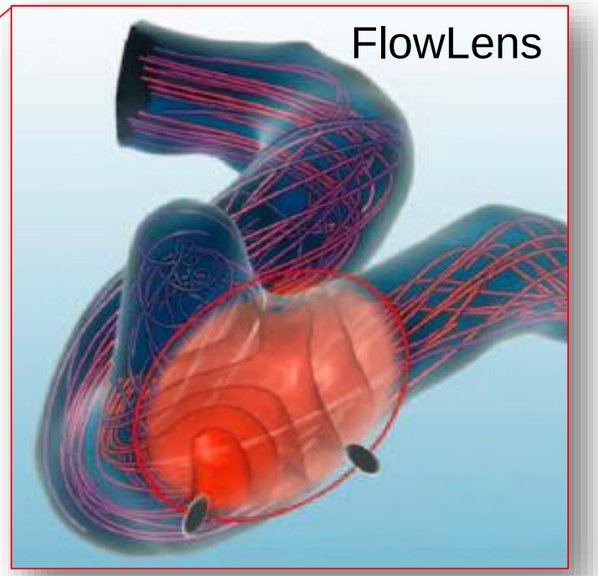
Lenses applied to surface/3D data

# Introduction

- Interactive Lenses in Visualization



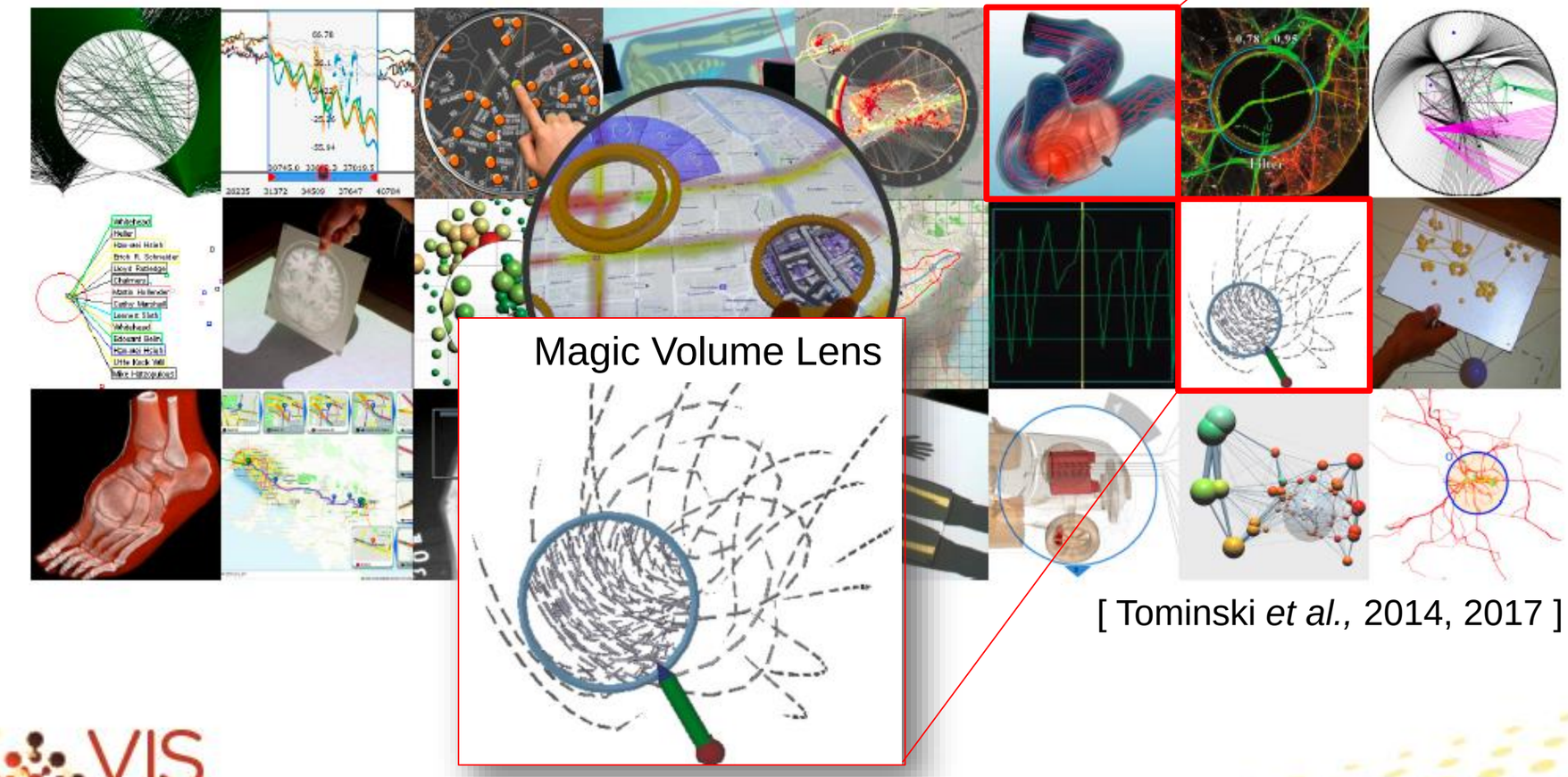
[ Tominski *et al.,* 2014, 2017 ]




[Gasteiger *et al.,* 2011]

# Introduction

- Interactive Lenses in Visualization

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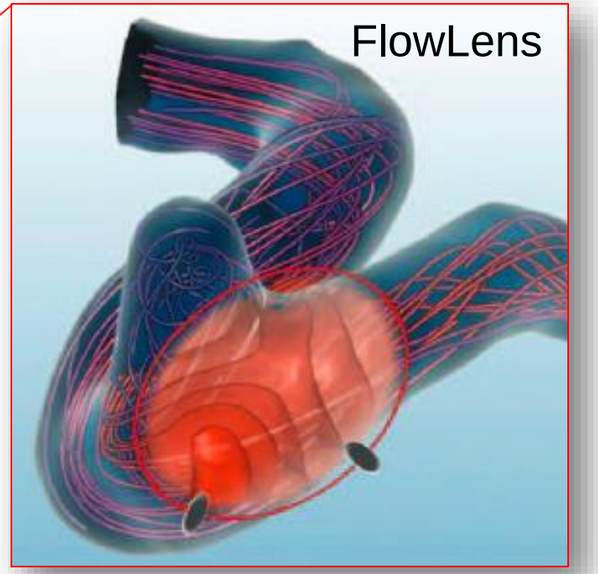


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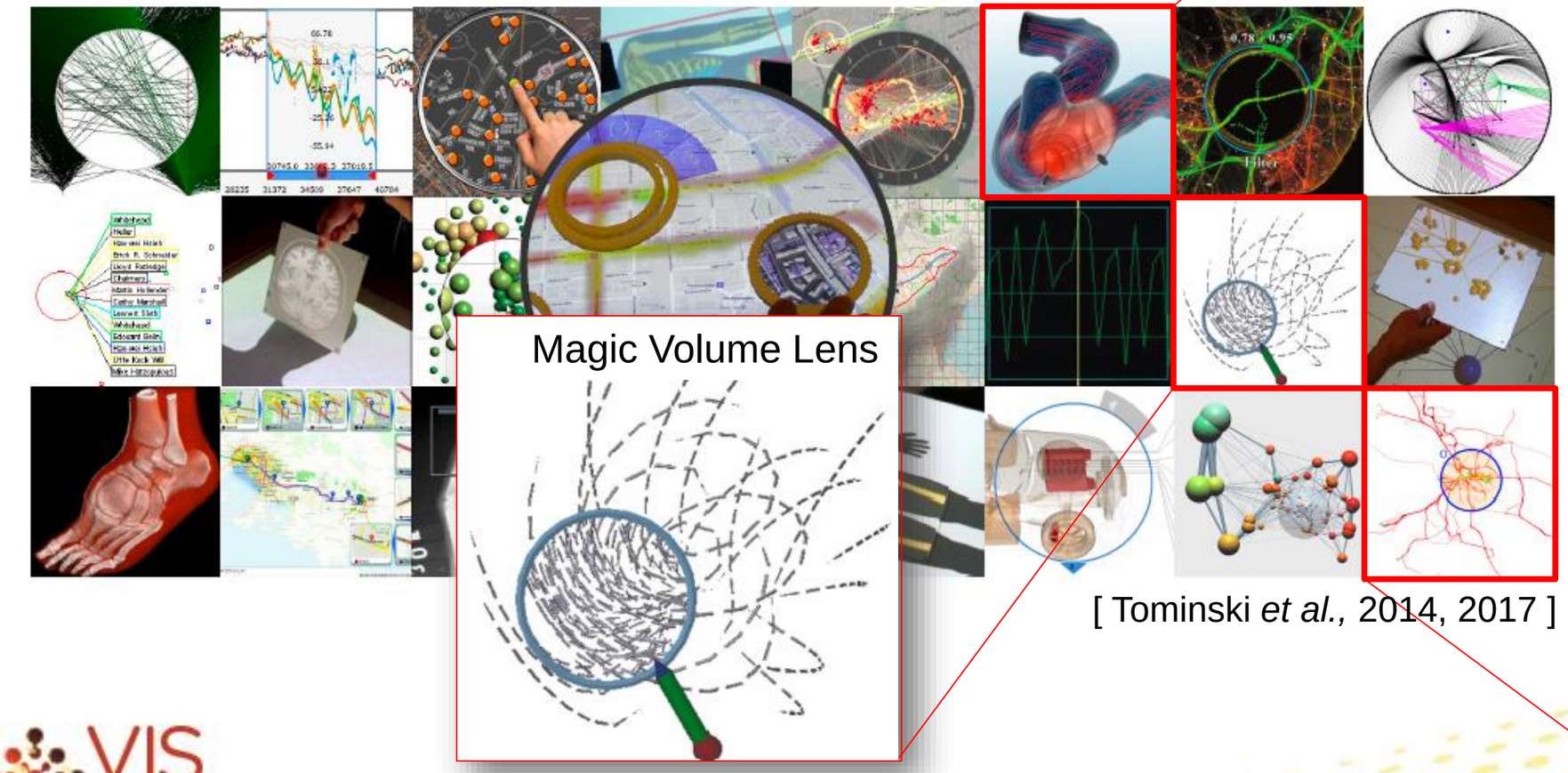
# Introduction

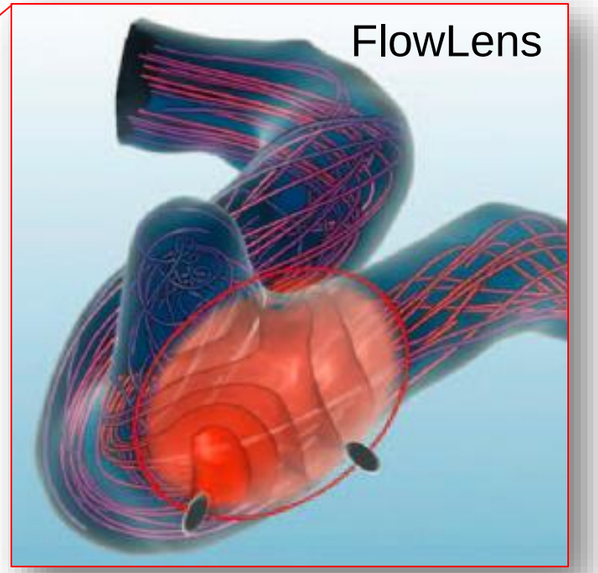
- Interactive Lenses in Visualization



Magic Volume Lens

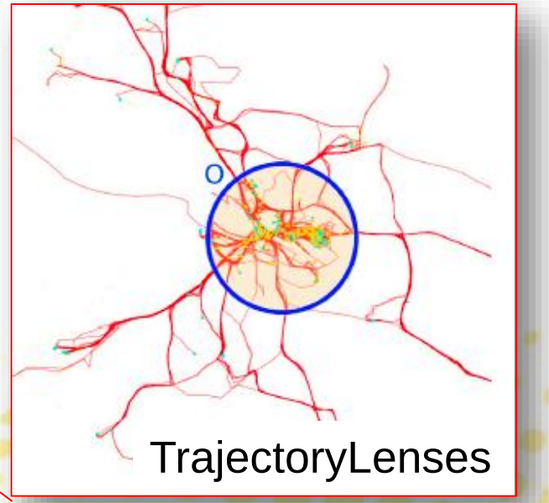
[ Wang *et al.*, 2005 ]

[ Tominski *et al.*, 2014, 2017 ]




[Gasteiger *et al.*, 2011]

[Krüger *et al.*, 2013]

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# Interactive Lenses for Surface Data

- Lenses Dimensionality
  - 2D – defined in image space
  - 2.5 – 2D objects placed in object space
  - 3D – volumetric shapes placed in object space

# Interactive Lenses for Surface Data

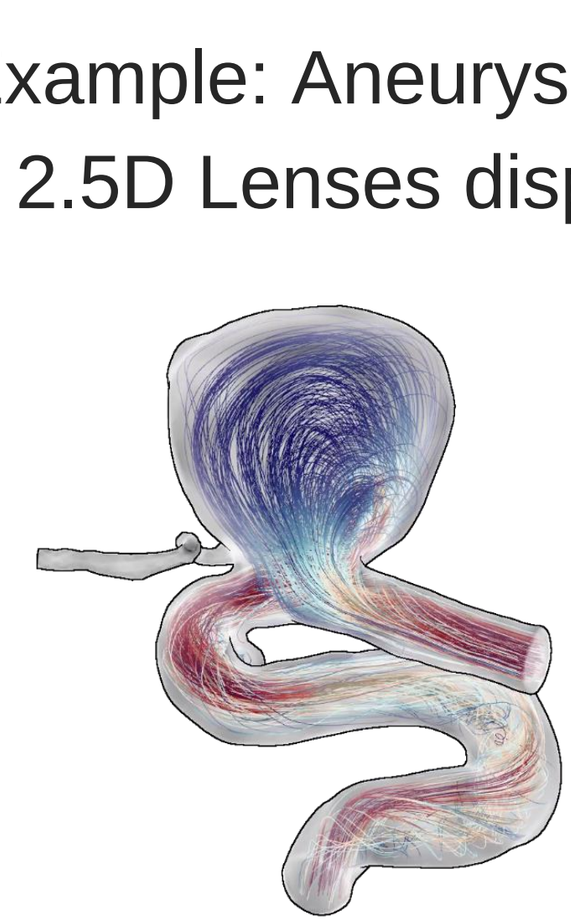
- Lenses Dimensionality - Limitations
  - 2D – defined in image space
    - Lack correlation between the 2D screen position and 3D dataset
  - 2.5 – 2D objects placed in object space
  - 3D – volumetric shapes placed in object space

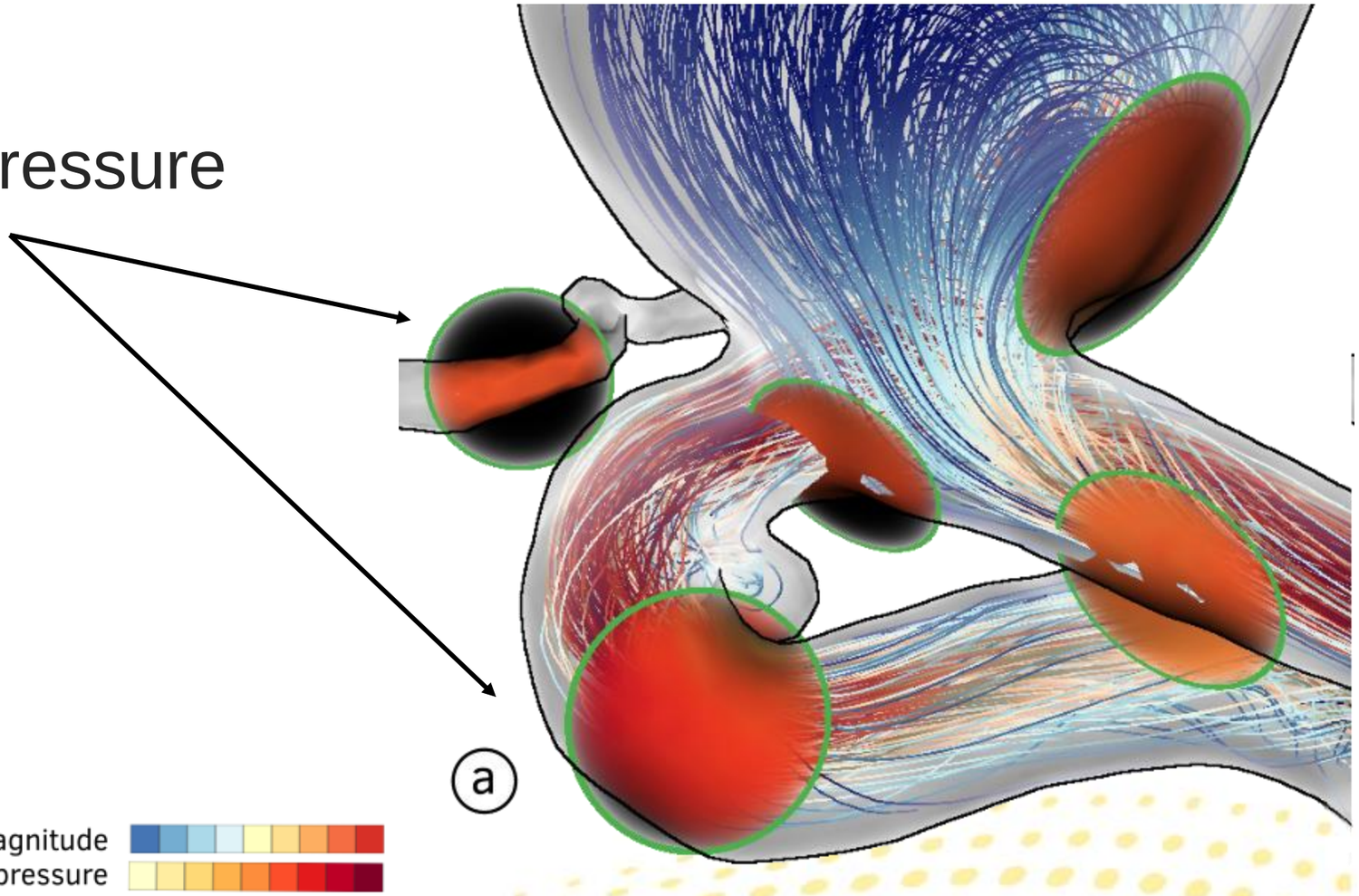
# Interactive Lenses for Surface Data

- Lenses Dimensionality - Limitations
  - 2D – defined in image space
    - Lack correlation between the 2D screen position and 3D dataset
  - 2.5 – 2D objects placed in object space
  - 3D – volumetric shapes placed in object space
    - Require a high interaction effort
      - proper placement and
      - alignment within the 3D object
    - Do not allow for compositing operations

# Interactive Lenses for Surface Data

- Example: Aneurysm Data
  - 2.5D Lenses displaying pressure





# Our approach

# Design Goals

- **DG1** – *Consider spatial correlation*
- **DG2** – *Facilitate placement*
- **DG3** – *Support scalability*
- **DG4** – *Provide fluid interaction*
- **DG5** – *Consider depth disambiguation cues*

# Decal-Lenses Concept

Patches of 2D manifolds built to attach smoothly to non-flat surfaces.

- Resemble 2D decals drawn over a surface

- Fundamentally different
  - Decals – textures stamped onto surfaces
  - Decal-Lenses – F+C interaction technique

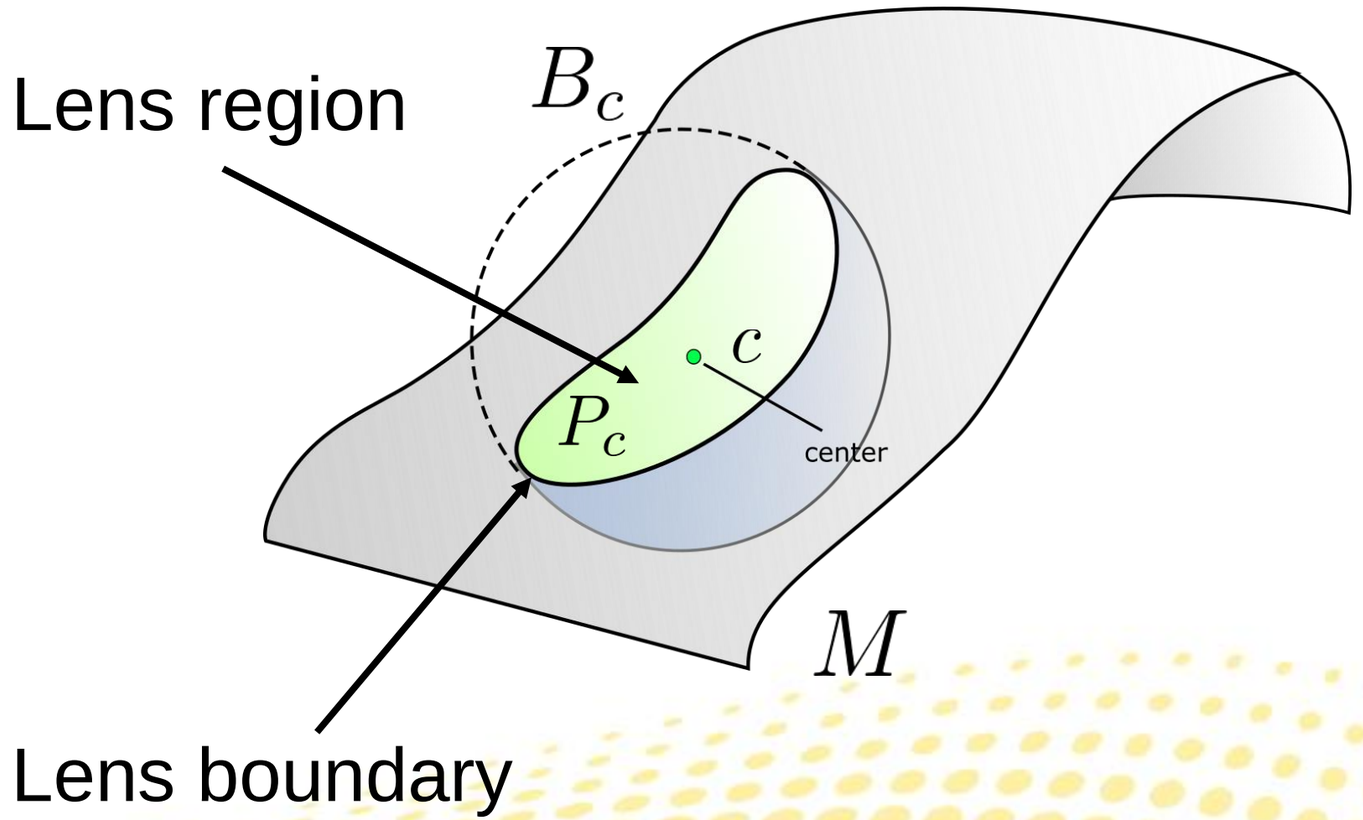
# Decal-Lenses Concept

Patches of 2D manifolds built to attach smoothly to non-flat surfaces.

- Construction

$$P_c := B_c \cap M$$

- May not be a disk



# Decal-Lenses Concept

Patches of 2D manifolds built to attach smoothly to non-flat surfaces.

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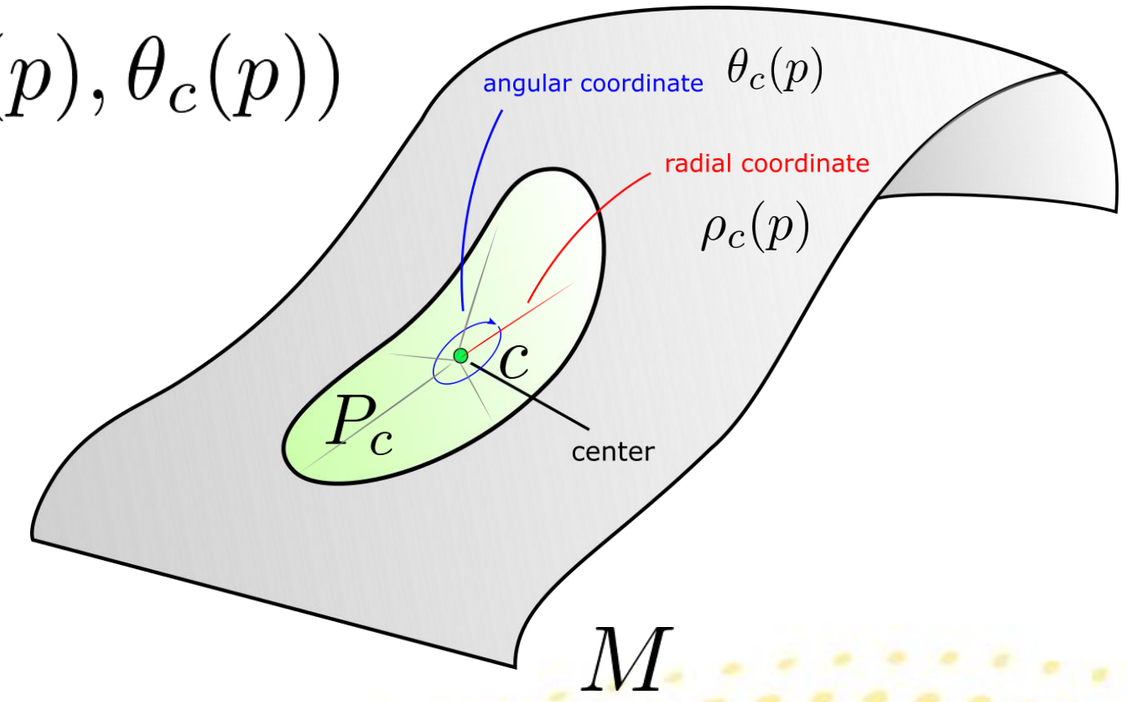
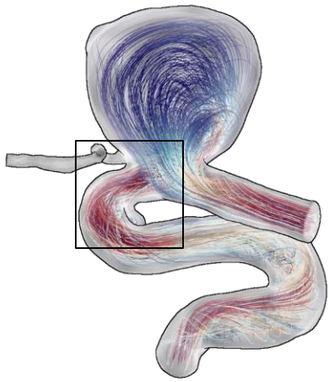
$$P_c := B_c \cap M \qquad p = (\rho_c(p), \theta_c(p))$$

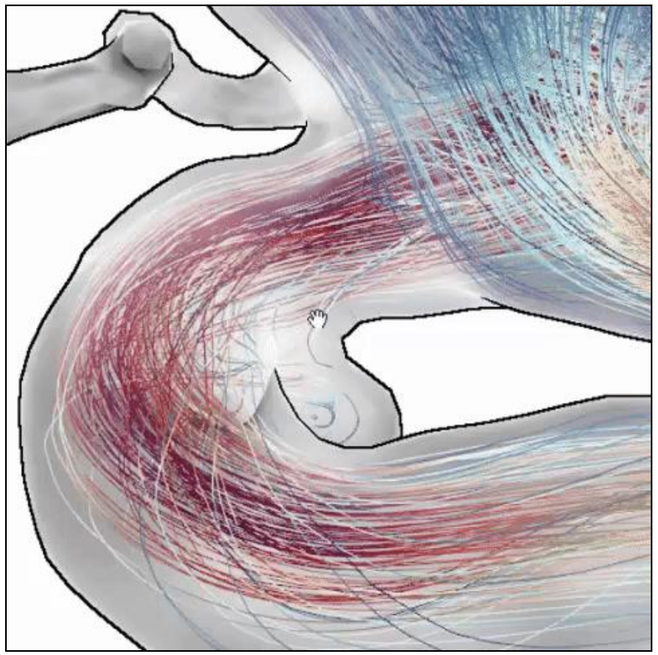



- May not be a disk
- Local parametrization
  - Blending
  - Composition

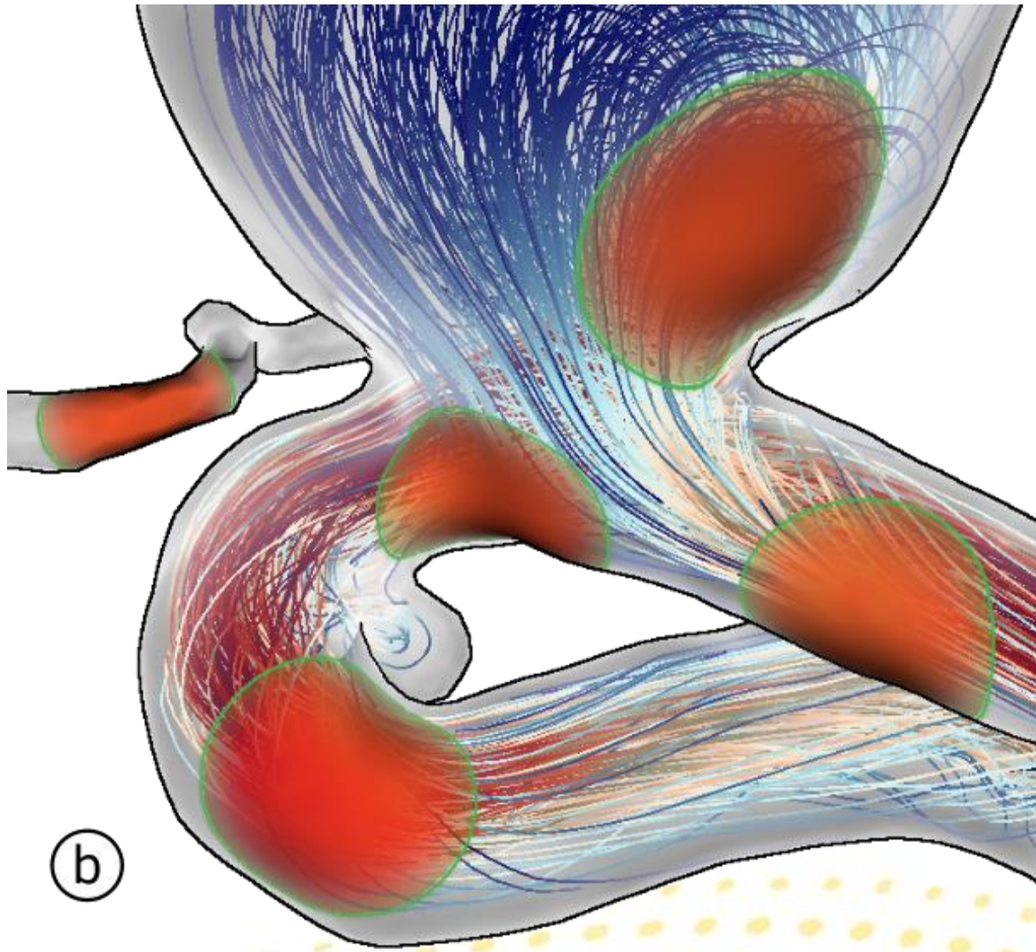
# Demonstration Example

- Aneurysm Data
  - Decal-Lenses displaying pressure





Lens comparison: 2.5D Lens *vs* Decal-Lens



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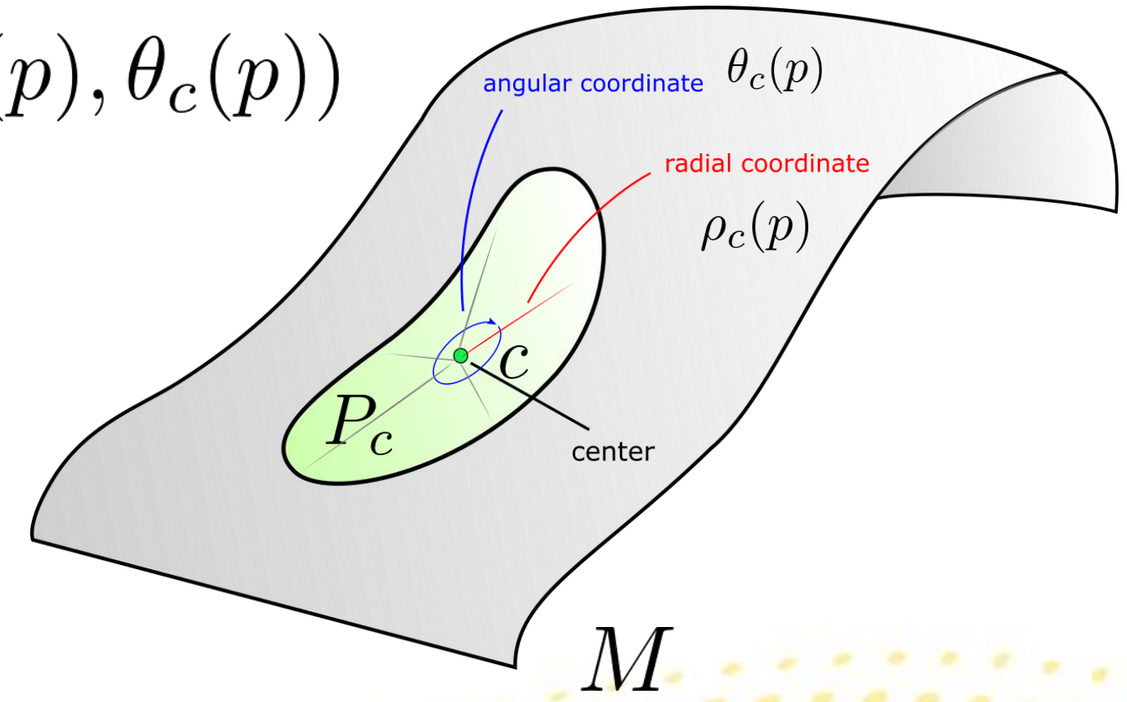


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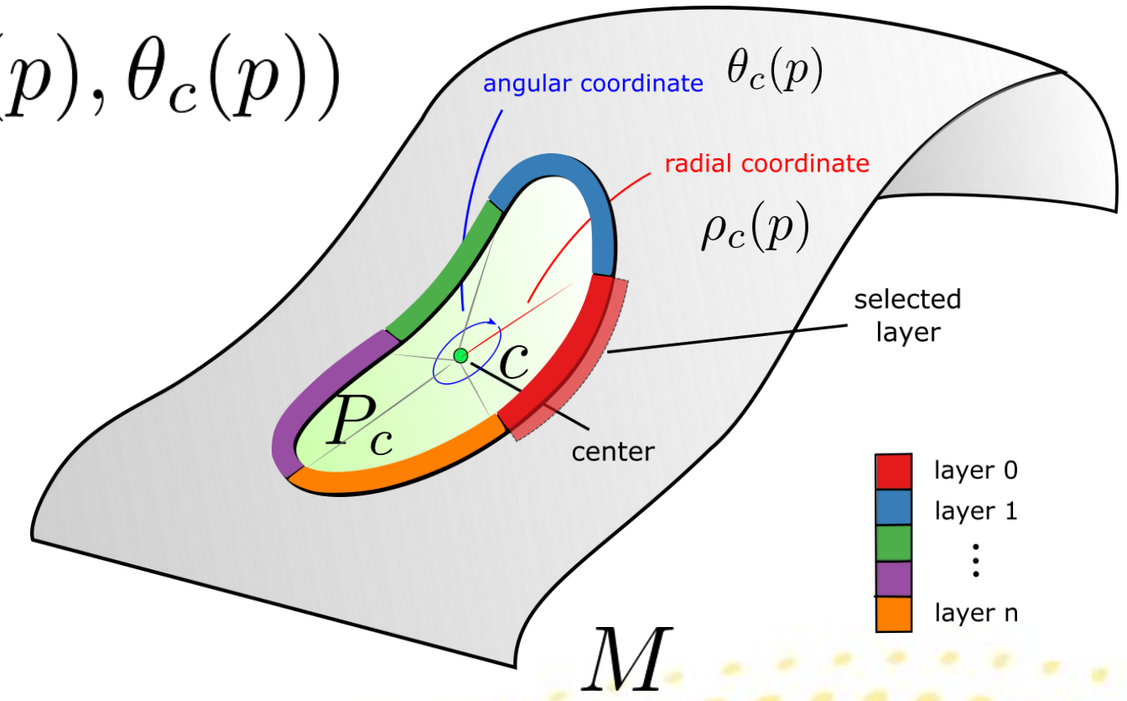
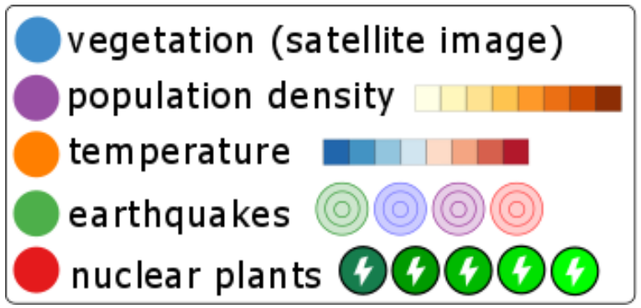
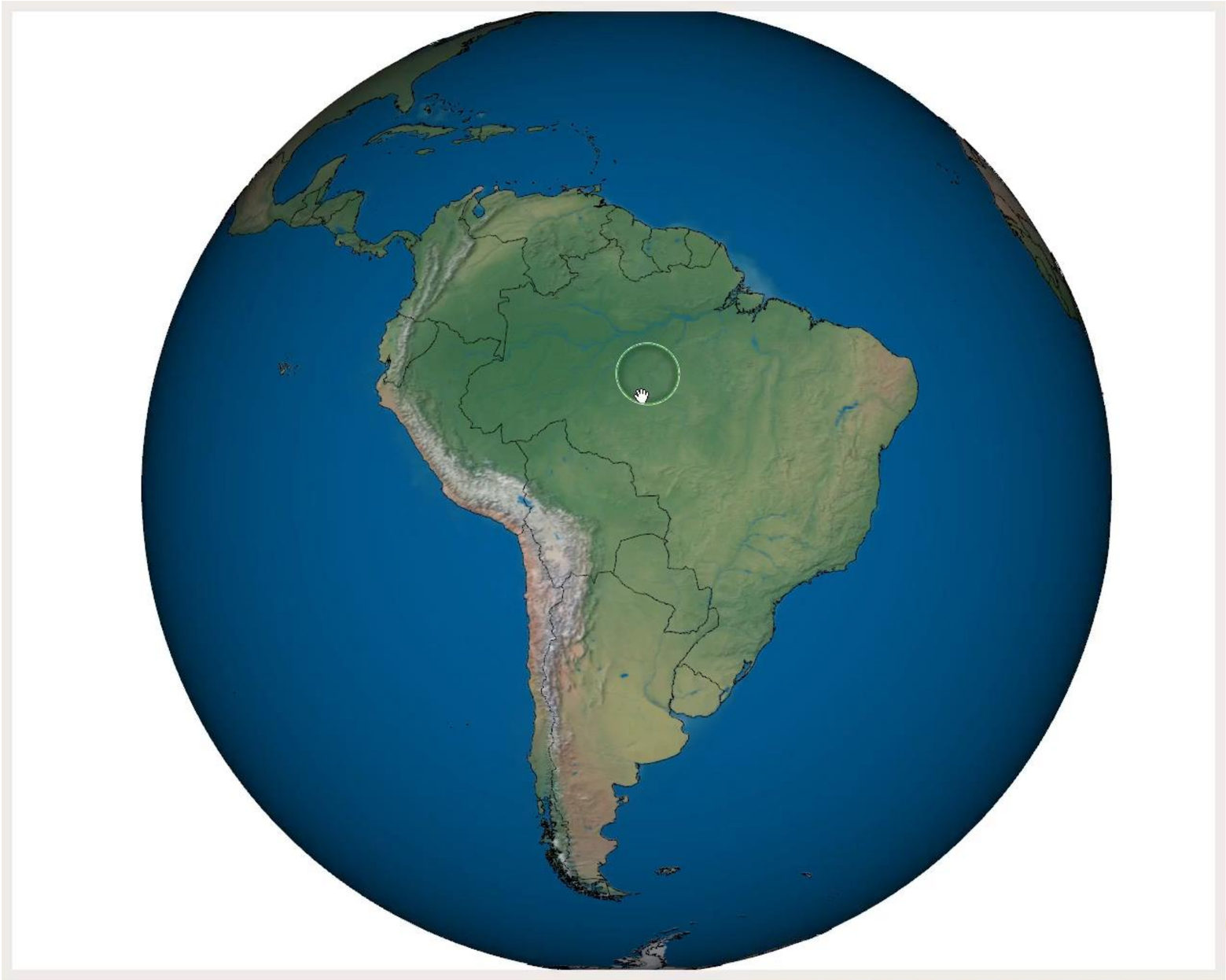



- May not be a disk
- Local parametrization
  - Blending
  - Composition
- Widgets: *Wheel*

# Decal-Lenses

- Earth Data
- Sphere
  - $p = (\rho_c(p), \theta_c(p))$
    - computed exactly
- Attributes



# Operations over Multiple Decal-Lenses

# Operation Over Multiple Decal-Lenses

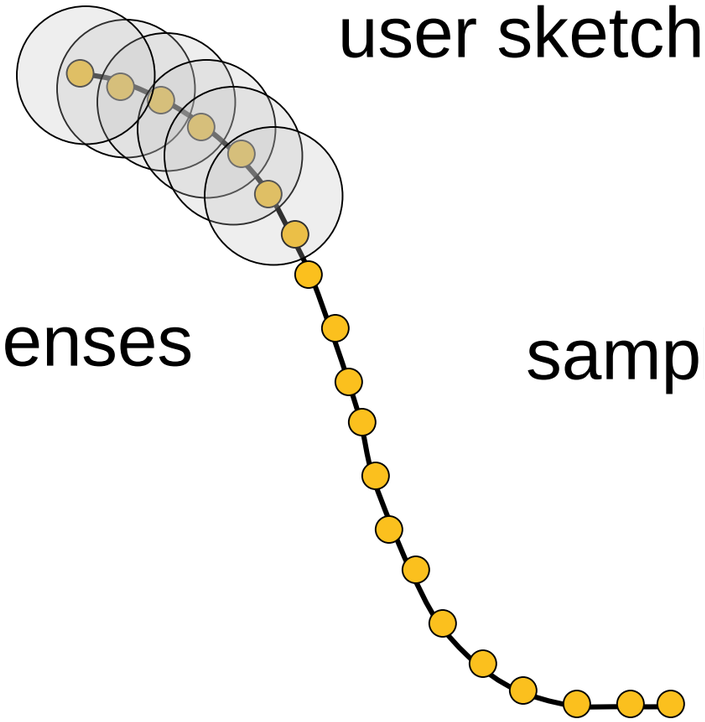
Lens-regions of arbitrary shapes

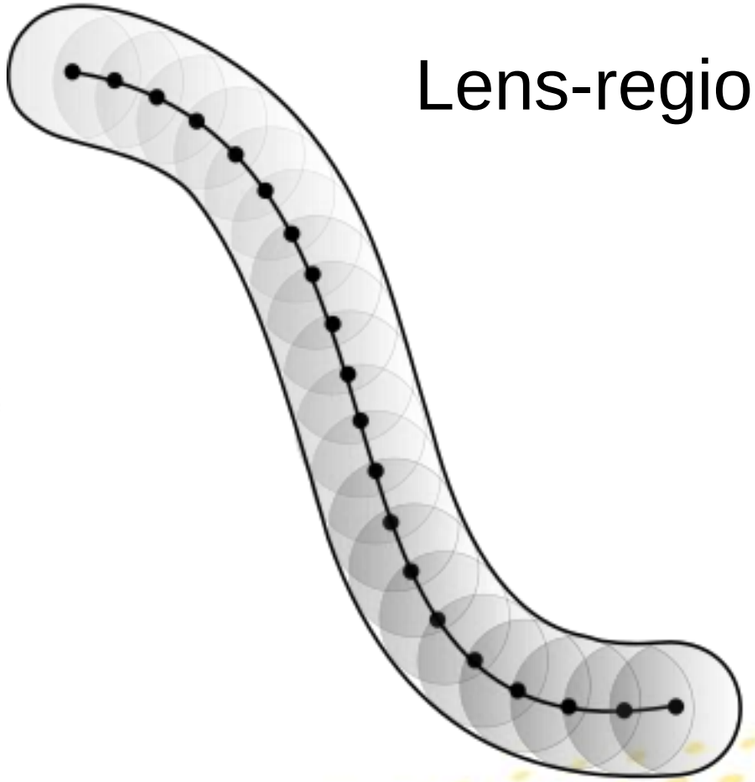
- Operations
  - Brushing
  - Lassoing
  - Other operations could be defined

- Decal-lenses are amenable to composition

# Operation Over Multiple Decal-Lenses

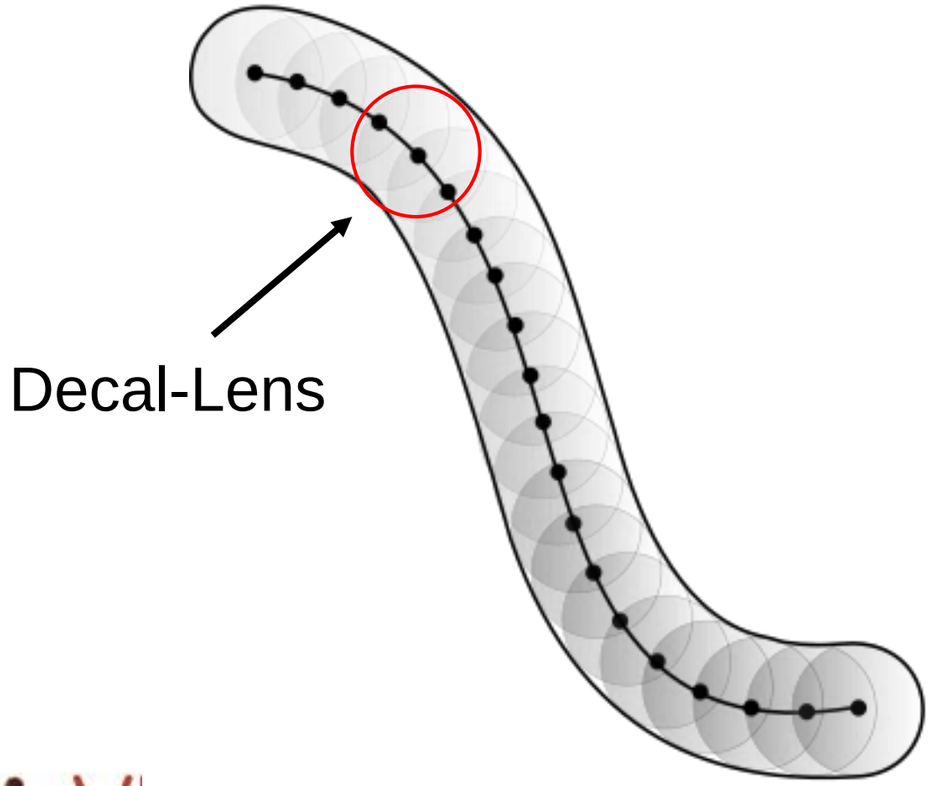
- Brushing

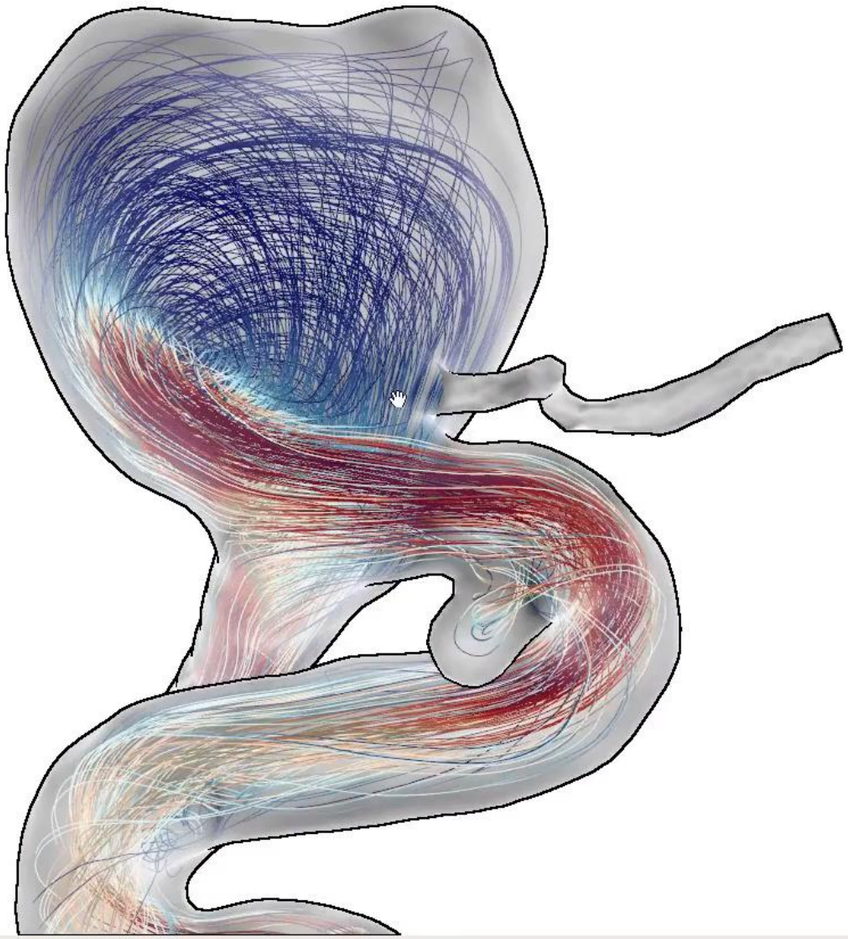


# Operation Over Mu

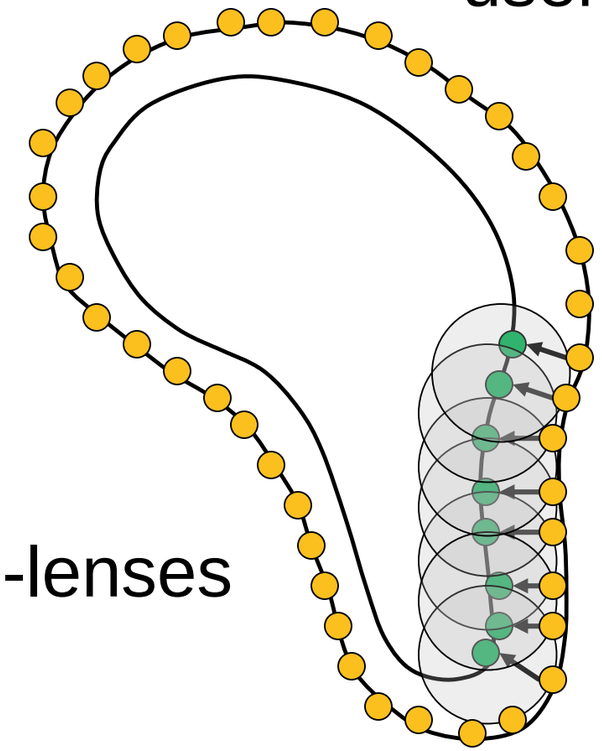
- Brushing

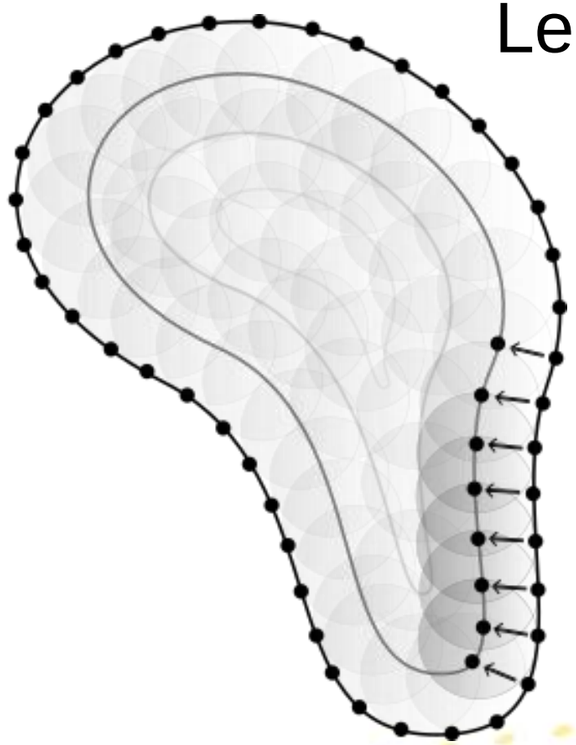


# Operation Over Multiple Decal-Lenses

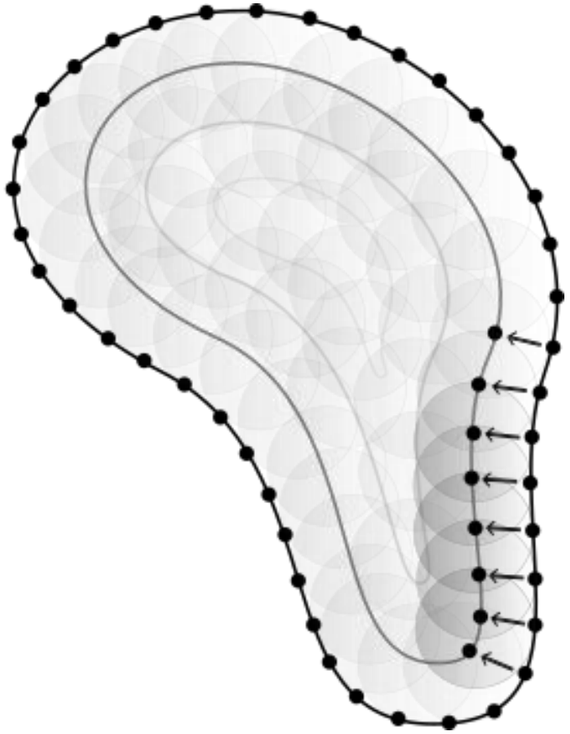
- Lassoing

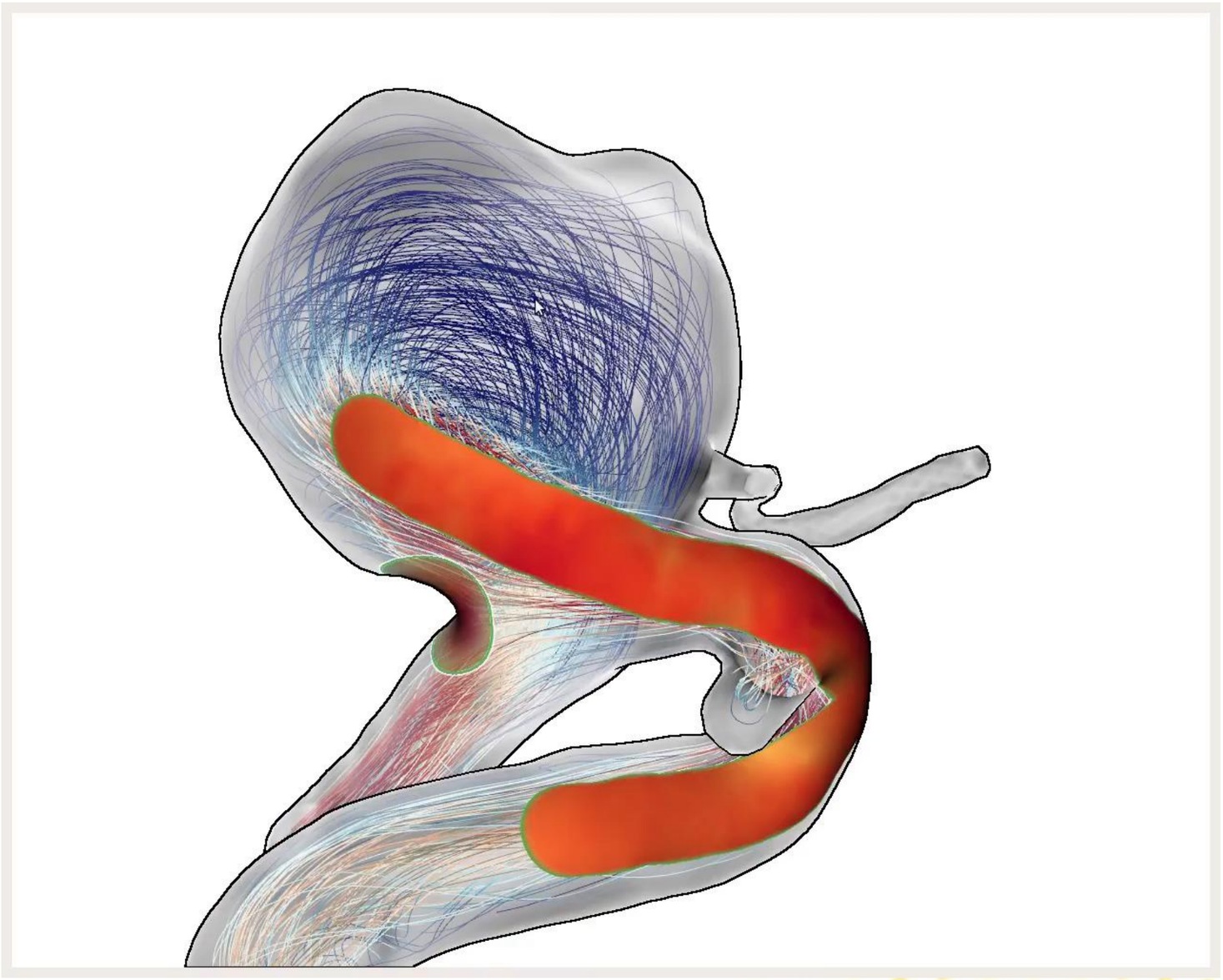


# Decal-Lenses

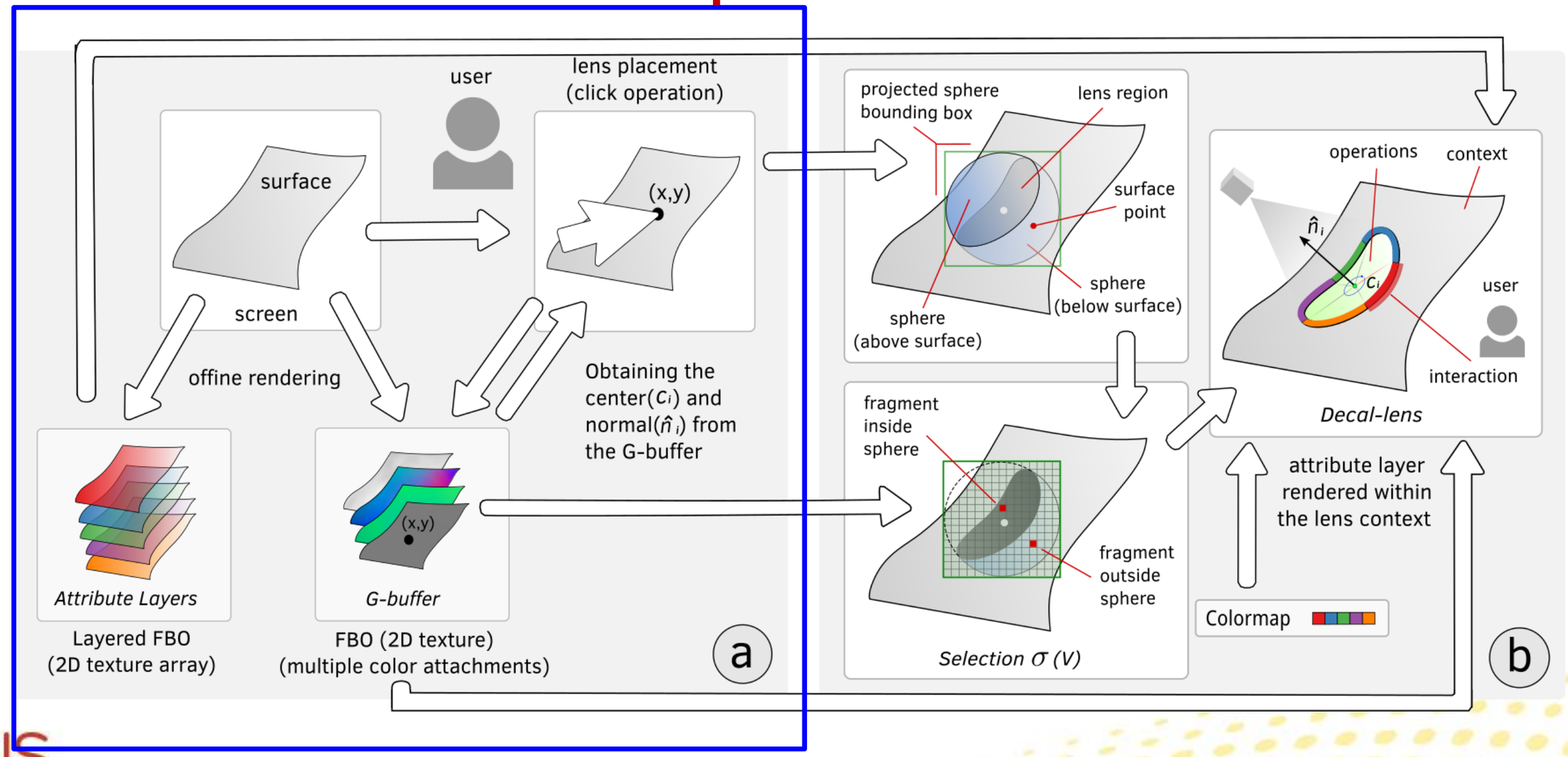
- Lassoing



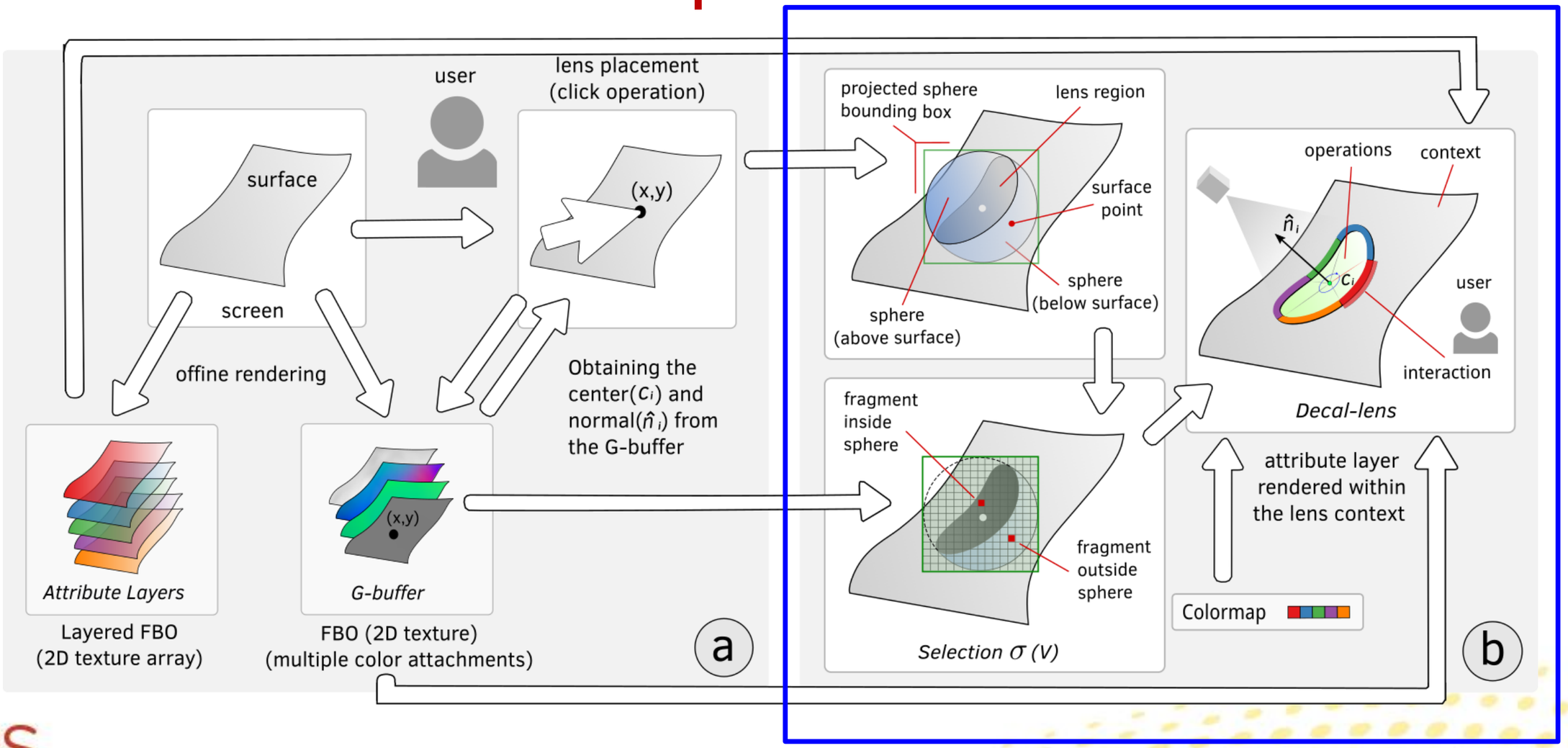


# GPU Implementation

# Decal-Lenses GPU Implementation



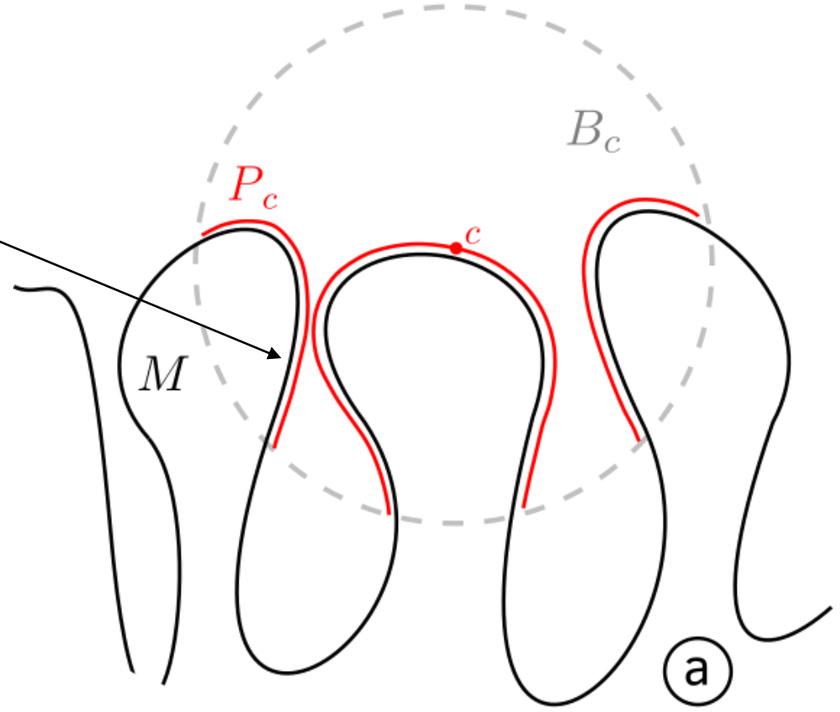
# Decal-Lenses GPU Implementation



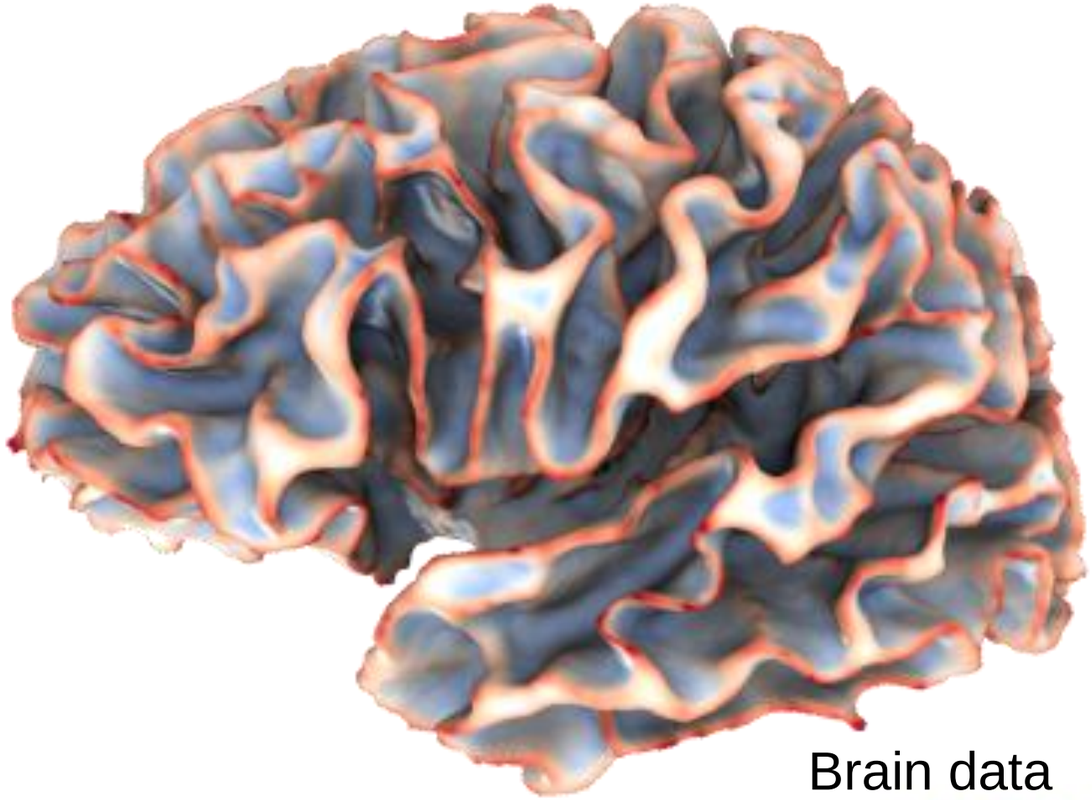
# Extensions

# Decal-Lenses on Complex Geometry

Depth cues



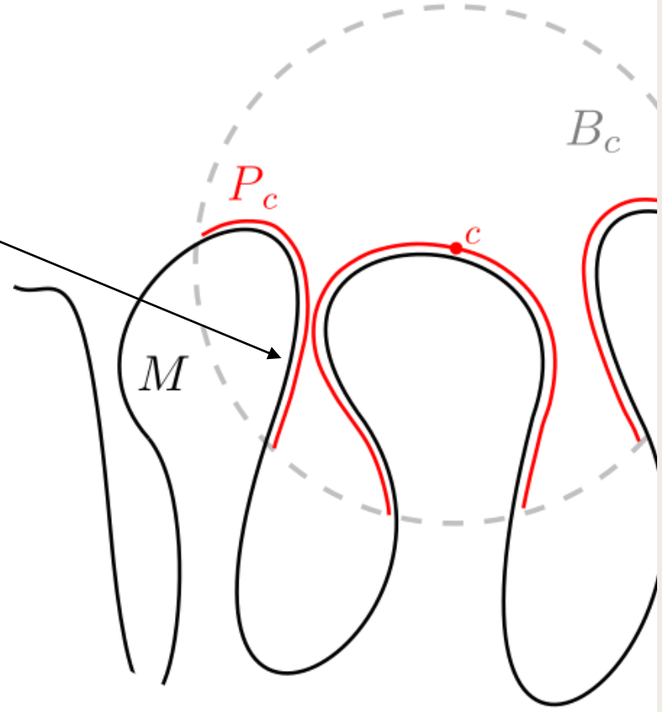

$$P_c := B_c \cap M$$



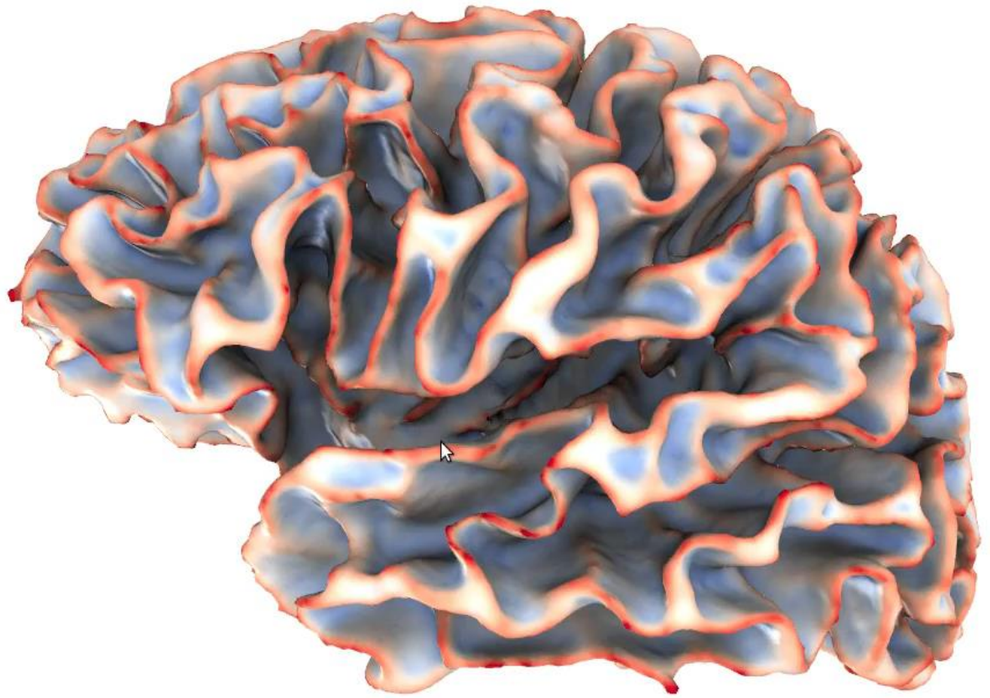
Brain data

# Decal-Lenses on C

Depth cues

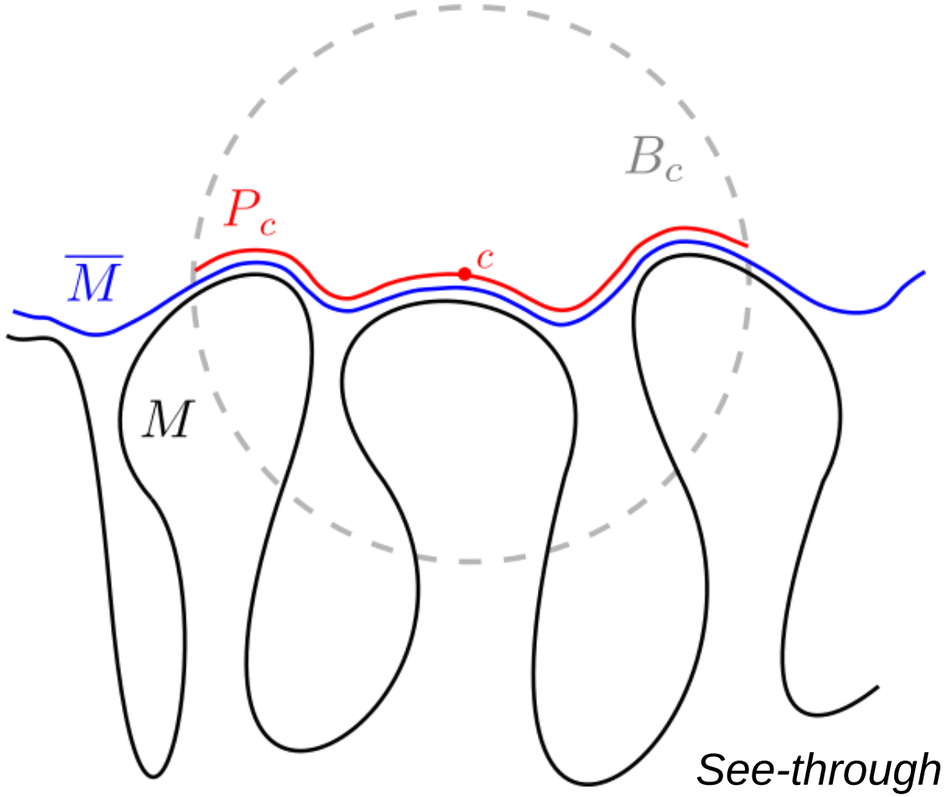



$$P_c := B_c \cap M$$

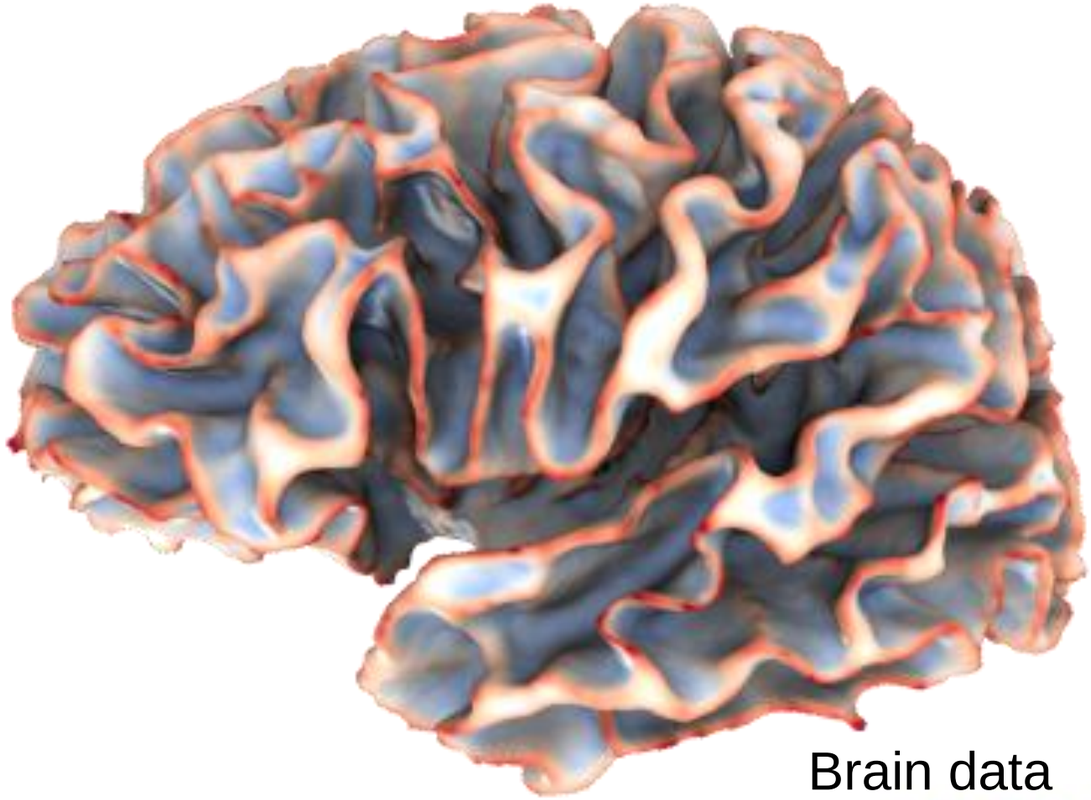


# Decal-Lenses on Complex Geometry

## Support Surface




*See-through* window metaphor



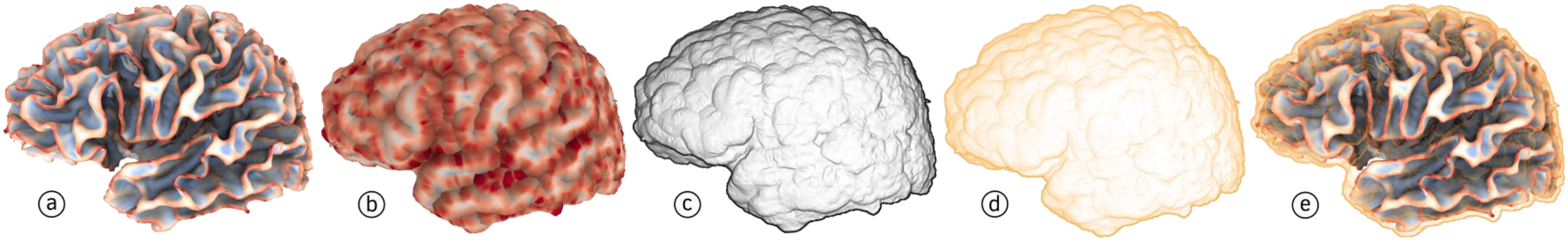
Brain data

# Support Surfaces

- Several ways to define such surfaces
- Related work
  - Outer envelopes [Cohen, et al. 2006]
  - Text scaffolds [Cipriano & Gleicher, 2008]
  - Bounding proxies [Calderon & Boubekeur, 2017]

- Our approach focuses on *support surfaces* for interaction

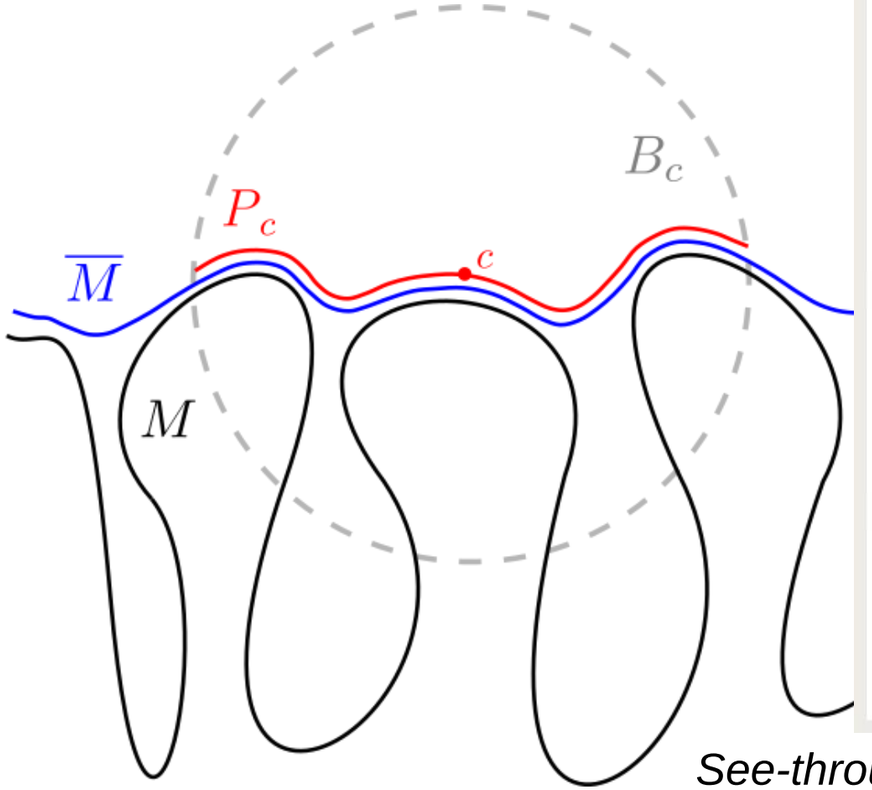
# Support Surface Implementation

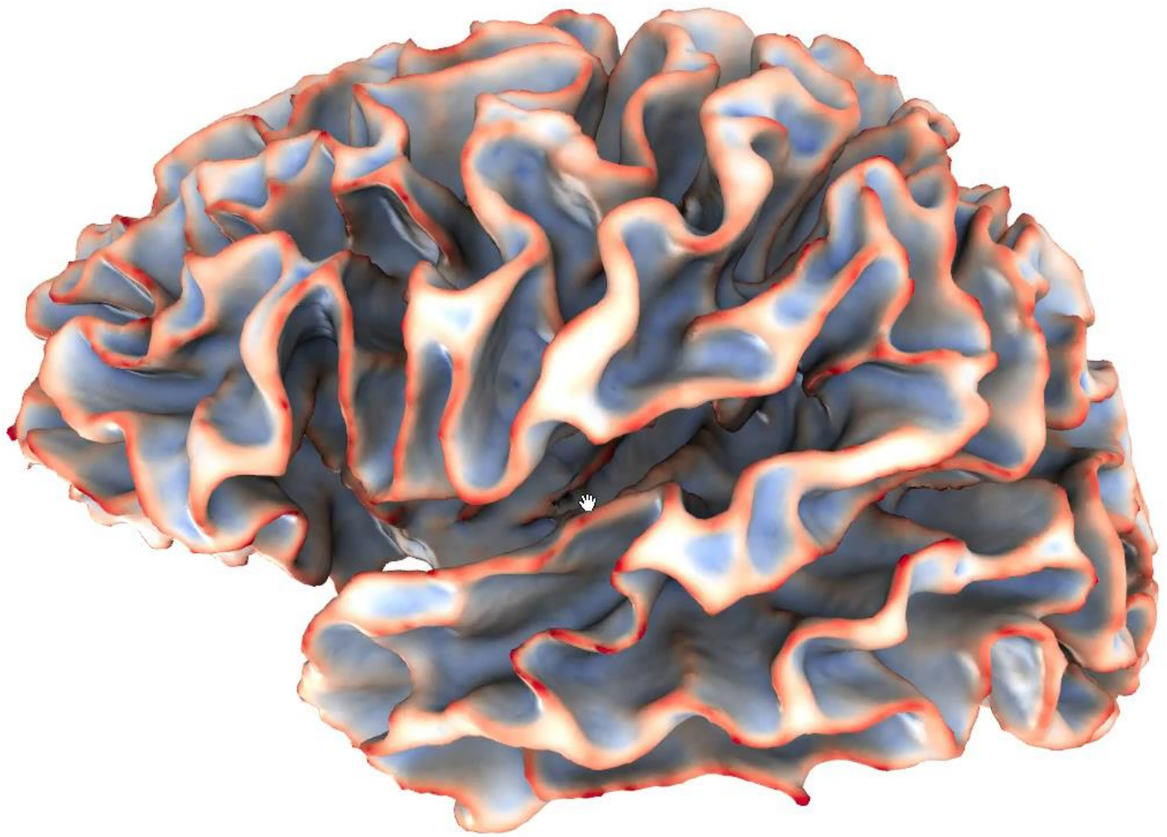



Refer to our paper for more details

# Decal-Lenses on C

## Support Surface



*See-through* window metaphor

# Conclusions

# Remarks

Survey on Interactive Lenses [Tominski et al. 2016]

- Emphasize the need to develop lens techniques
  - Simple placement, interaction, and parametrization
  - Flexibility of combining lenses
  - Reuse of lenses for other datasets in other domains

- Decal-Lenses address the aforementioned requirements

# Contributions

- Decal-Lenses, a new category of lenses for multivariate visualization
- Possibility to create *lens-regions* by operating over multiple lenses
- Simple GPU implementation
- Concept of support surfaces for designing interaction techniques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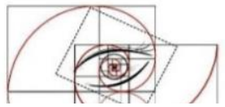

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contact: acarocha@ucalgary.ca


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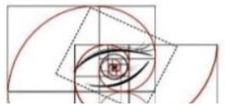

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**Allan Rocha**, Julio Daniel Silva, Usman Alim, Sheelagh Carpendale, and Mario Costa Sousa

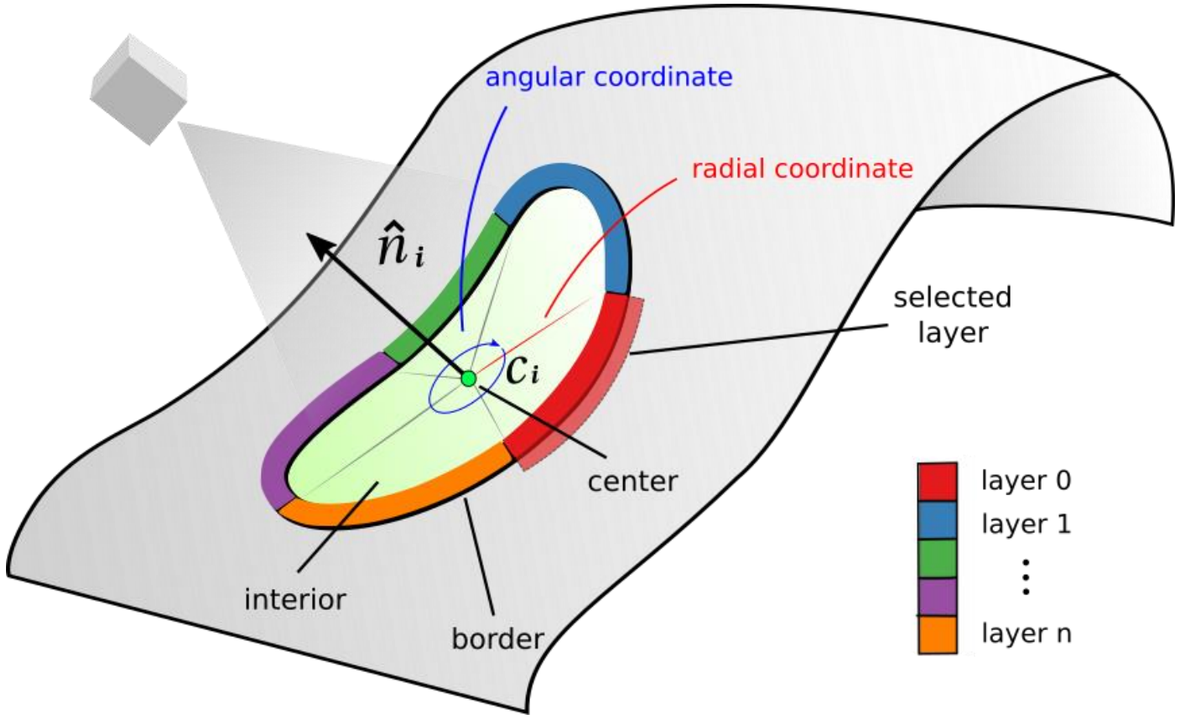
contact: acarocha@ucalgary.ca

# Performance

- Real-time
  - Test up to 5000 lenses
- Limitations
  - Multiple rendering calls (one for each decal-lens)

# Decal-Lenses

- Local Cameras
  - Visualize multiple points of view
  - Facilitate data comparison/correlation



# Evaluation

- Qualitative