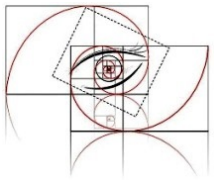
UNIVERSITY OF CALGARY

VIS 2016

Decal-maps: Real-time Layering of Decals on Surfaces for Multivariate Visualization

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



illustrares

Interactive Modeling, Visualization & Analytics R&D Group

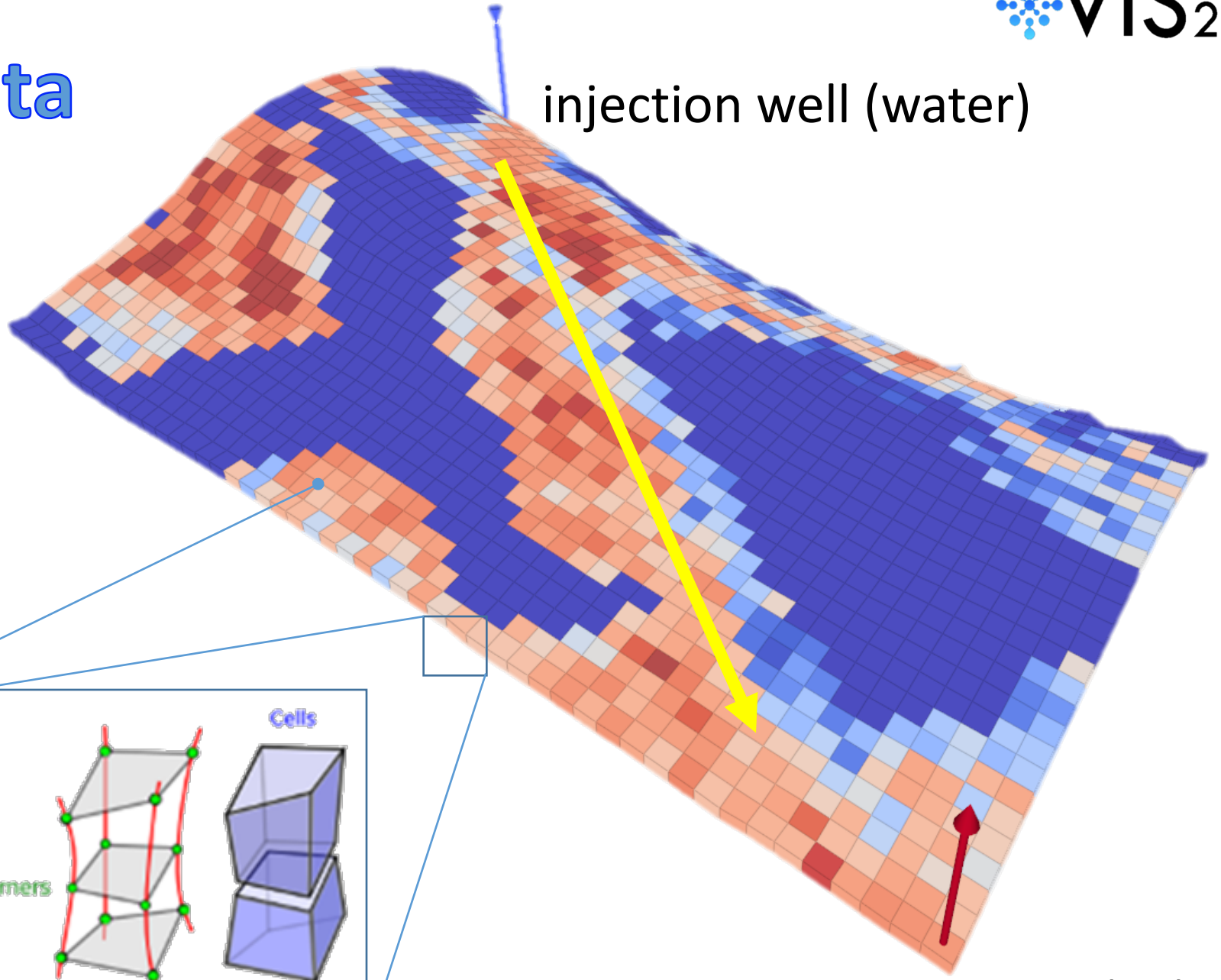
VISAGG

Visualization and Graphics Group

Research Problem

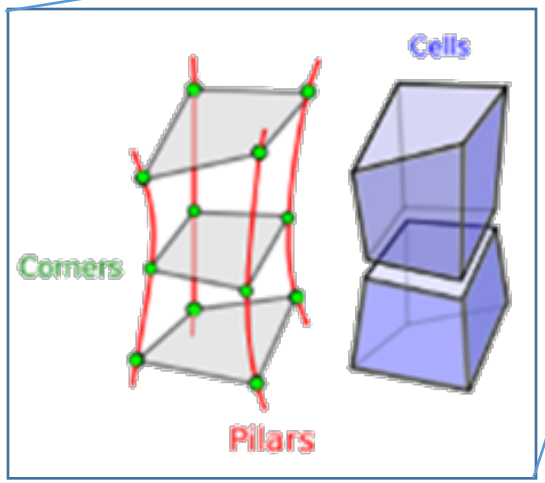
Multivariate Data

Geological Model



Attributes

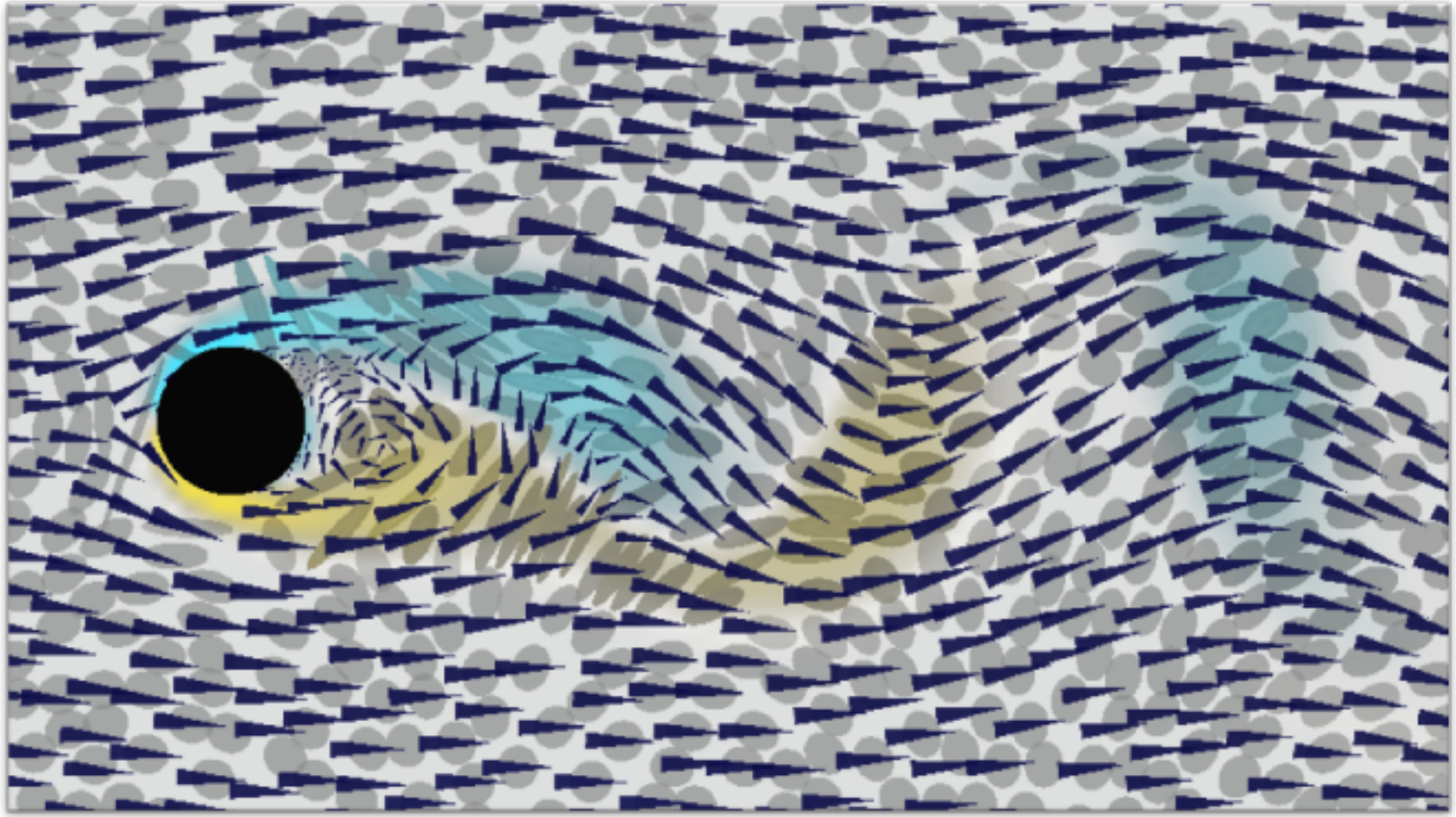
- Rock type
- Porosity
- Permeability
- Water Saturation
- Oil Saturation
- Oil flow rate
- Water flow rate
- Pressure
- …



How to visualize multiple attributes in a single view?

2D Layering

[Kirby *et al.*, VIS, 1999]



Visual encoding

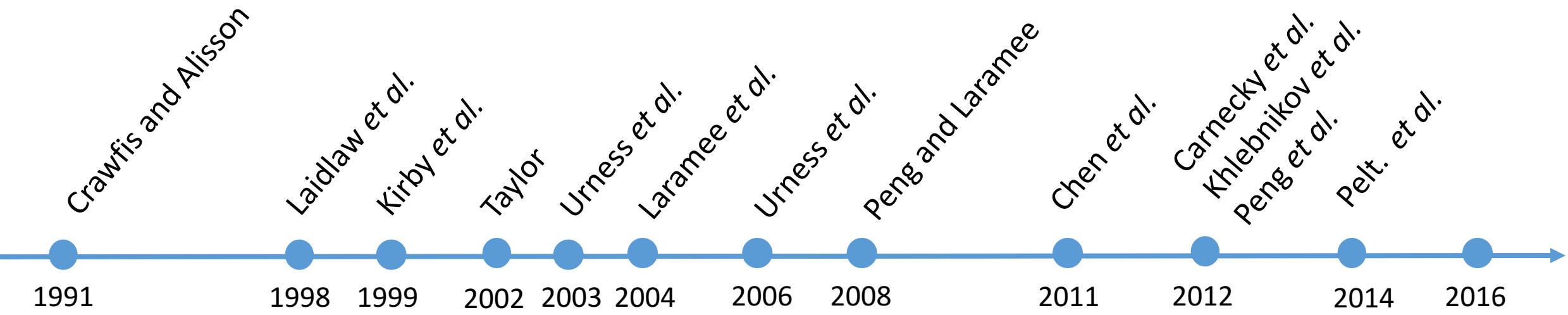
1st Layer
- Ellipse **glyphs** (divergence)

2nd Layer
- **Colors** (vorticity)

3rd Layer
- Arrow **glyphs** (velocity)

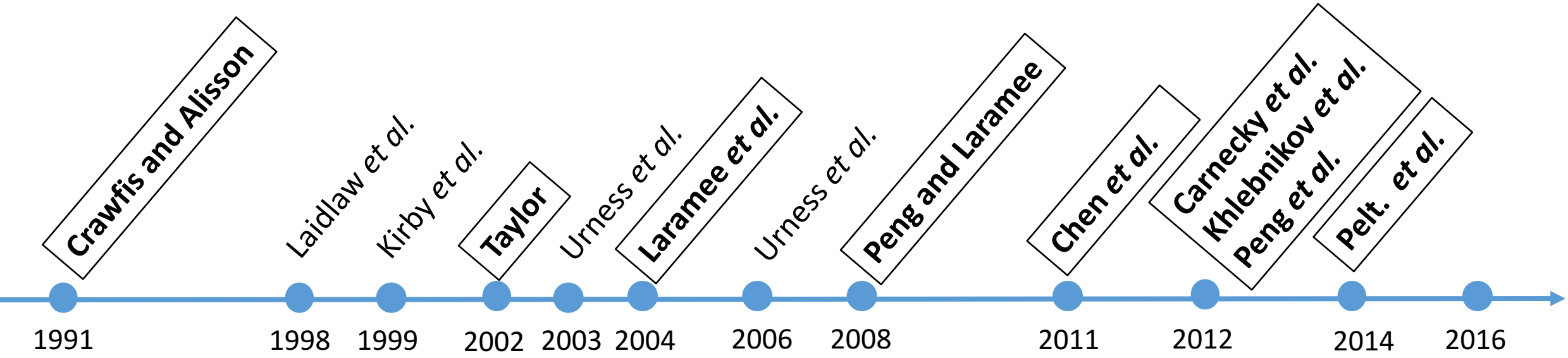
Layering on Surfaces

Previous Work



Previous Work

☐ Layering on Surfaces



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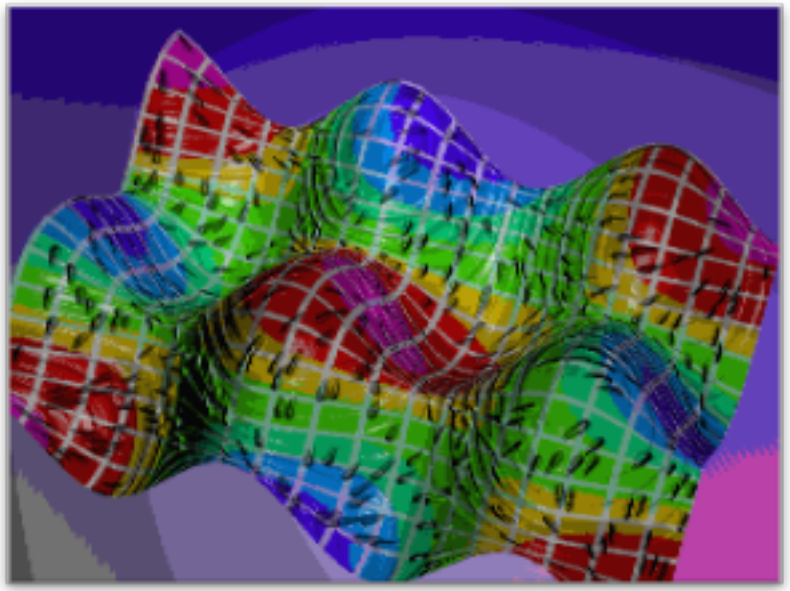
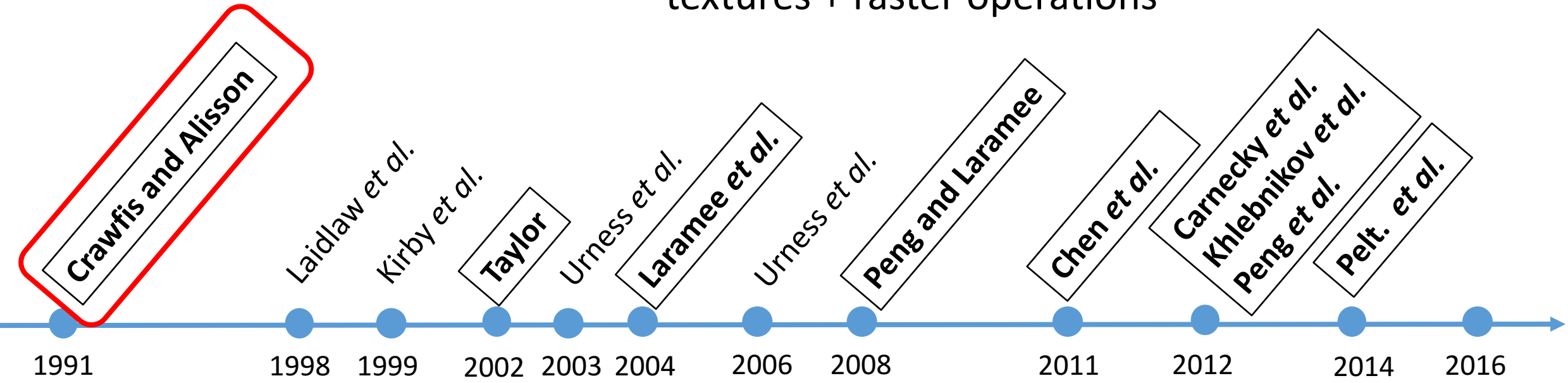
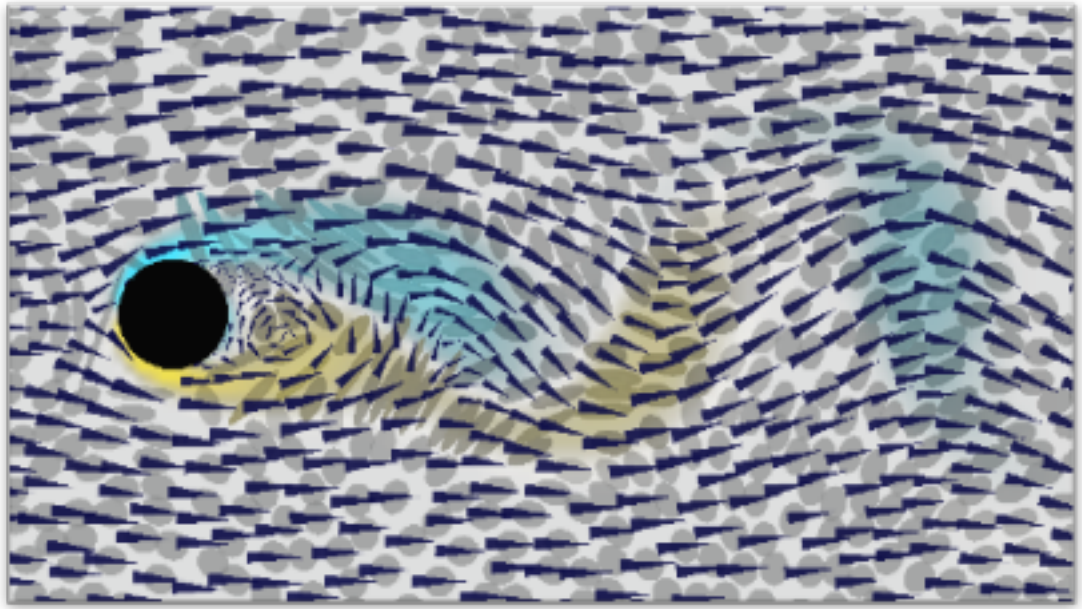


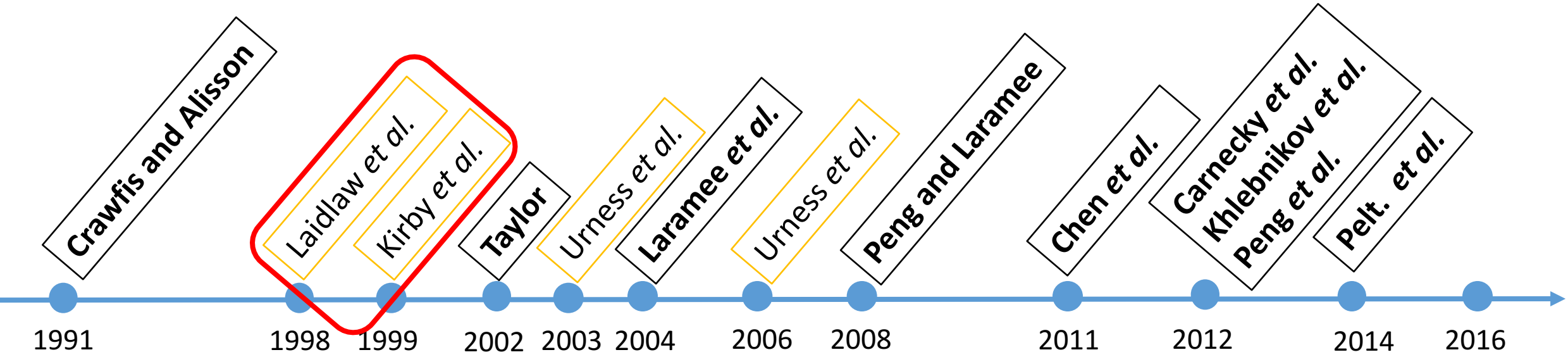
textures + raster operations



Previous Work

- 2D Layering
- Layering on Surfaces

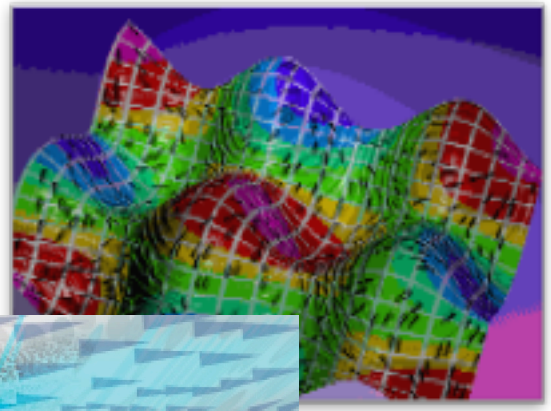


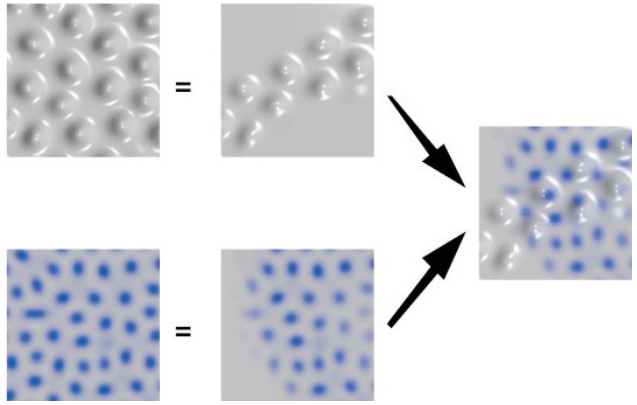


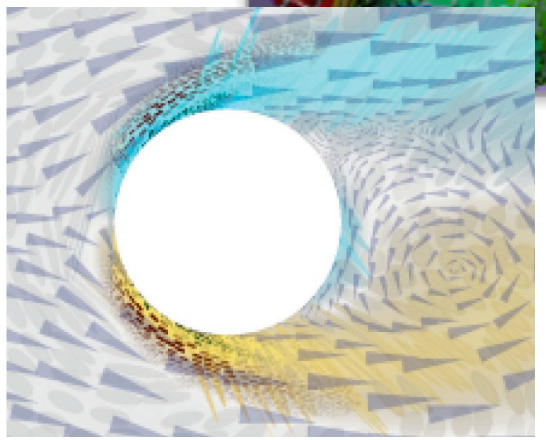
Previous Work

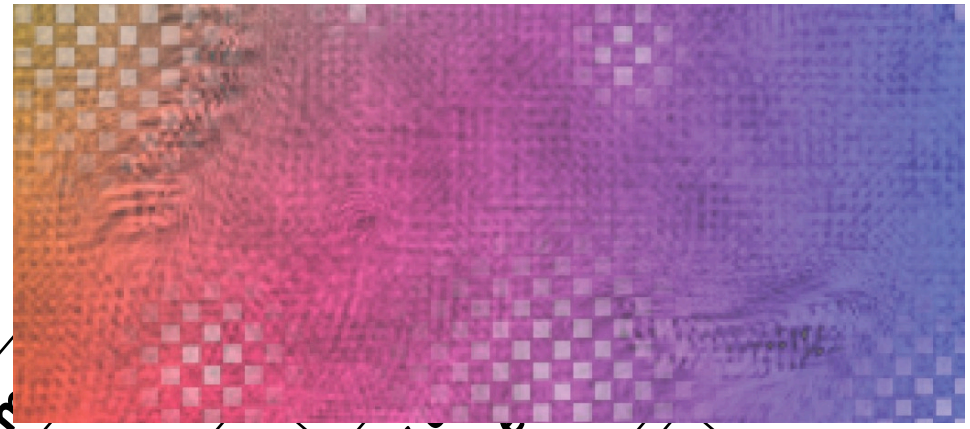
2D Layering

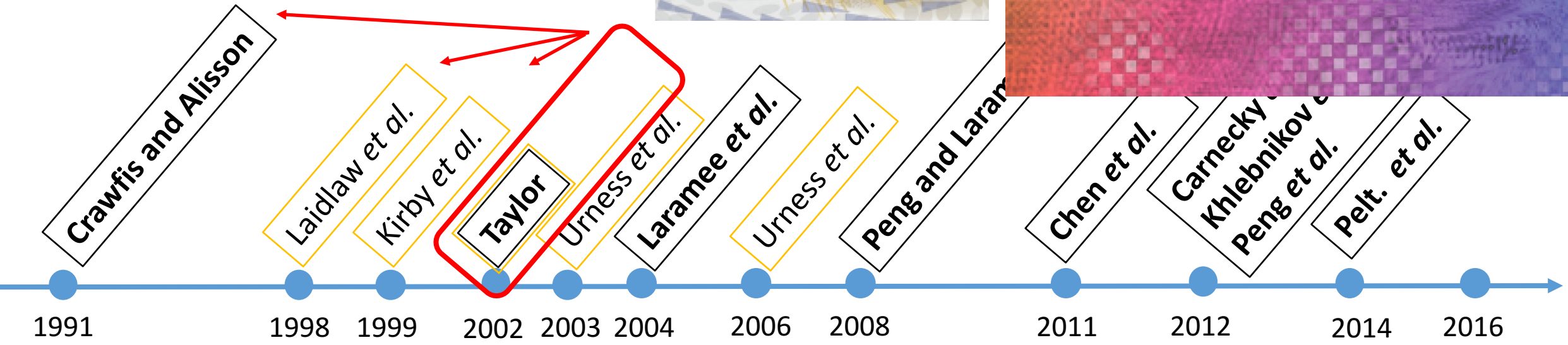
Layering on Surfaces







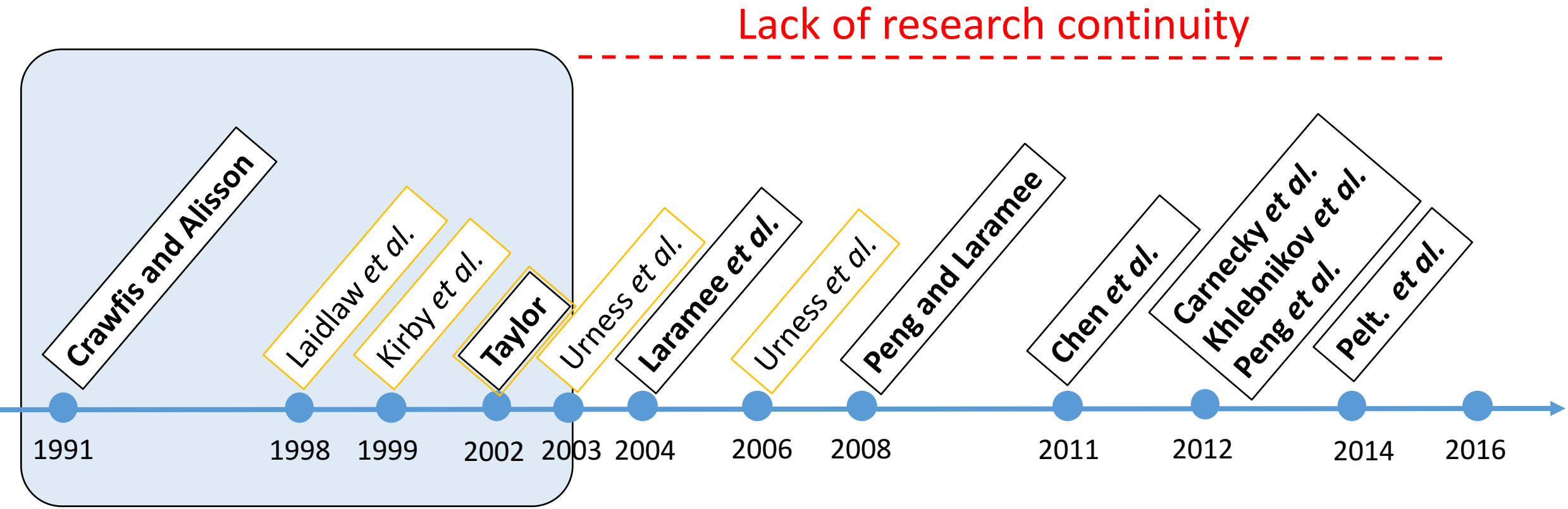




Previous Work

2D Layering

Layering on Surfaces

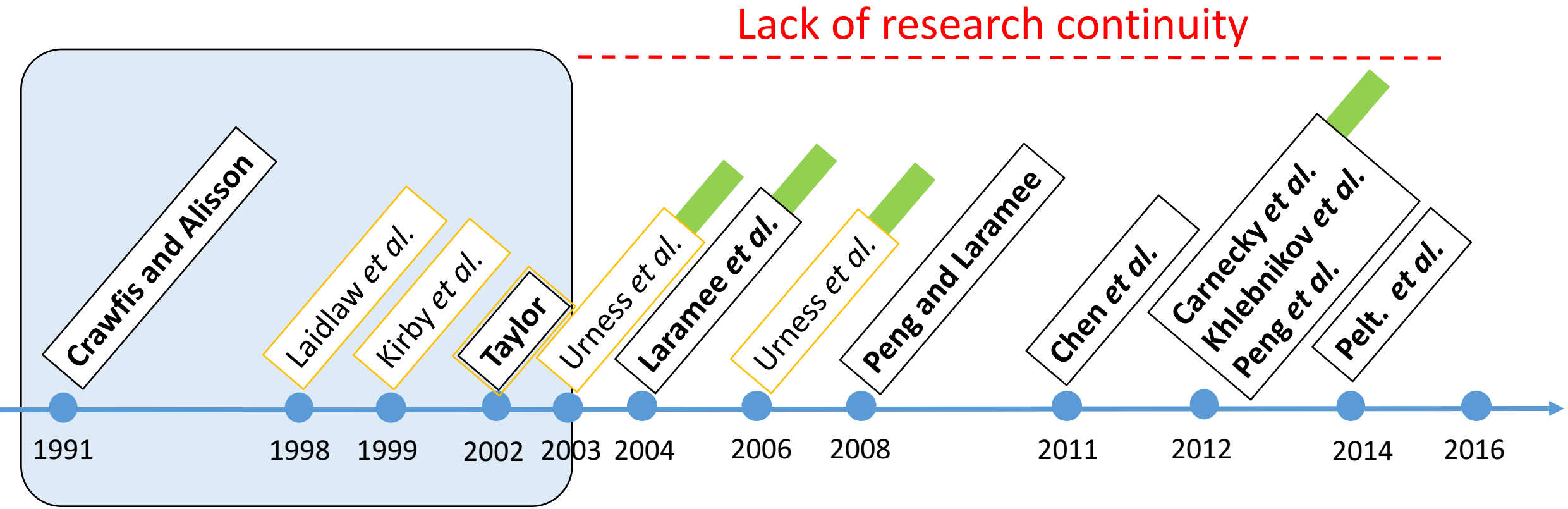


Previous Work

LIC + colormap

2D Layering

Layering on Surfaces



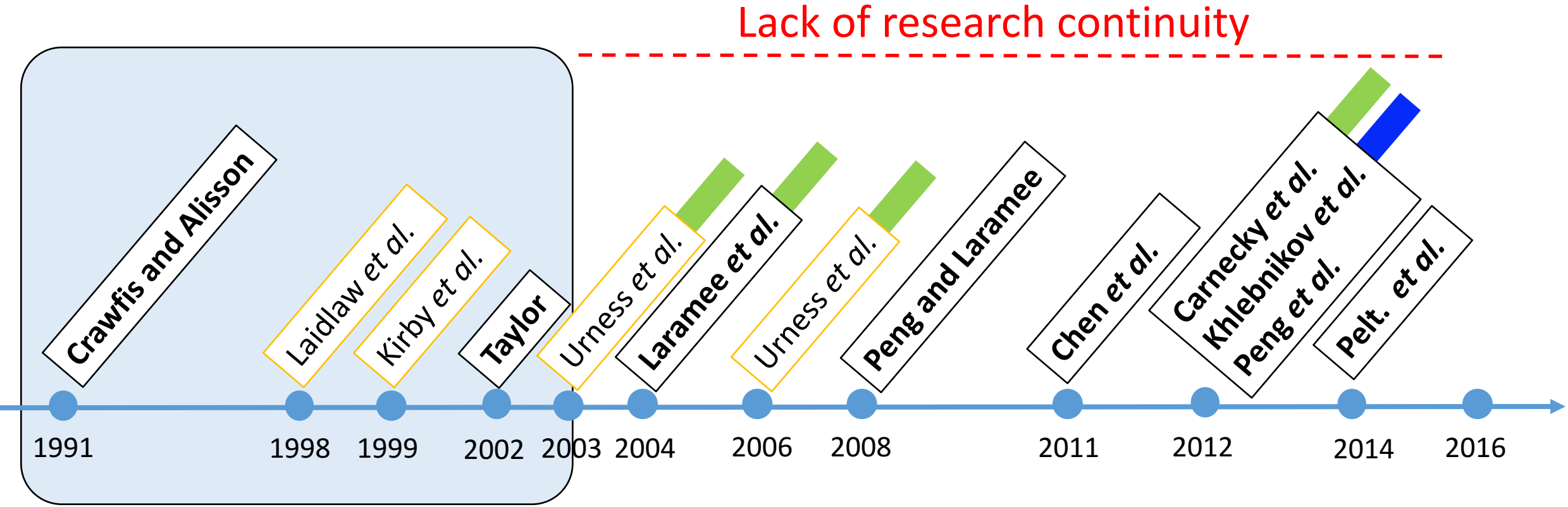
Previous Work

LIC + colormap

Procedural noise

2D Layering

Layering on Surfaces



Previous Work

2D Layering

Layering on Surfaces

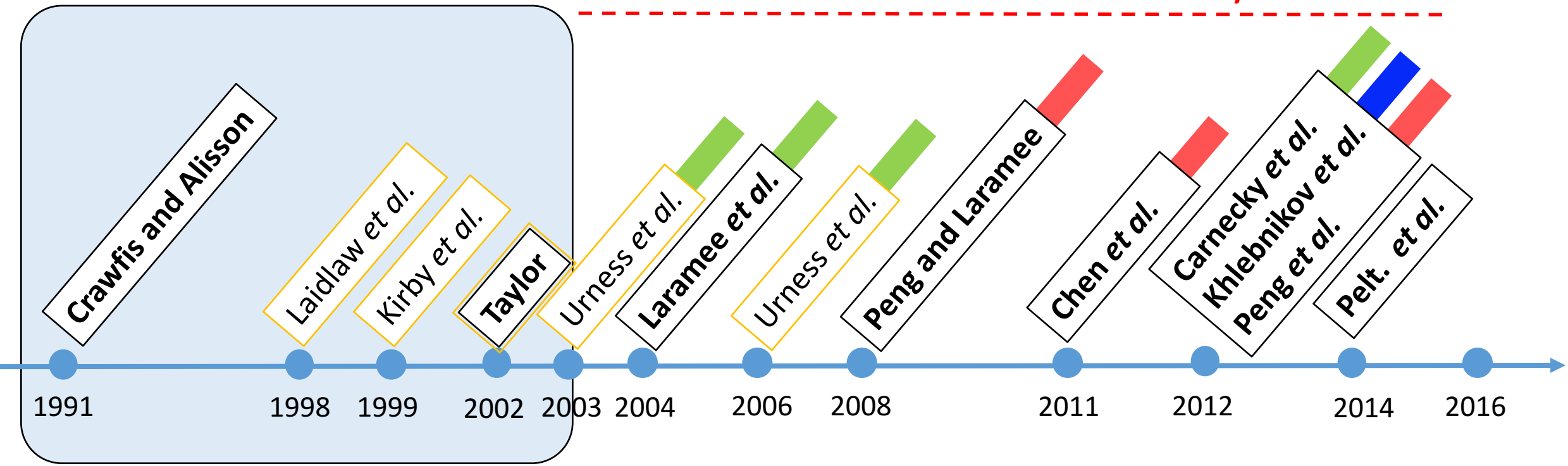
LIC + colormap

Procedural noise

image-space

2D-glyphs

Lack of research continuity



Previous Work

2D Layering

Layering on Surfaces

LIC + colormap

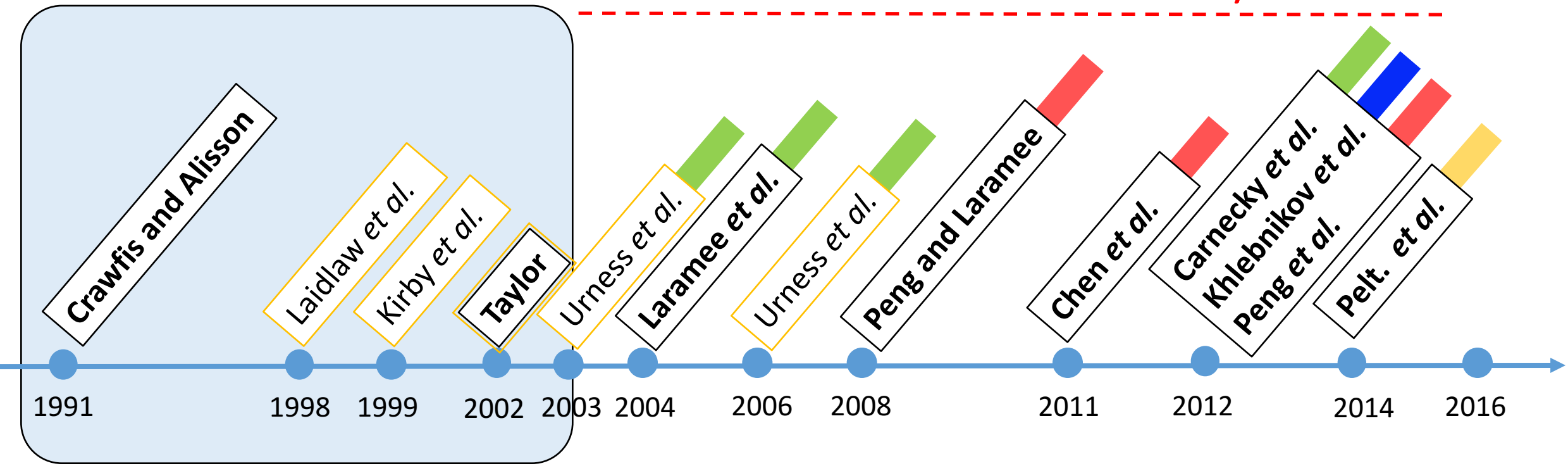
Procedural noise

2D-glyphs

image-space

object-space

Lack of research continuity

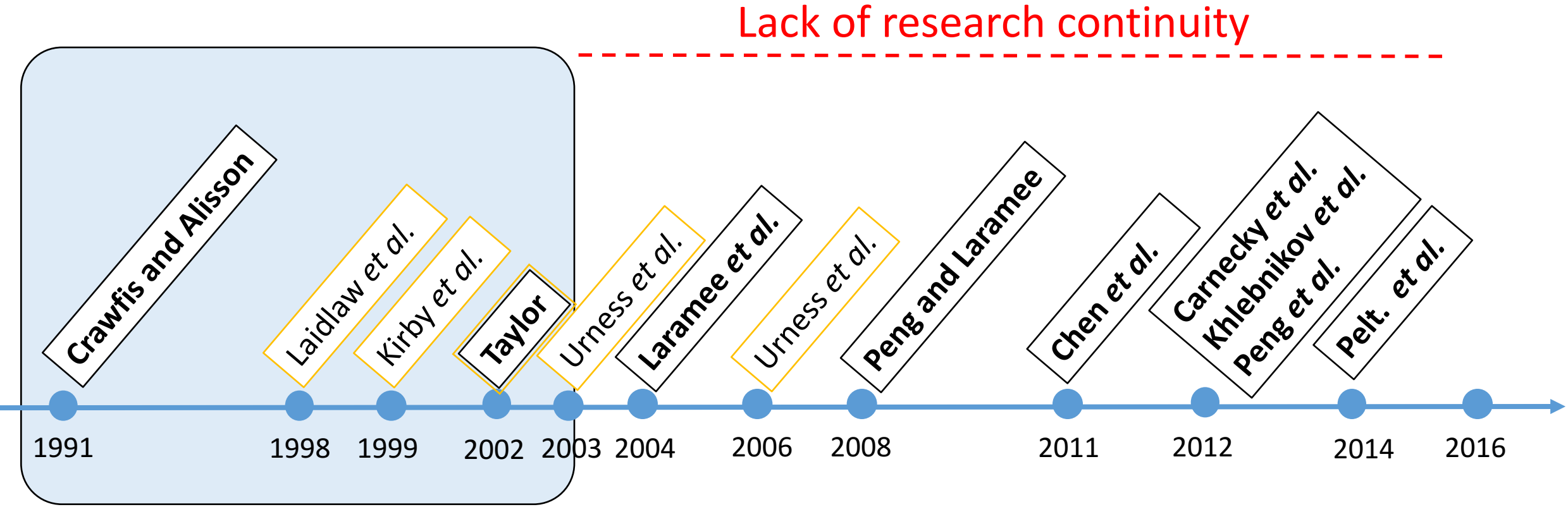


Previous Work

2D Layering

Layering on Surfaces

- Difficult to render 2D-glyphs and other visual representations on *arbitrary surfaces*



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2D Layering

Layering on Surfaces

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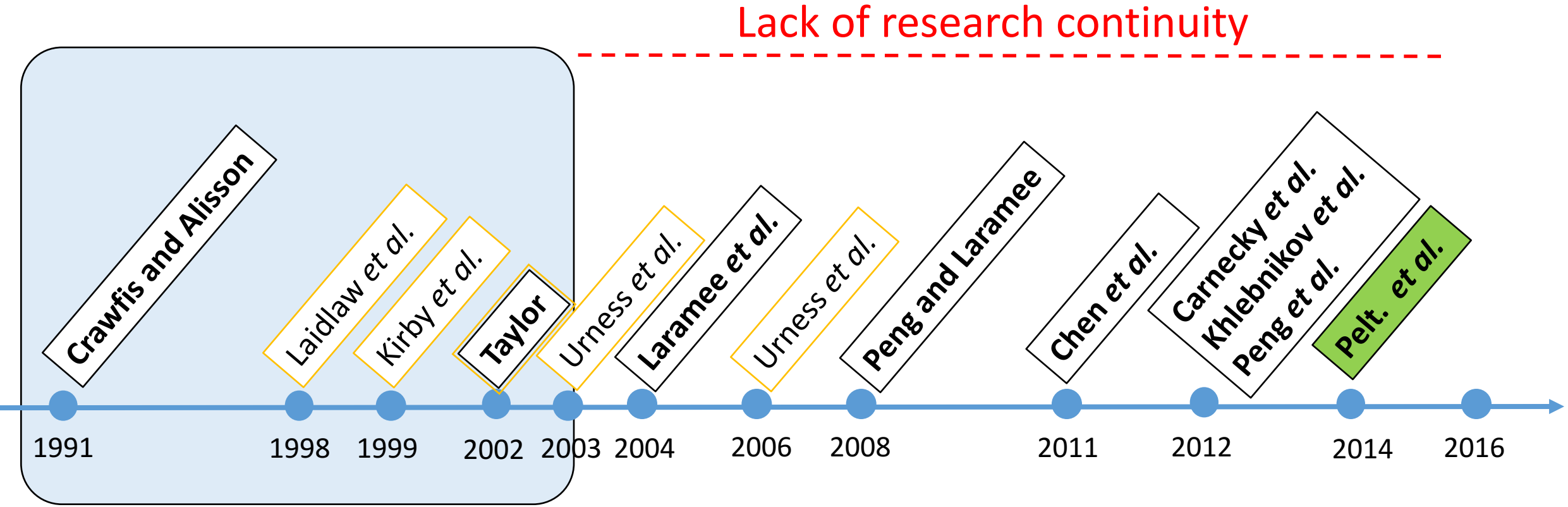
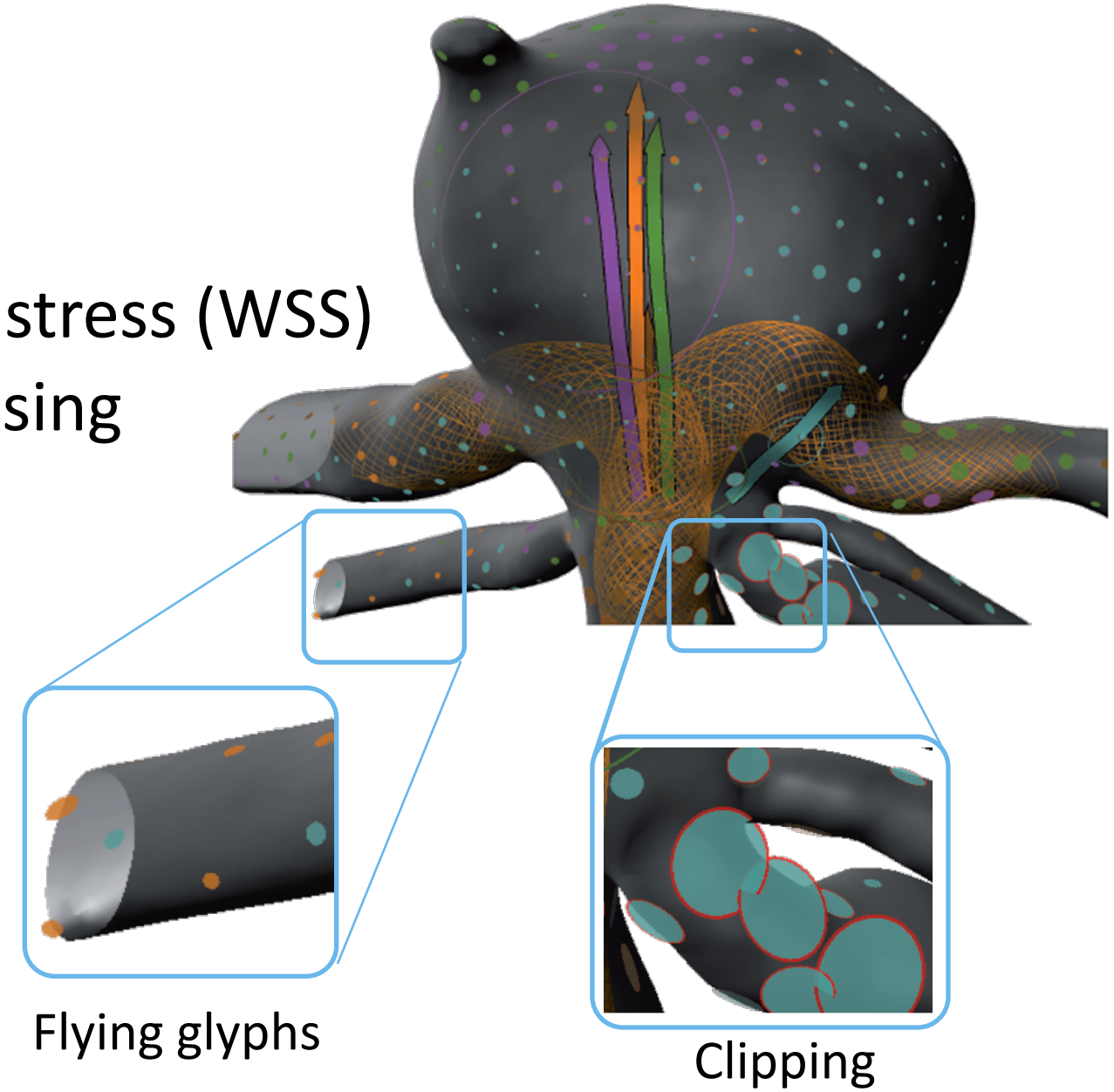


Previous Work

- Pelt. *et al., 2014*
  - Visualization of wall shear stress (WSS)
  - Design of four 2D-glyphs using **oriented quads**

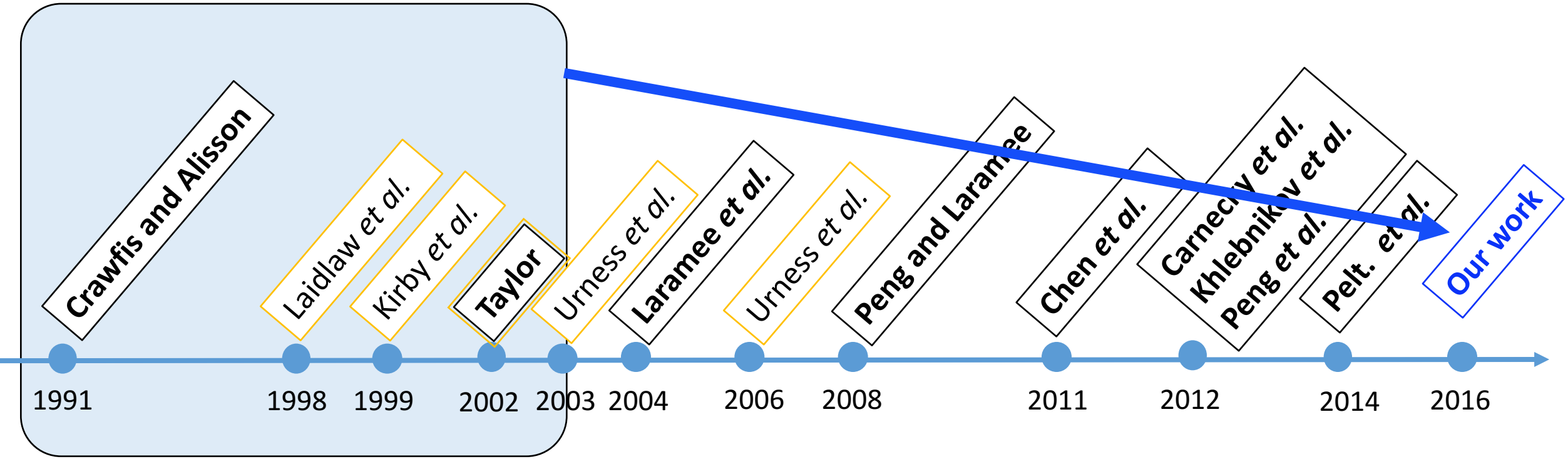


Research Goal

2D Layering

Layering on Surfaces

- A technique to place 2D representations on arbitrary surfaces.
- Visual design on surfaces similar to 2D
- Extend the concept of layering to co-visualize a high number of attributes on surfaces.

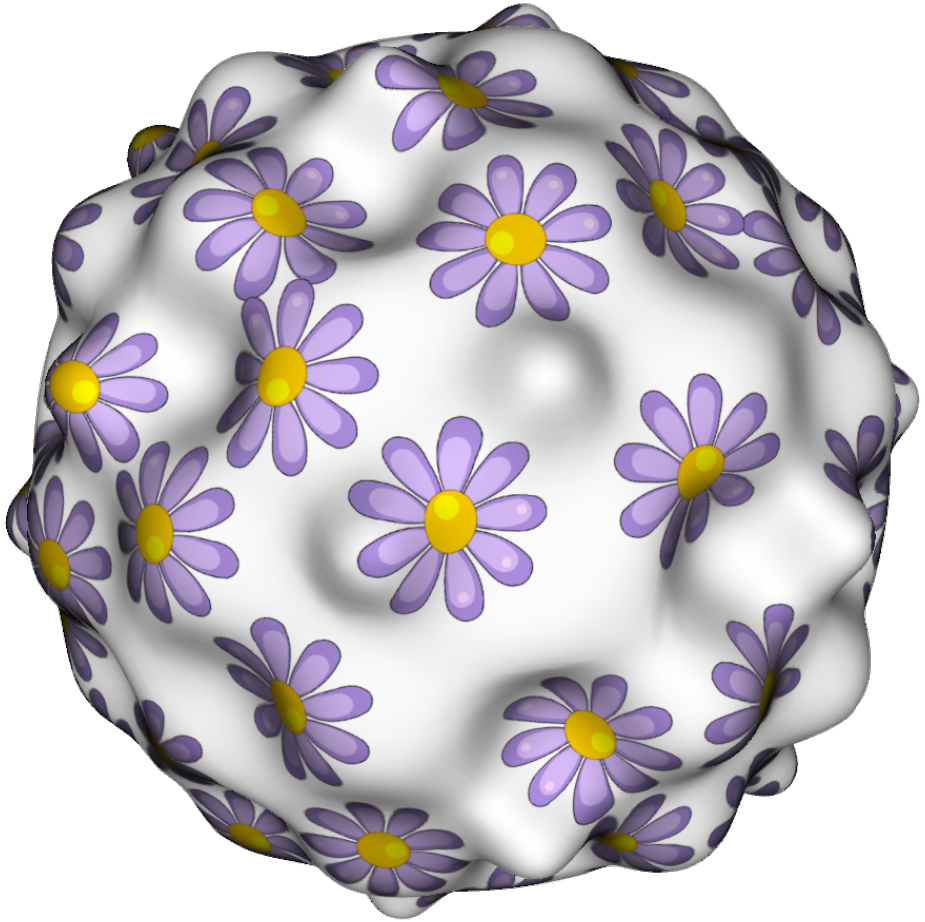


Our Approach

Decals

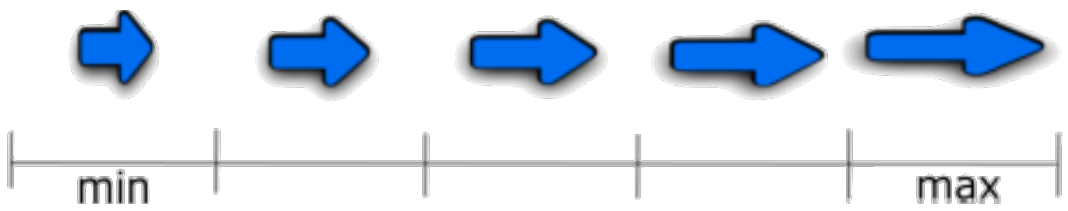
Definition. *Visual representations (a pattern, a text, a glyph, or a symbol) transferred from a 2D-image to a surface.*

Decal

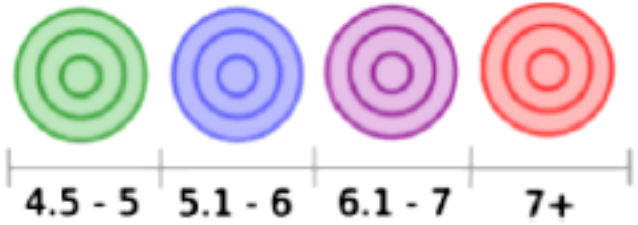


Decal-maps

Definition. *A set of images designed to represent one or more data attributes.*



Water flow decal-map



Earthquake decal-map

Decal-maps

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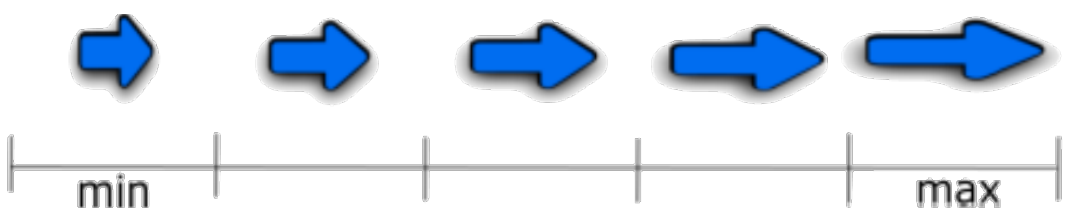
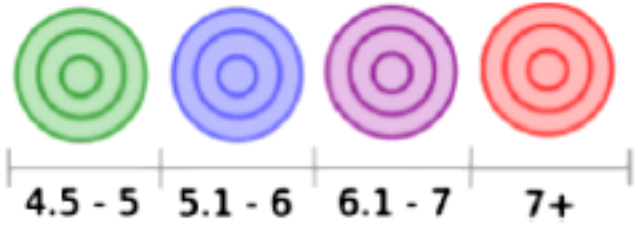


Water flow decal-map



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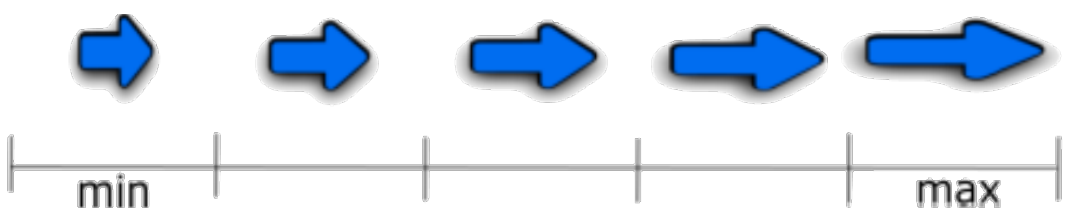
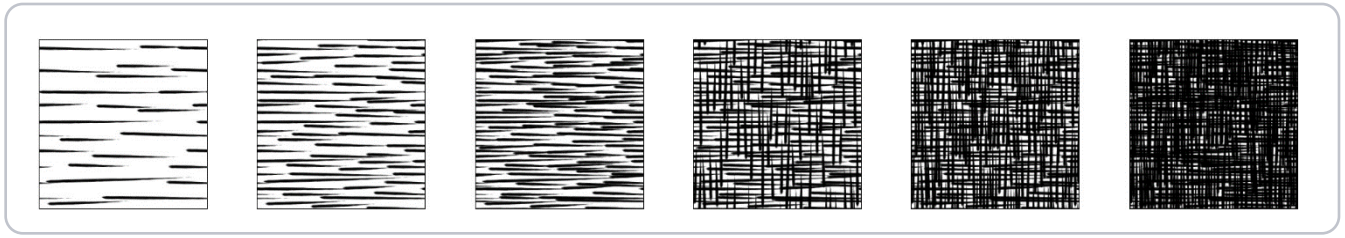
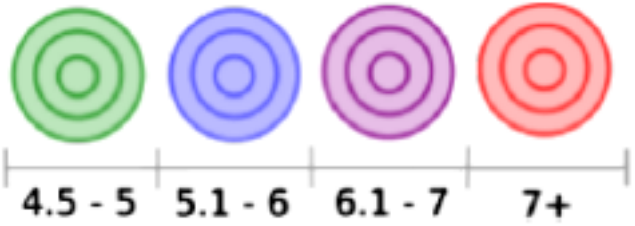


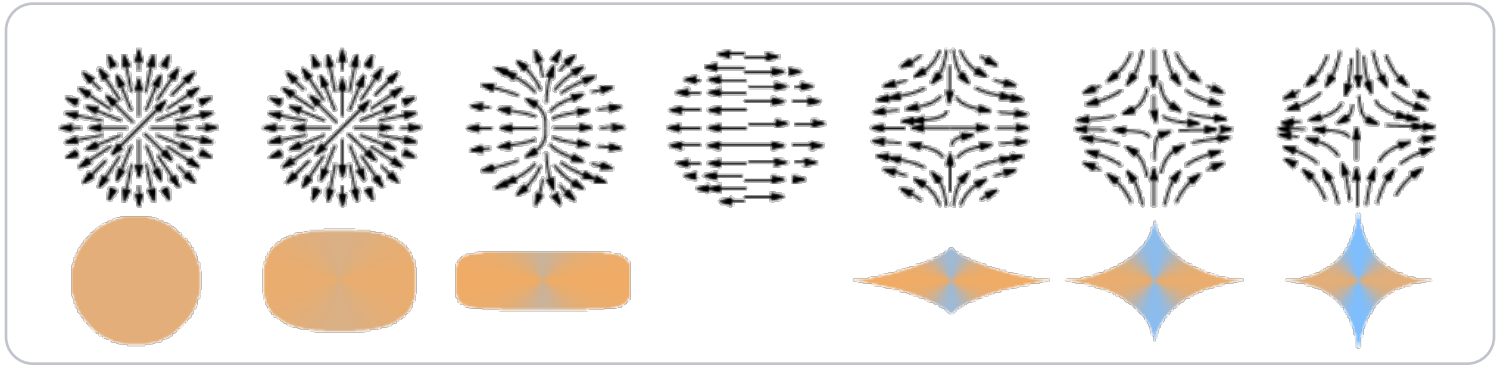
Water flow decal-map



[Praun et al., *TOG*, 2016]



Earthquake decal-map



[Seltzer and Kindlmann, *CGF*, 2016]

Decals – Previous Work

- Focus on aesthetic value

Character editing

[Schmidt *et al.*, 2006]

[de Groot *et al.*, 2013]

Games

[Krassnigg, 2010]

Decals for Visualization - ?

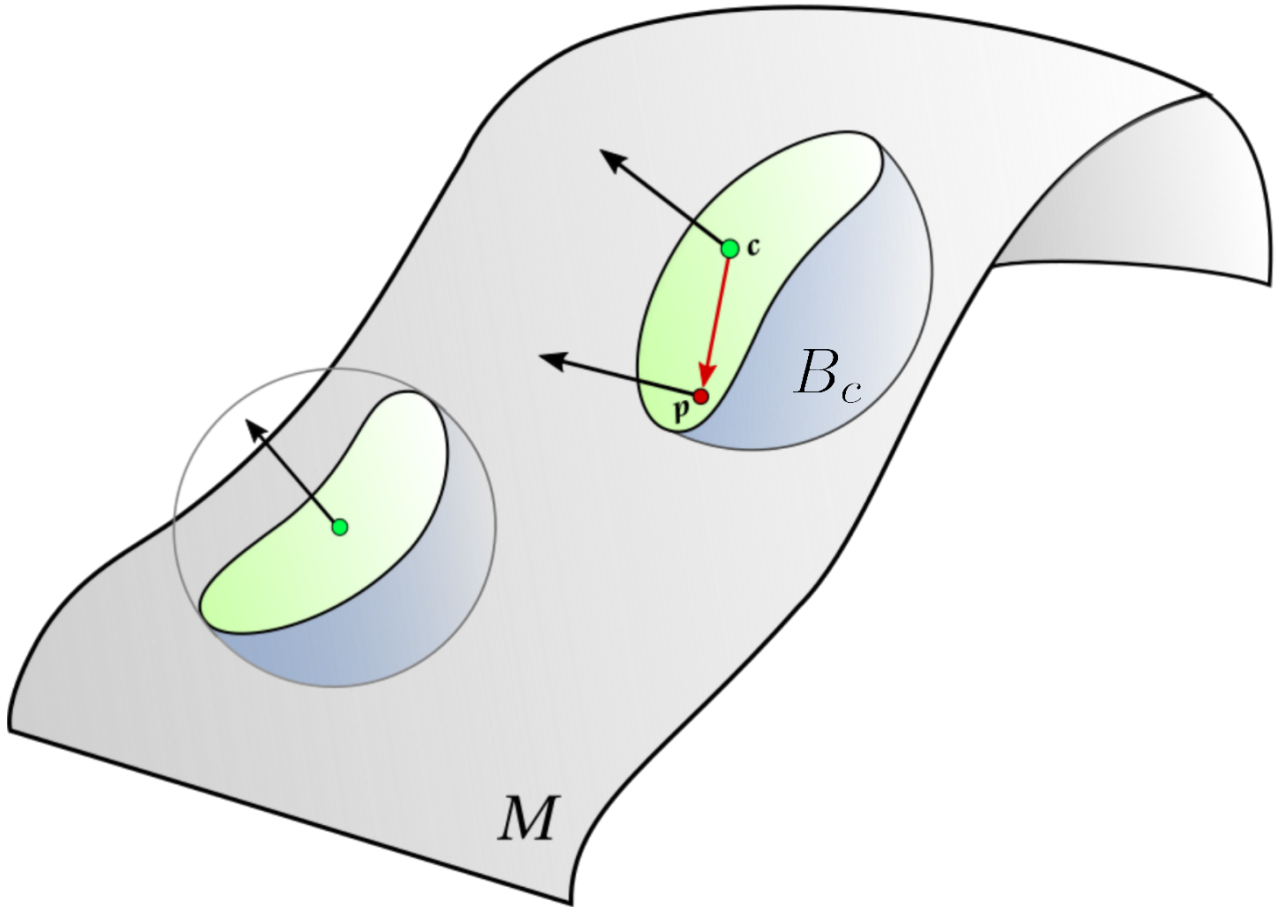
- First technique using decals for multivariate visualization

- Stringent requirements in visualization
  - Should be independent of surface parametrization
  - Should not rely on topological information
  - Should be simple and efficient

Proposed Technique

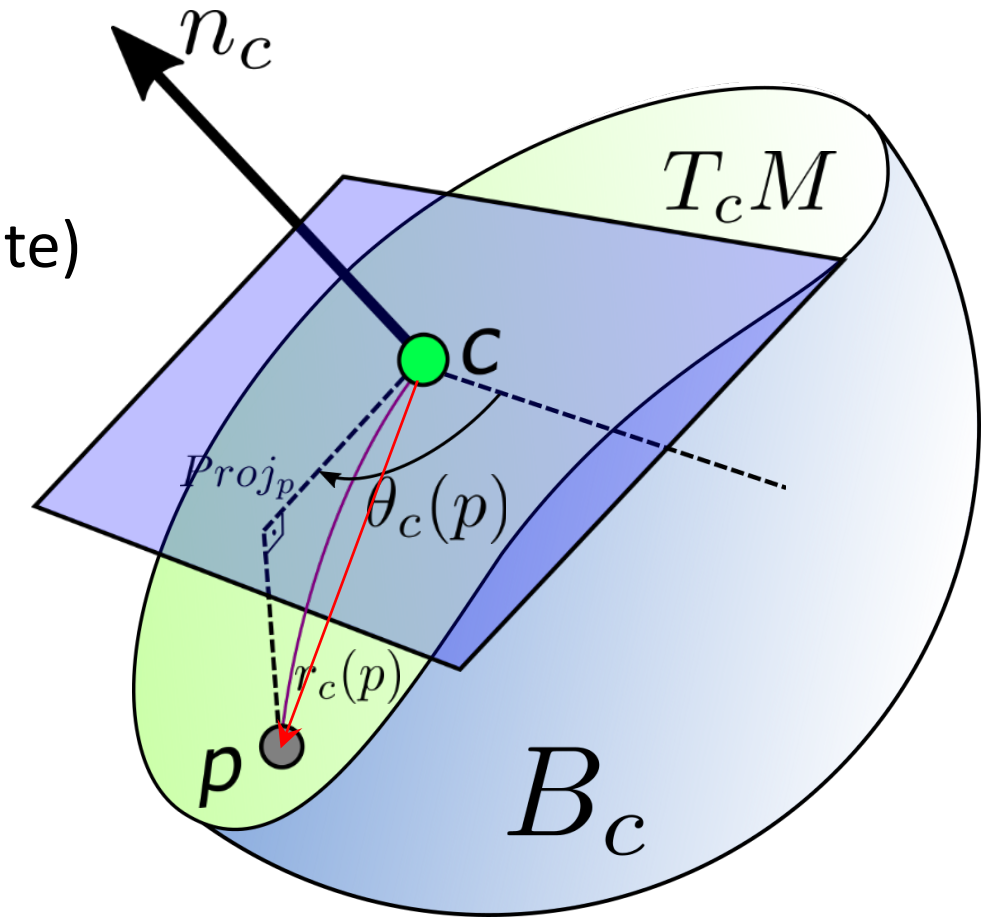
Proposed Technique – *Layered Decals*

- Sphere Mask: solid sphere intersected with a surface is a disk



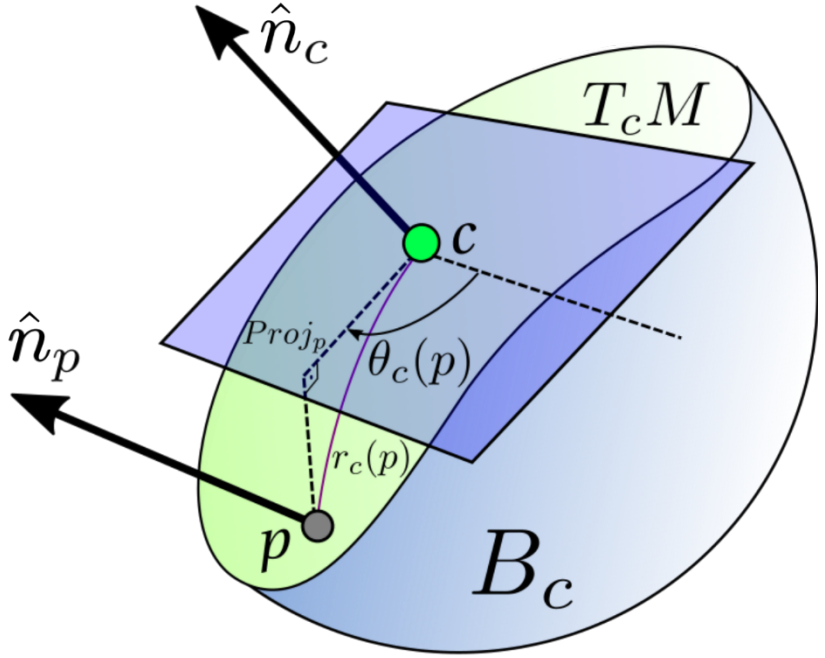
Proposed Technique – *Layered Decals*

- Local parametrization (exponential maps)
  - Angular coordinate $\theta_c(p)$
  - Radial coordinate $r_c(p)$
    - Geodesic (difficult and costly to compute)
  - Decals are small: fine distortions not required [de Groot *et al.*, 2013]
  - Geodesic approximation
    - Euclidean distance $\|p - c\|$
    - Paper discusses two other distances (Bowers *et al*, 2010; Geng *et al.* 2011).



Proposed Technique – *Layered Decals*

- Compute the sphere masking:
  - Area of the surface inside the sphere
- Build the local parametrization
- Apply a decal

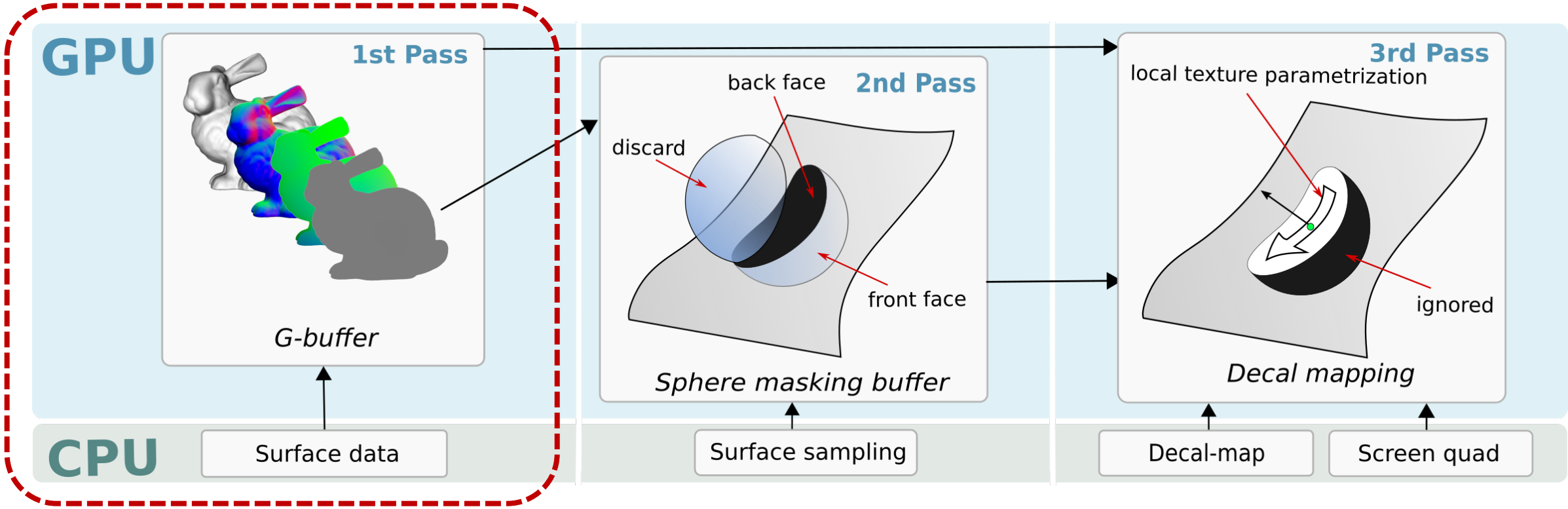


Local Parametrization

Implementation

GPU-based Implementation

- Overview



Layered decals

GPU-based Implementation

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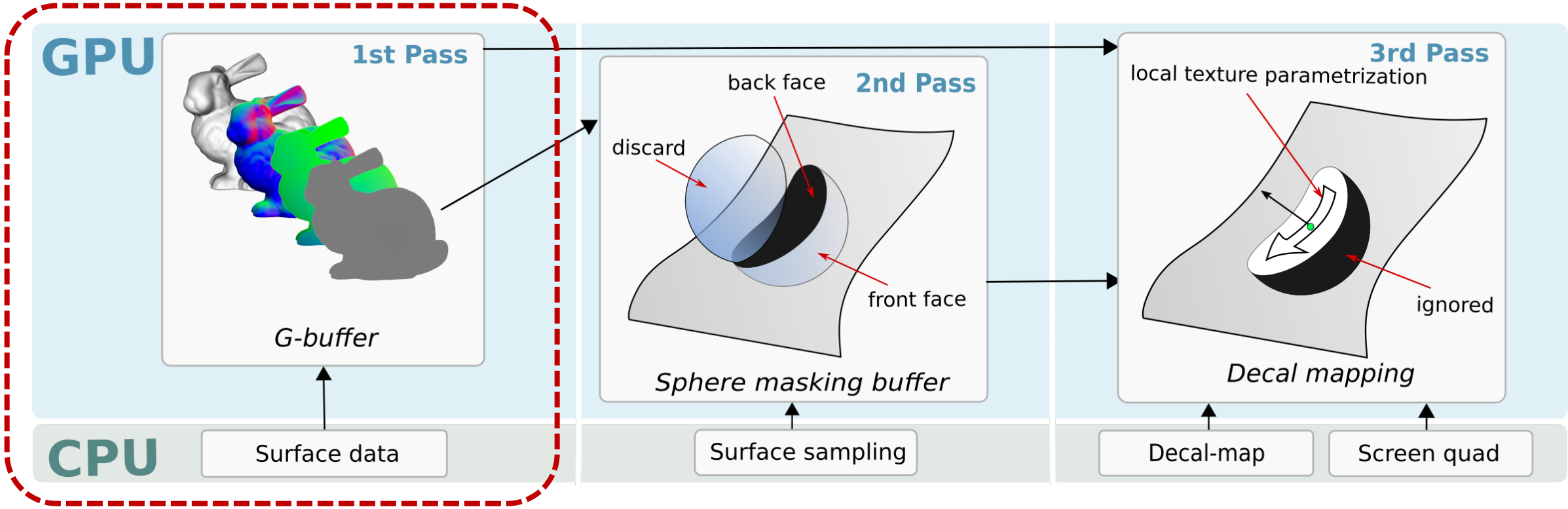

Layered decals

GPU-based Implementation

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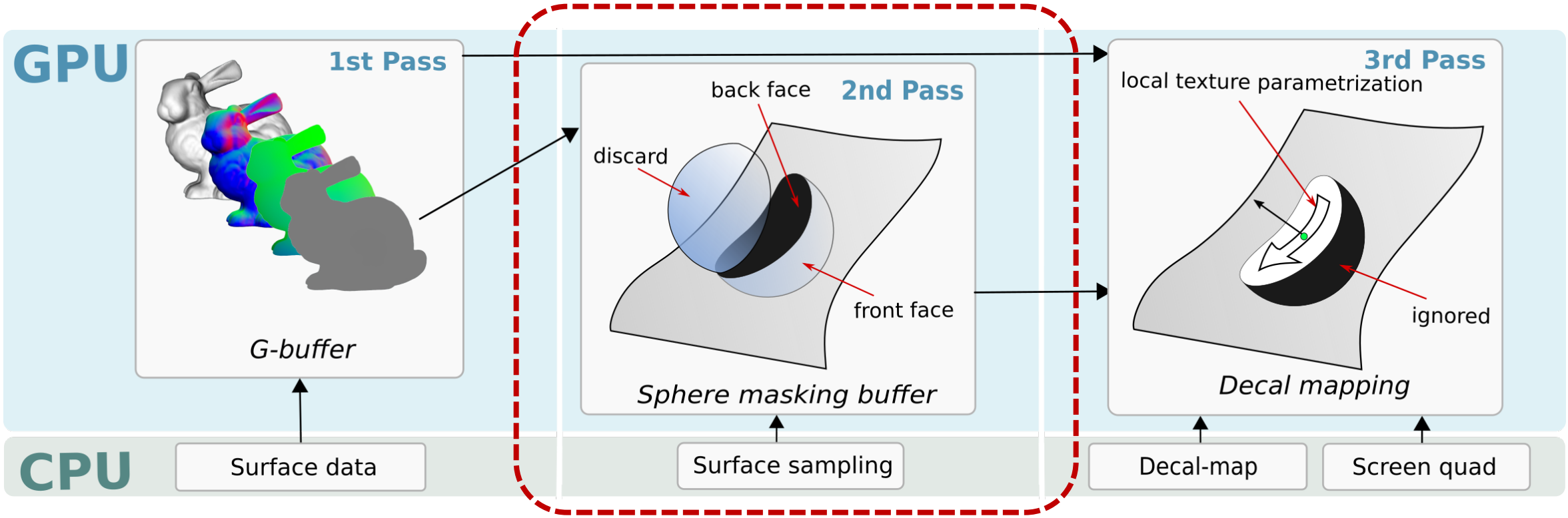
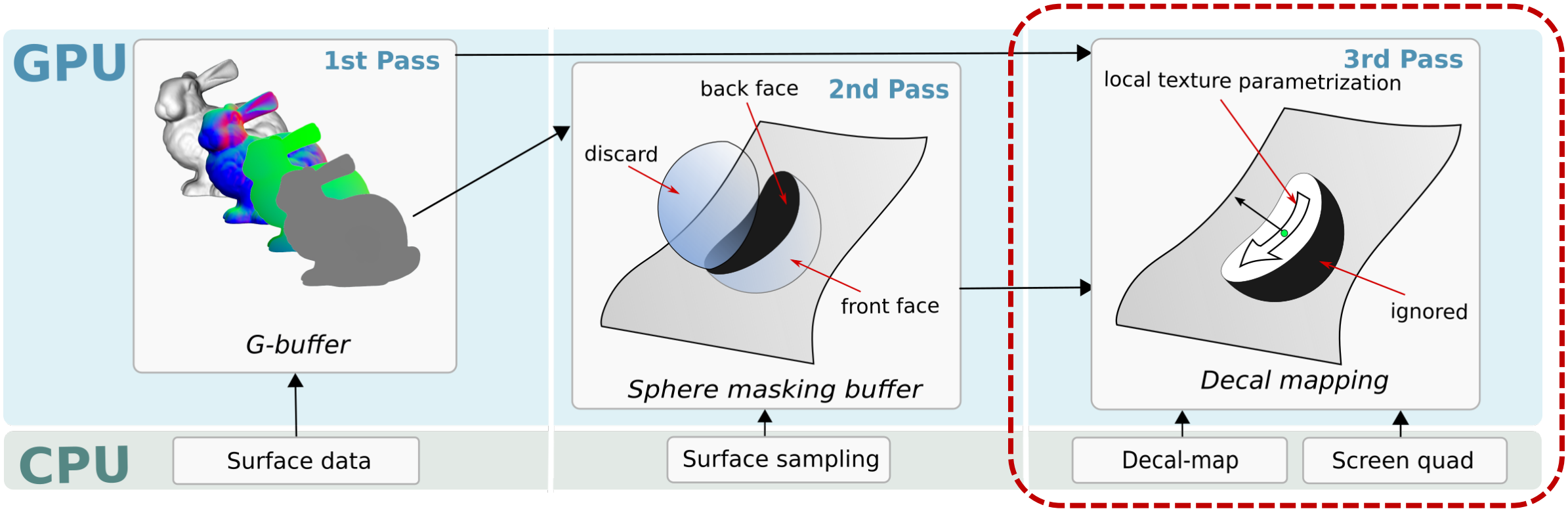


Layered decals

GPU-based Implementation

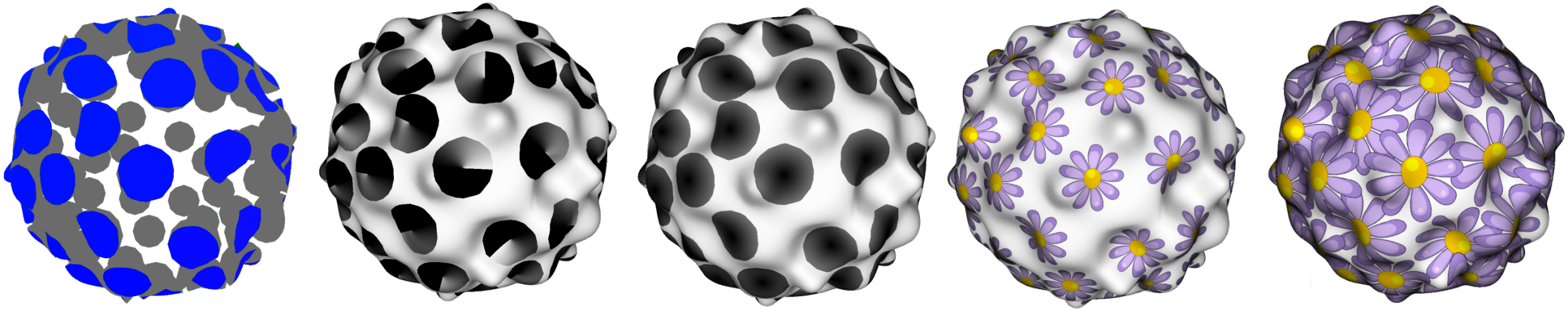
- Overview



Decal overlapping refer to the paper

Layered Decals

- Implementation Steps

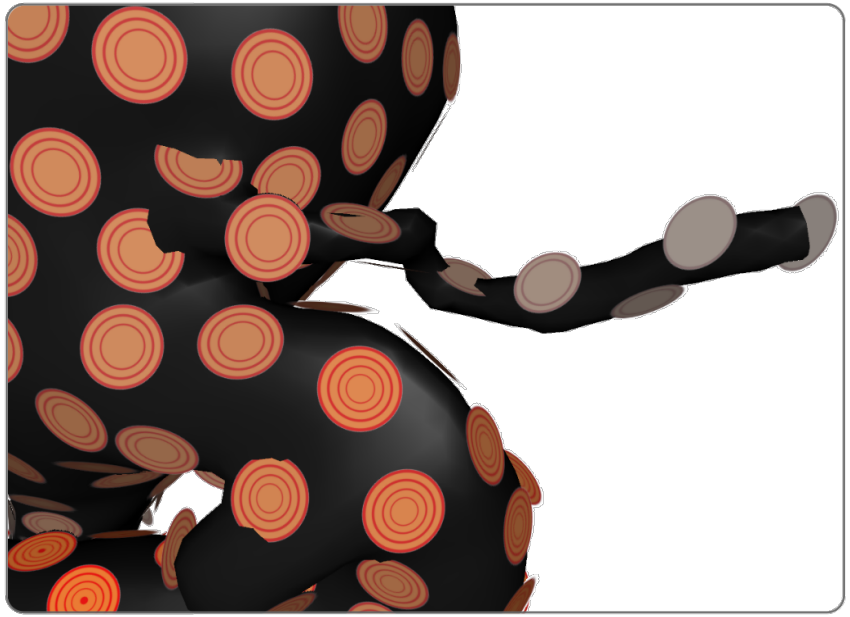


Sphere masking | Angular coordinate | Radial coordinate | Decal mapping | Decal overlapping

Results

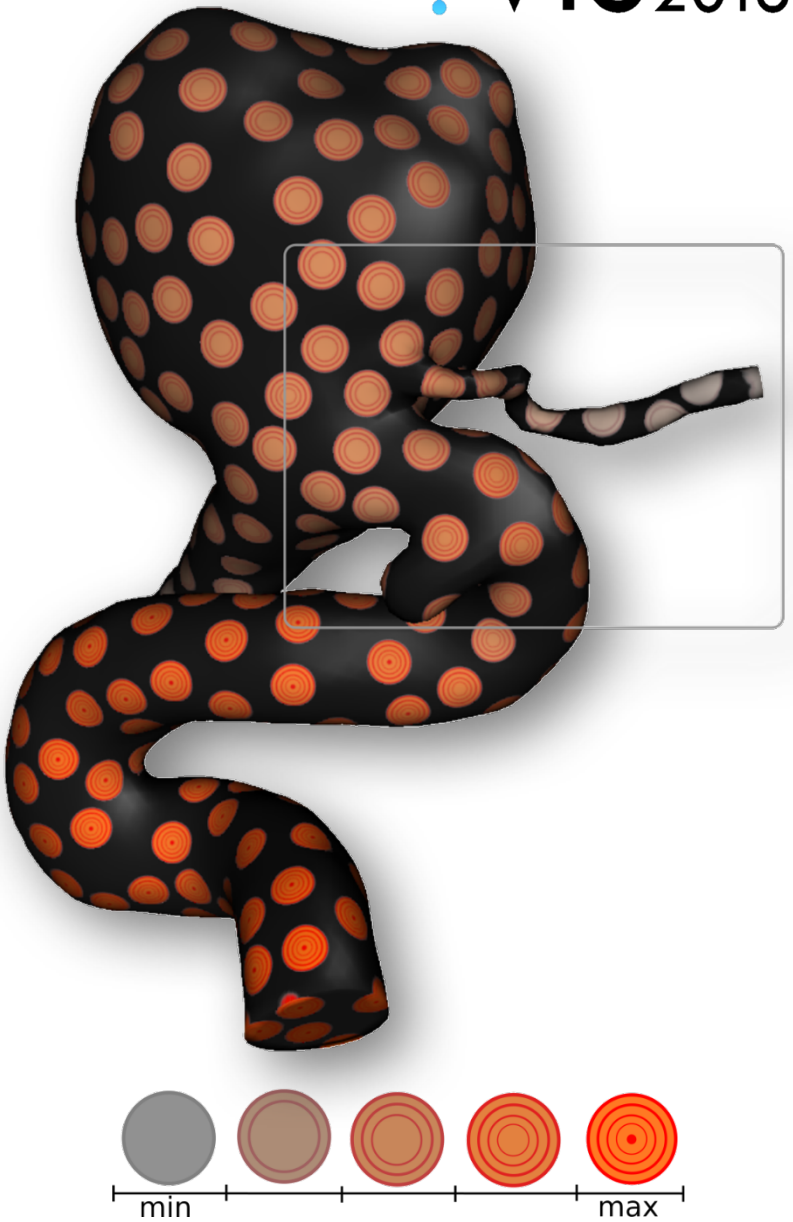
Decal mapping

- Aneurysm data



Quad-based method
[Inspired by Pelt *et al.*, 2014]

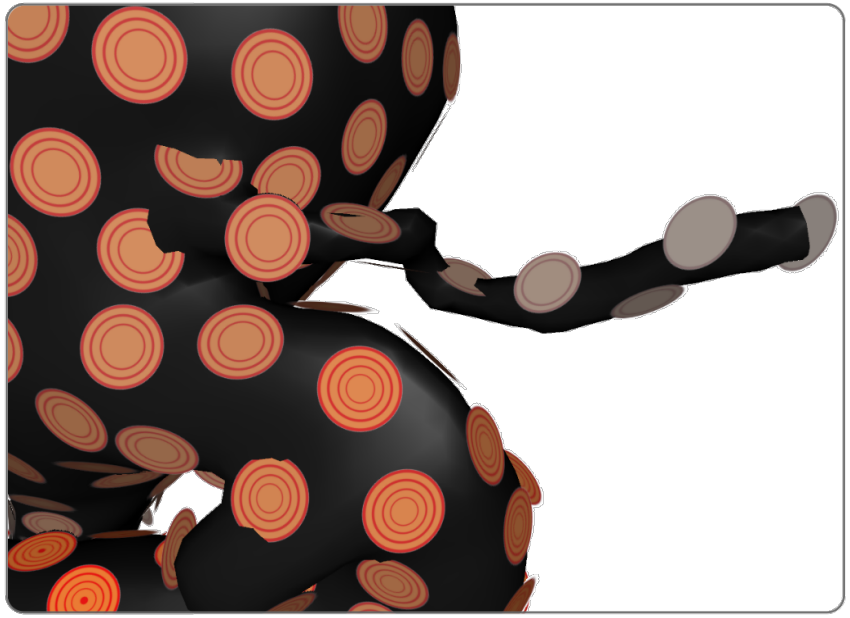
Decal-based method
(our approach)



Pressure decal-map

Decal mapping

- Aneurysm data



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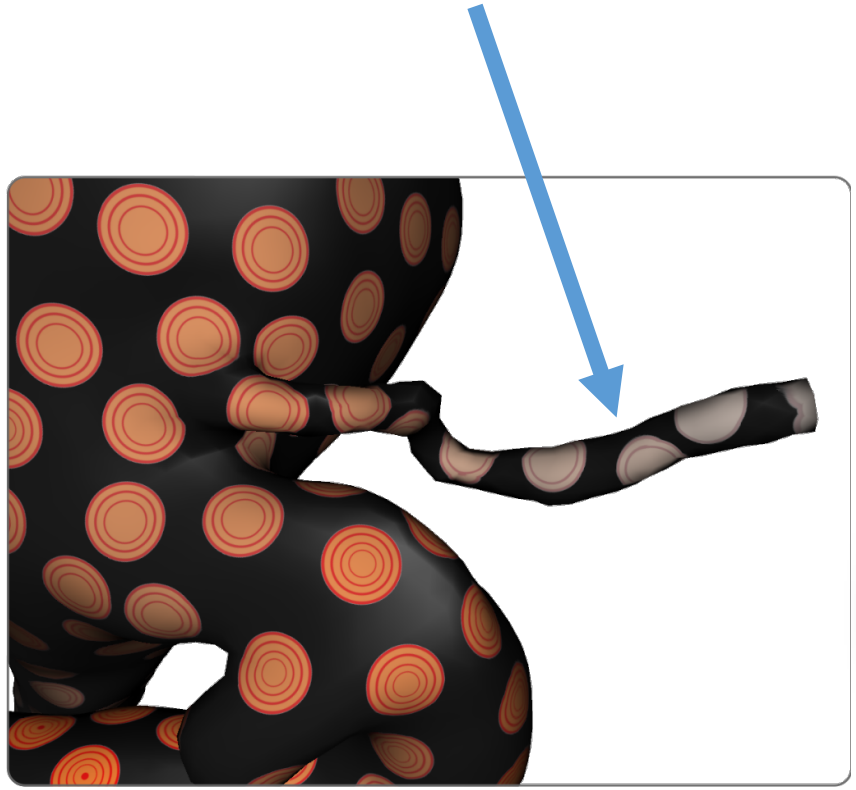

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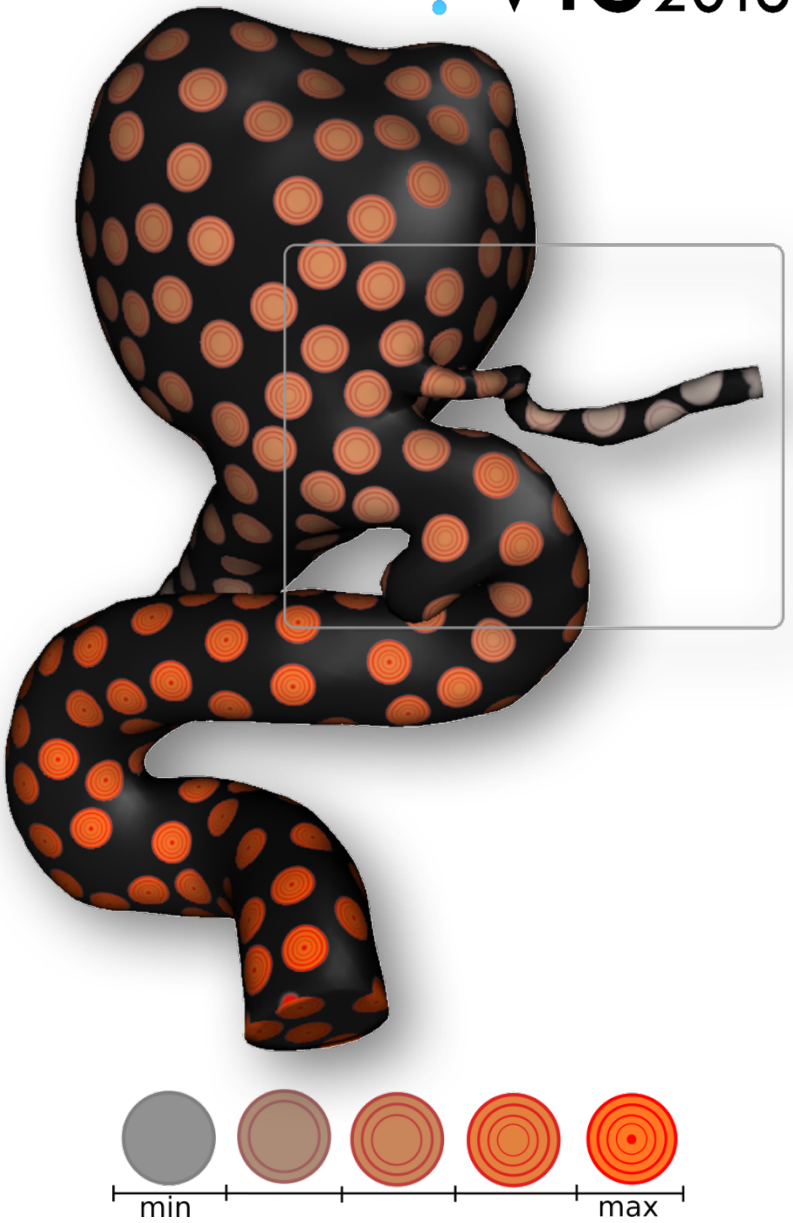


Pressure decal-map

Results: Multivariate Visualization Design

Results

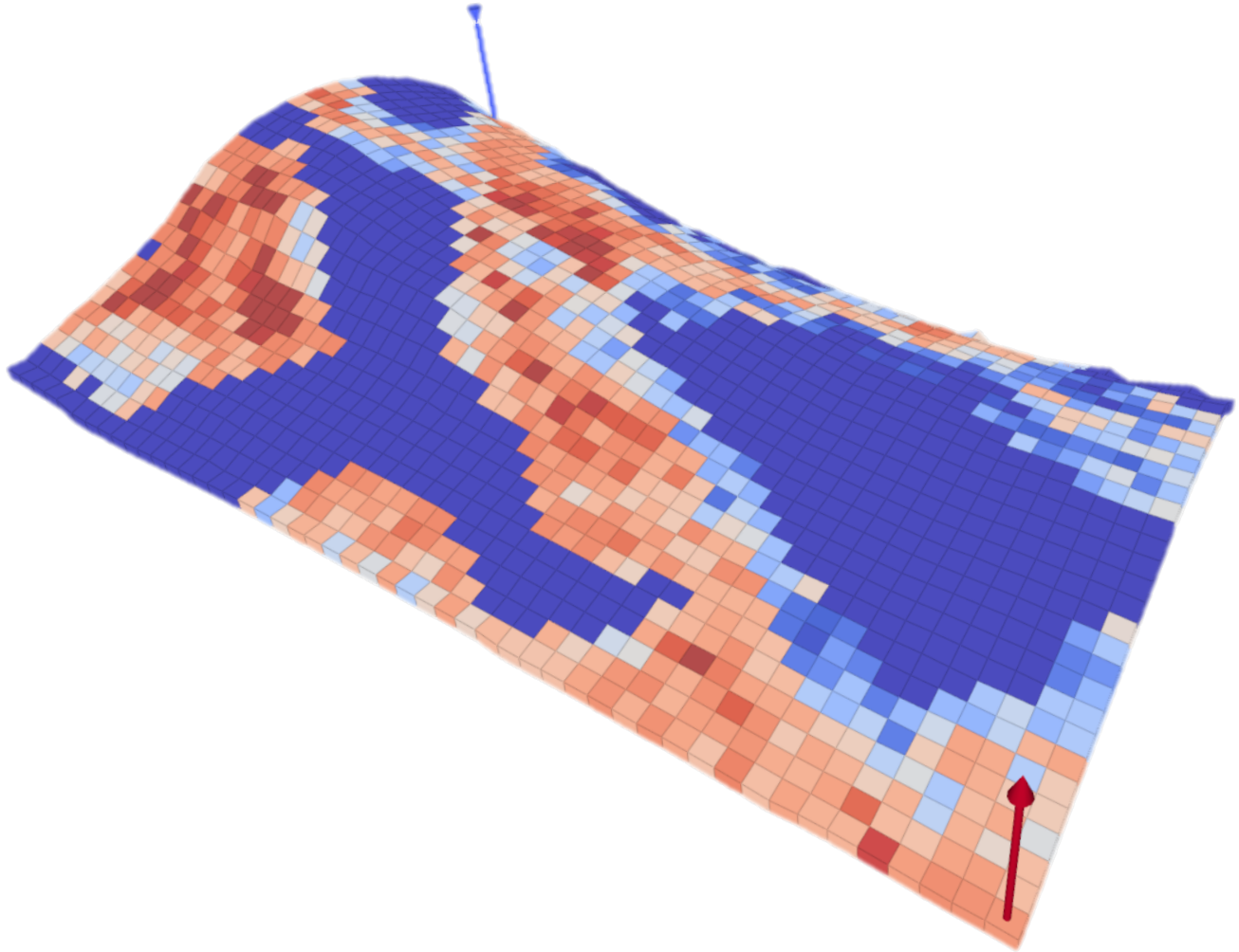
- Two case studies
  - Multivariate Geographic Visualization
  - **Multivariate Geological Visualization**

- Apply the layering concept on surfaces using decal-maps
- Represent several attributes in a single view

Results: Multivariate Visualization Design

Multivariate Geological Visualization Design

- Attributes
  - Rock type
  - Porosity
  - Water Flow
    - Magnitude and direction
  - Oil Flow
    - Magnitude and direction



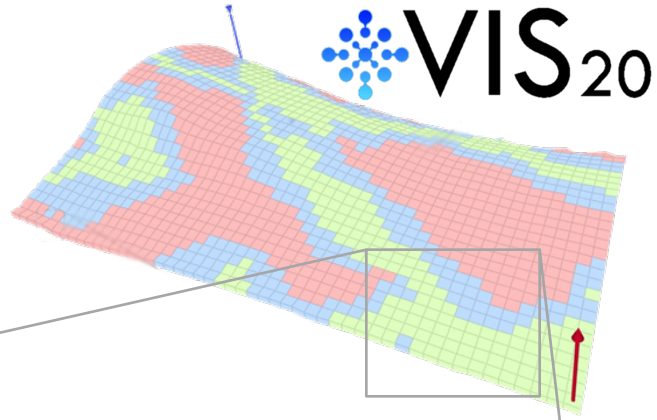
Geological Reservoir Model

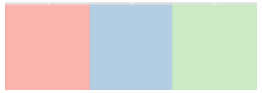
Layering Process

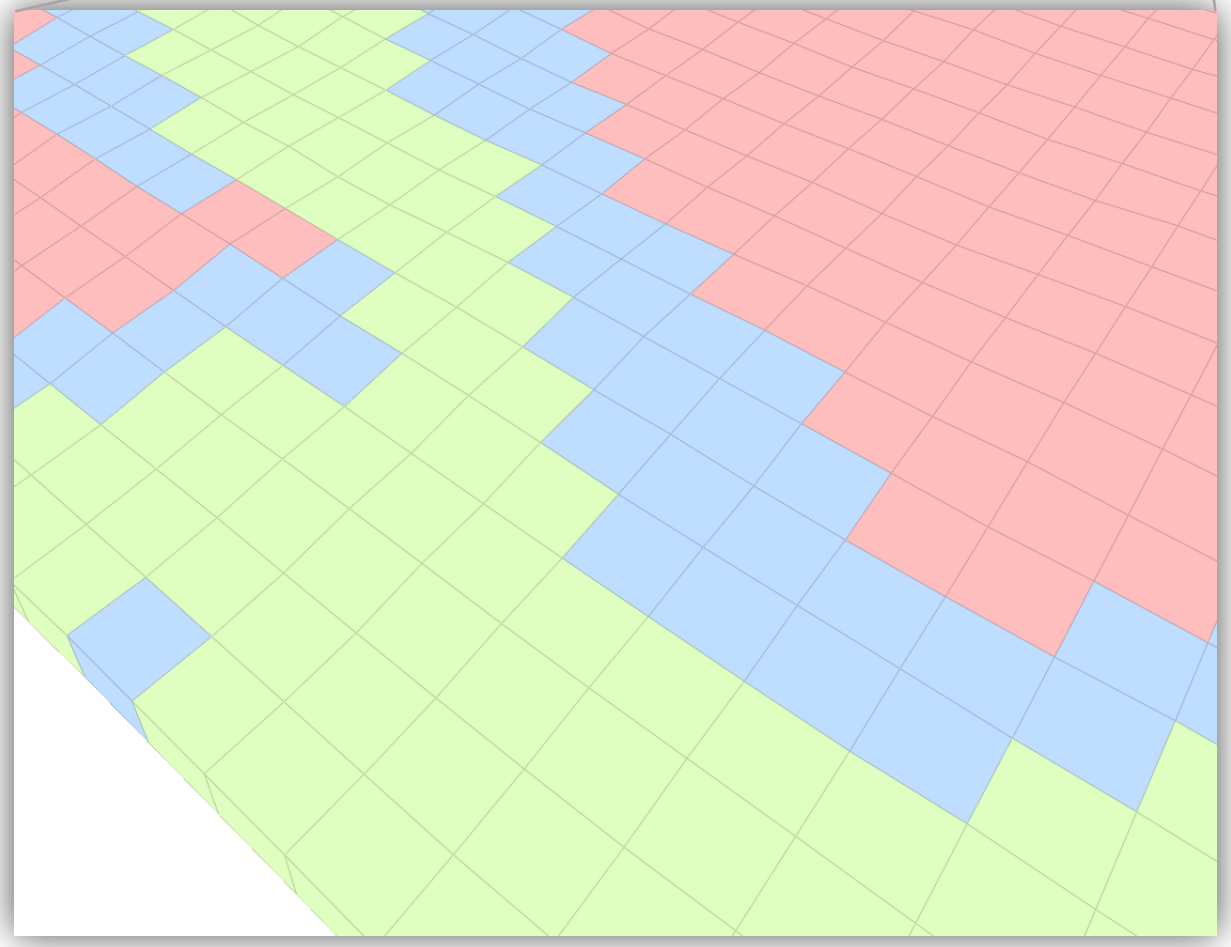
- Minimize the visual interference between attributes
- Highly exploratory task (design space)

- Design Guidelines
  - (2D) Scientific Visualization and Information Visualization
    - T. Ropinski, 2011; Borgo et al., 2013; Fuchs and Hauser, 2009; Kehrer and Hauser, 2013; Munzner 2014.
  - Perceptual Studies for Design [Ware, 2012]
  - Traditional Illustrations

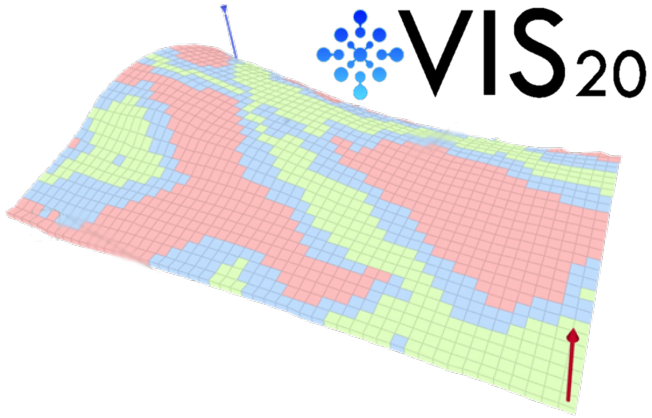
Visualization Design – 1st Layer



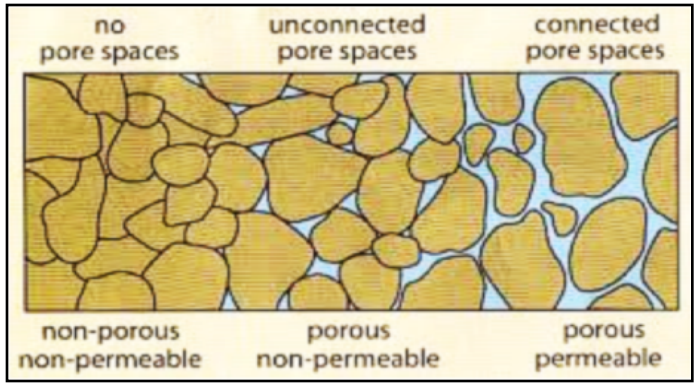
- Rock type 
  - Categorical data
- Visual Variables
  - Color, texture
- Guidelines for 2D Maps
  - Large areas, light tones
  - Base Layer
  - Pastel colormap

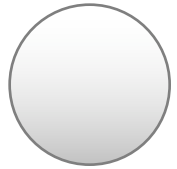


Visualization Design – 2nd Layer

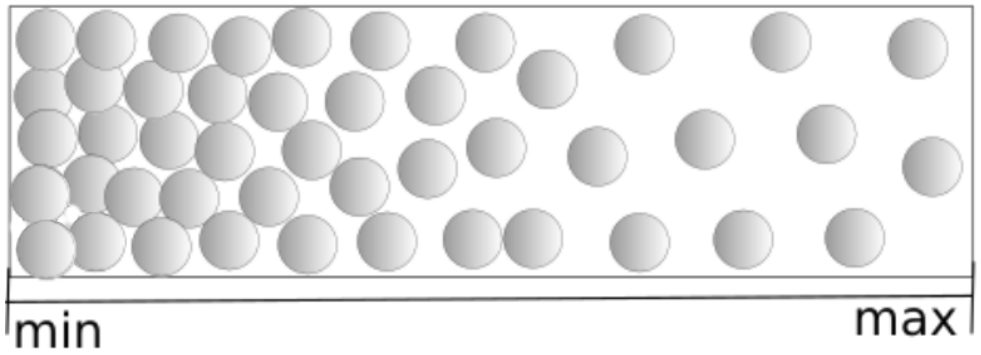


- Porosity (%)
  - Measures the capacity of rocks to store fluids
  - Quantitative data
- Visual variables
  - Position, size, saturation, …
- Traditional illustration
  - Space between grains

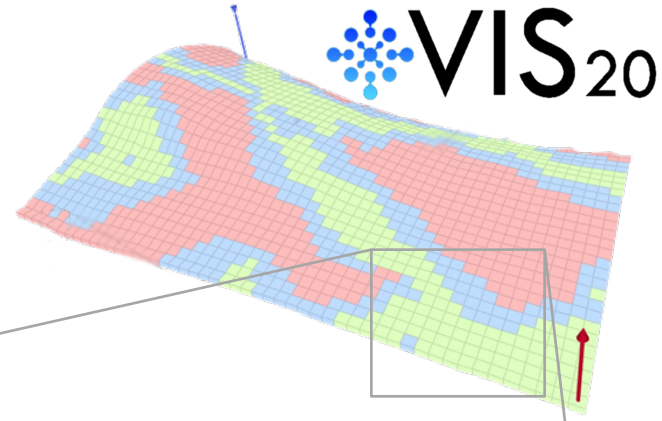




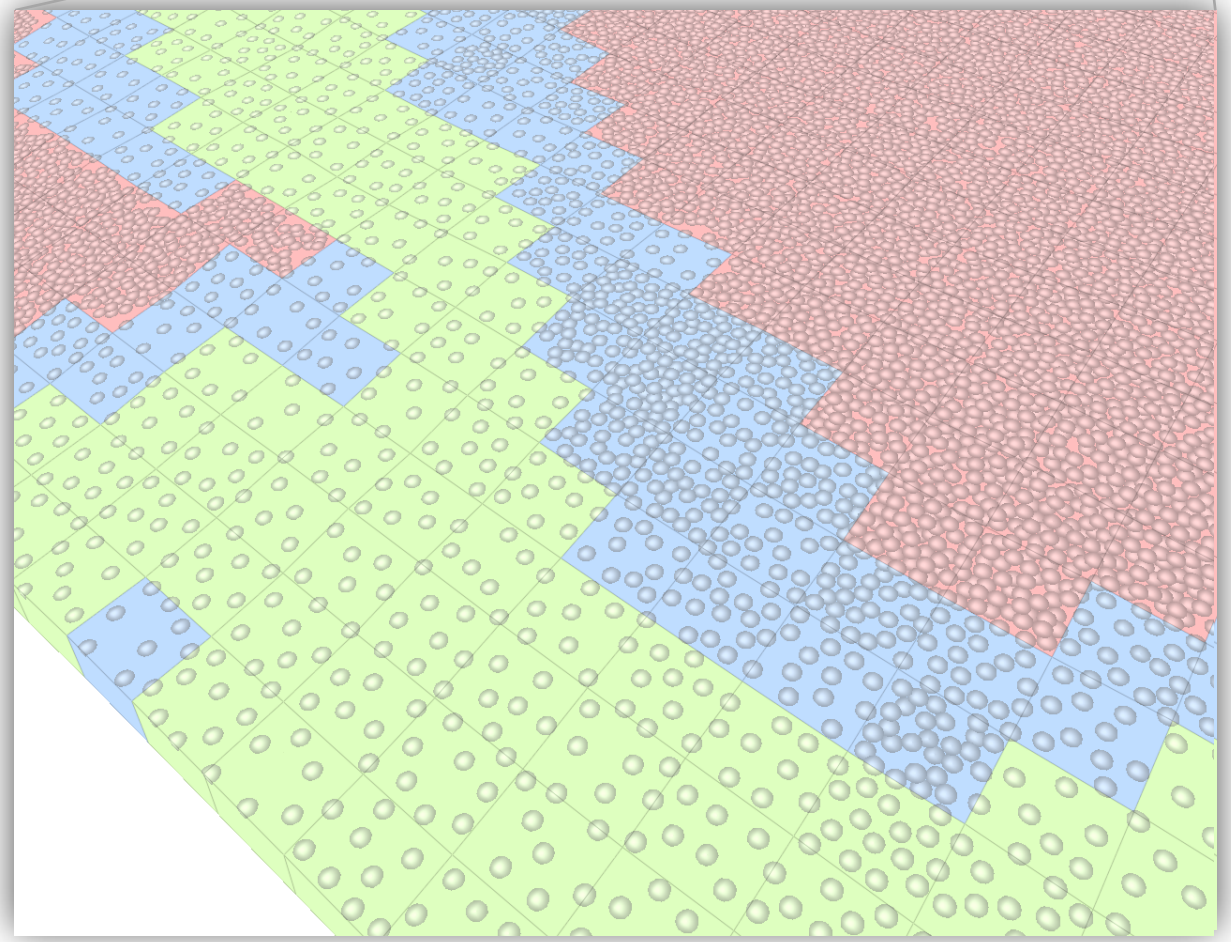
Grain decal



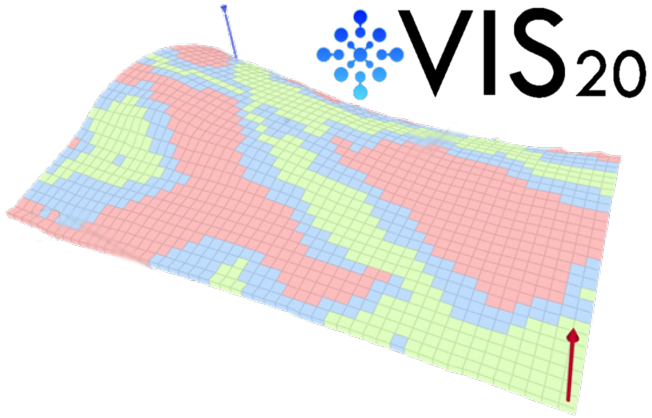
Visualization Design – 2nd Layer



- Porosity (%)
  - Measures the capacity of rocks to store fluids
  - Quantitative data
- Visual variables
  - Position, size, saturation, …
- Traditional illustration
  - Space between grains
- Poisson importance sampling [Corsini et al., 2012]



Visualization Design – 3nd Layer

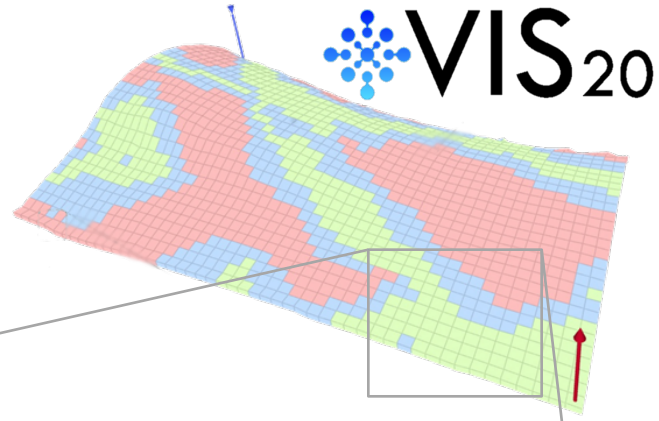


- Water Flow
  - Direction and magnitude
  - Traditional arrow glyphs
- Visual Variables
  - Color, shape
  - **Size, transparency,** texture, saturation, …

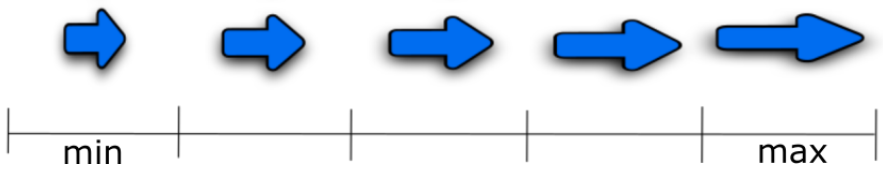
Water flow decal

Water flow decal-map

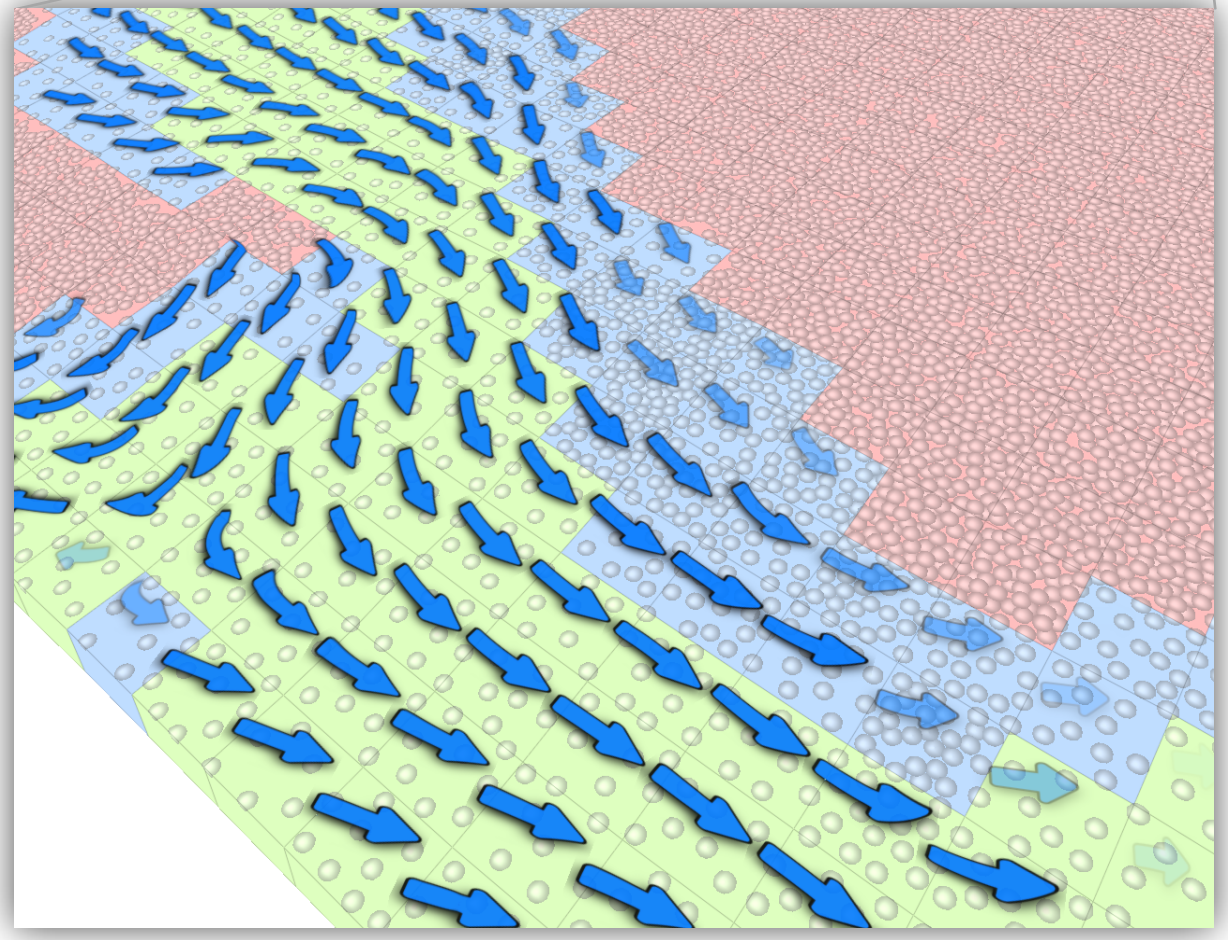
Visualization Design – 3nd Layer



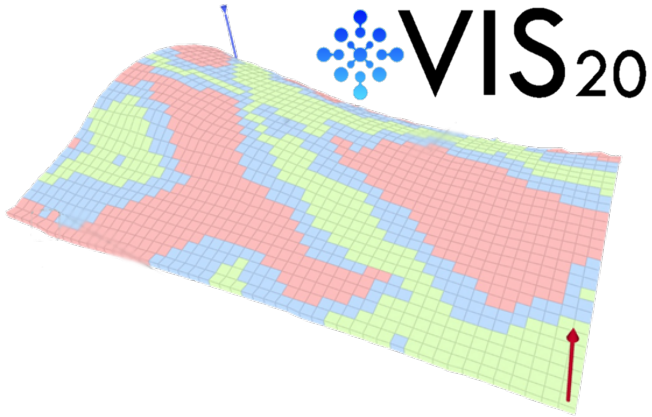
- Water Flow
  - Direction and magnitude
  - Traditional arrow glyphs
- Visual Variables
  - Color, shape
  - **Size, transparency,** texture, saturation, …



Water flow decal-map



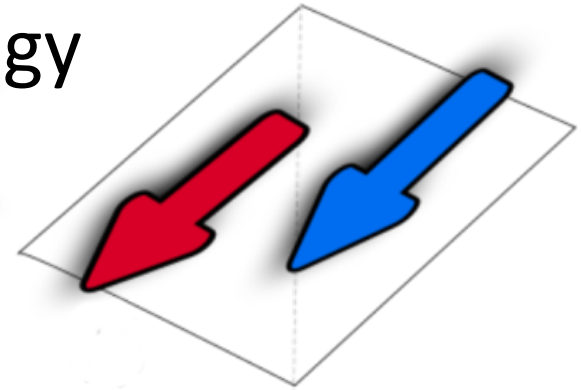
Visualization Design – 4th Layer



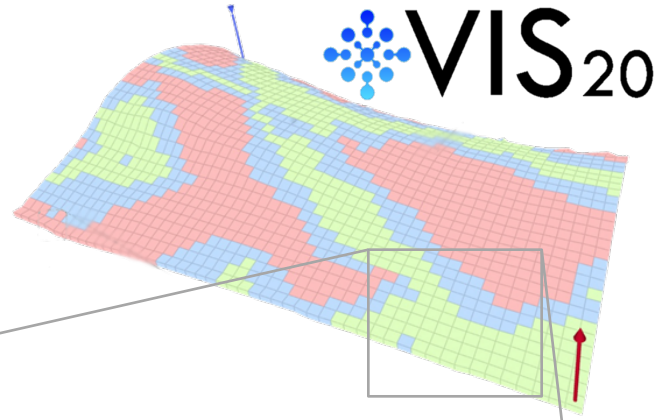
- Oil Flow
  - Direction and magnitude
  - Traditional arrow glyphs
- Visual Variables
  - Color, shape
  - **Size, transparency,** texture, saturation, …
- Placement Strategy

Oil flow decal

Oil flow decal-map



Visualization Design – 4th Layer



- Oil Flow
  - Direction and magnitude
  - Traditional arrow glyphs
- Visual Variables
  - Color, shape
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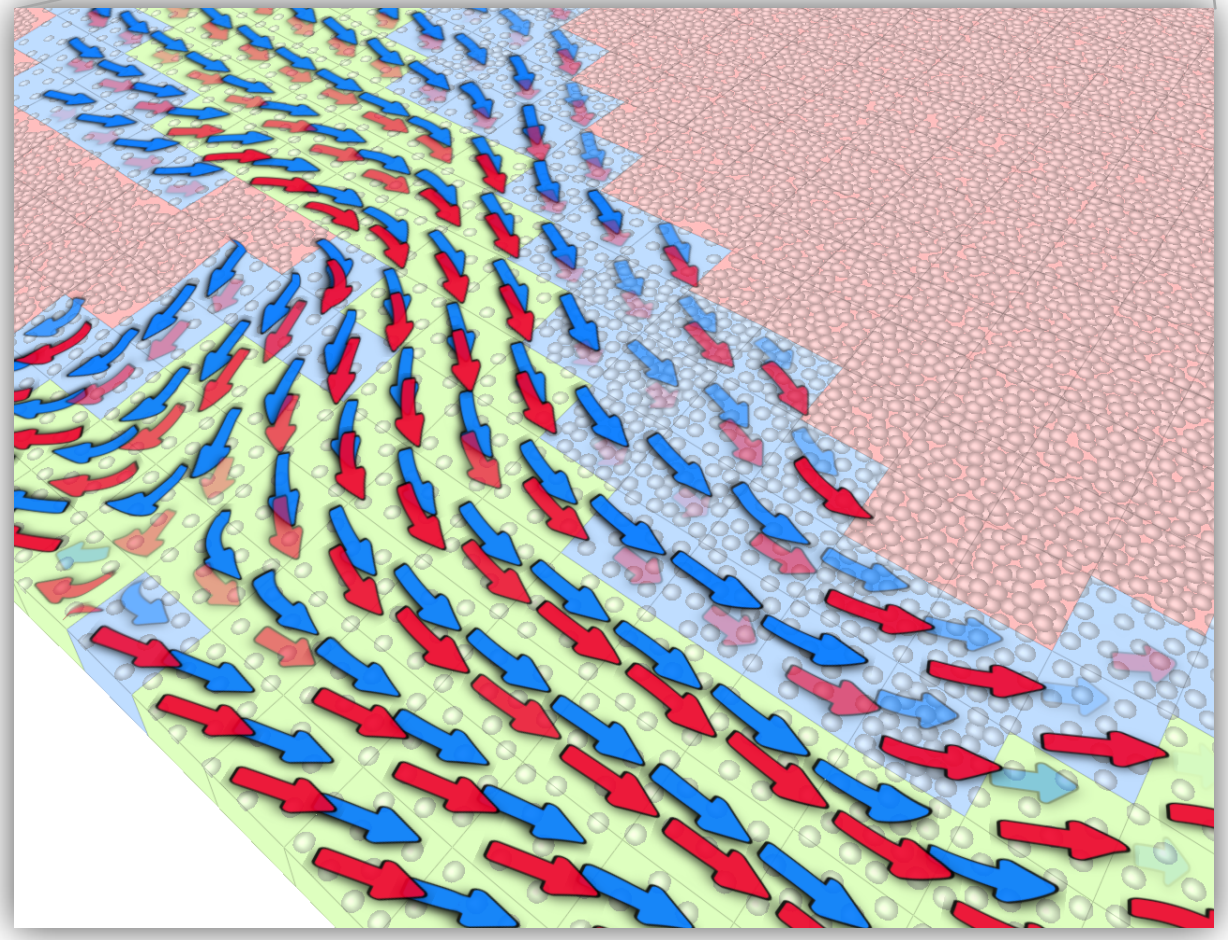
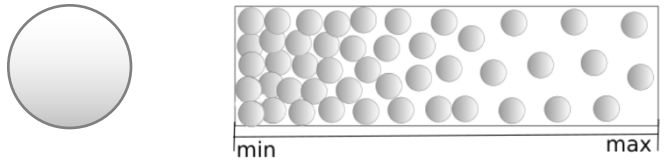
Oil flow decal-map



Multivariate Geological Visualization

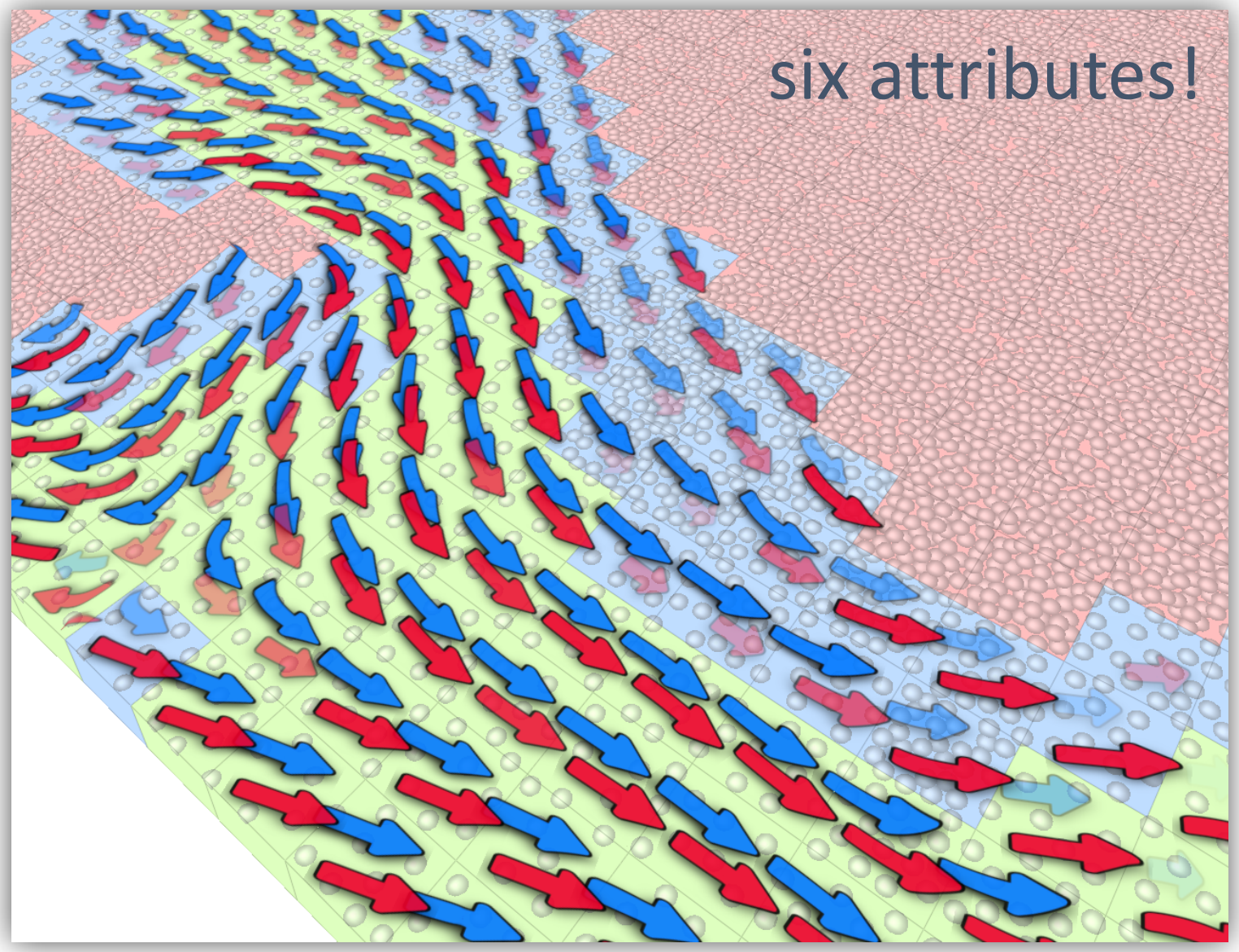
VIS 2016

- Rock type
- Porosity



- Water flow

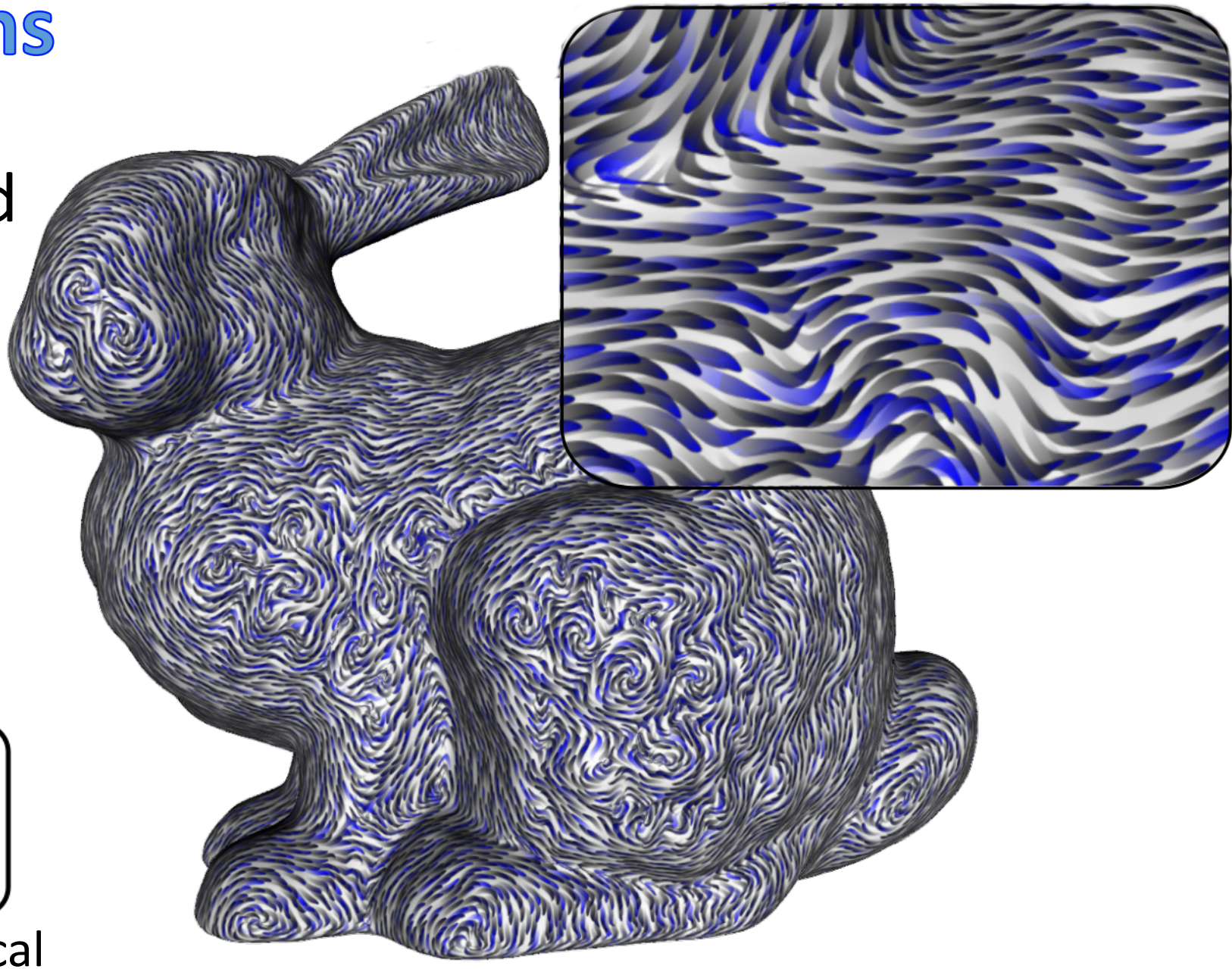
- Oil flow

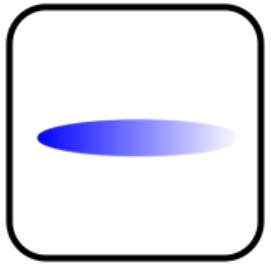


Other Applications

- Synthetic Vector Field
- Illustrative

  Flow Visualization
- Similar to LIC
- Decal deformation refer to the paper





Stroke decal

Conclusions

Contributions

- Decals as form of representation for visualization design
- The concept of decal-map to represent and visualize multivariate data on surfaces
- A real-time technique to place a high number of decals on arbitrary surfaces
- Concept of layering on surfaces by providing an abstract framework applicable to a variety of contexts

ACKNOWLEDGMENTS

- The anonymous reviewers for their constructive comments.
- NASA. Socioeconomic Data and Applications Center (SEDAC) for providing the Earth dataset
- This research was supported in part by the NSERC/ AITF/ FCMG IRC program in Scalable Reservoir Visualization.

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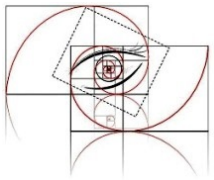
UNIVERSITY OF CALGARY

VIS 2016

THANK YOU!

Decal-maps: Real-time Layering of Decals on Surfaces for Multivariate Visualization

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



illustrares

Interactive Modeling, Visualization & Analytics R&D Group

VISAGG

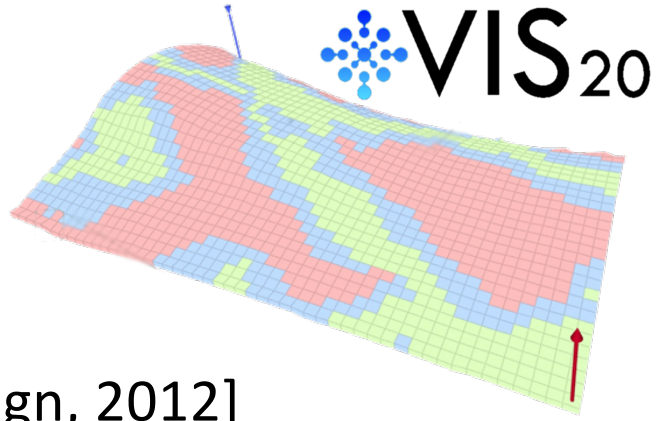
Visualization and Graphics Group

Results - Technique

- Performance (laptop Intel i7 with a GeForce GTX 960M 2G, 1280 x 1024)
  - Context of Multivariate Visualization
  - Bunny Stanford Model (normalized coordinates)
  - Monte Carlo Sampling

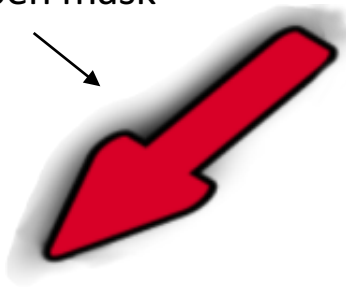
	No. decals	No. sub-layers	FPS
random uniform sampling	50K	26	19
	100K	41	11
	150K	58	7.5
	200K	72	5.9

Visualization Design – 4th Layer

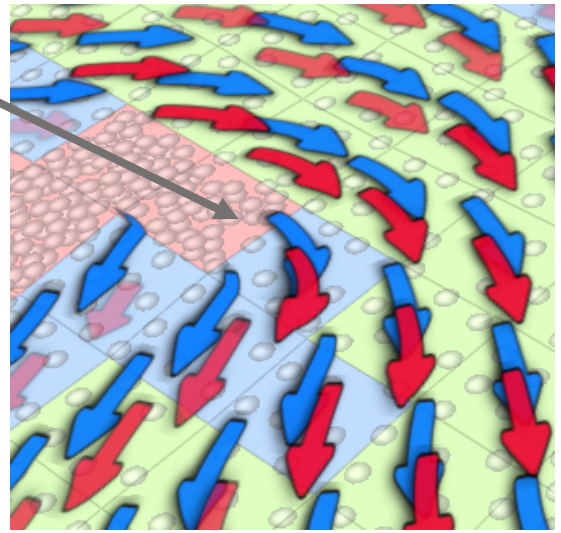


- Other design observations [Ware, Perception for Design, 2012]

Halo, unshapen mask



- Consider depth cues to separate layers
- "Strong" colors for small elements
- Concept of separated dimensions
  - E.g. color and texture

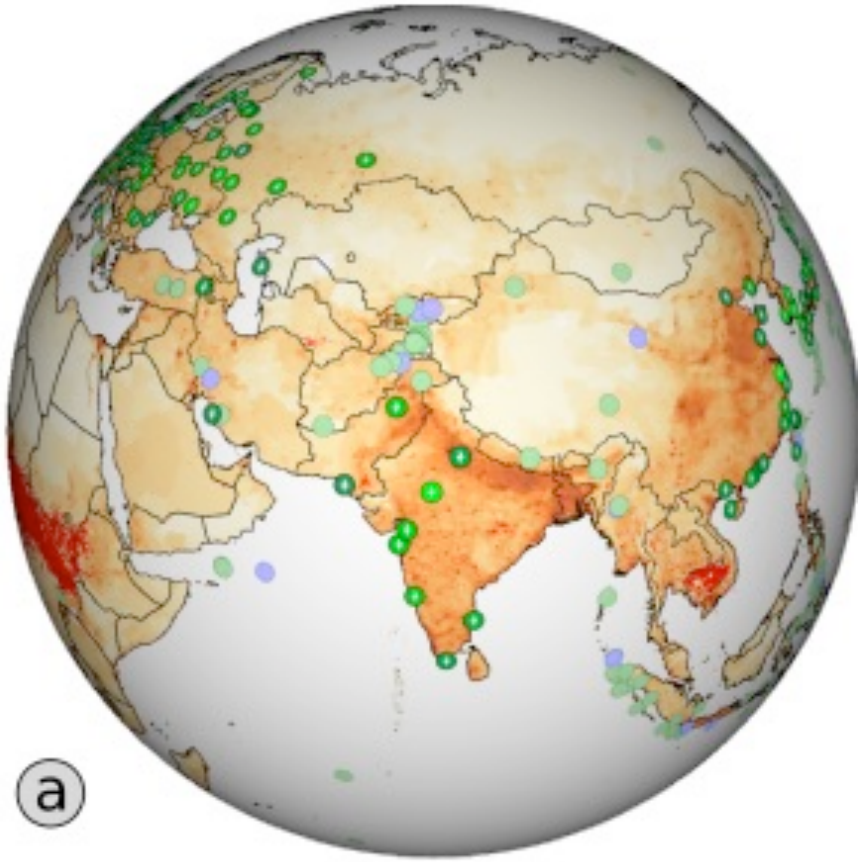


Results – Layering on Surfaces

Multivariate Geographic Visualization

- Visualization design

geographic data	visual mapping
population density	sequential colormap (one hue)
earthquake location	earthquake decal placement
earthquake magnitude	earthquake decal-map
NP location	NP decal placement
number of nuclear reactors	color saturation
fire detection	point placement



Results – Layering on Surfaces

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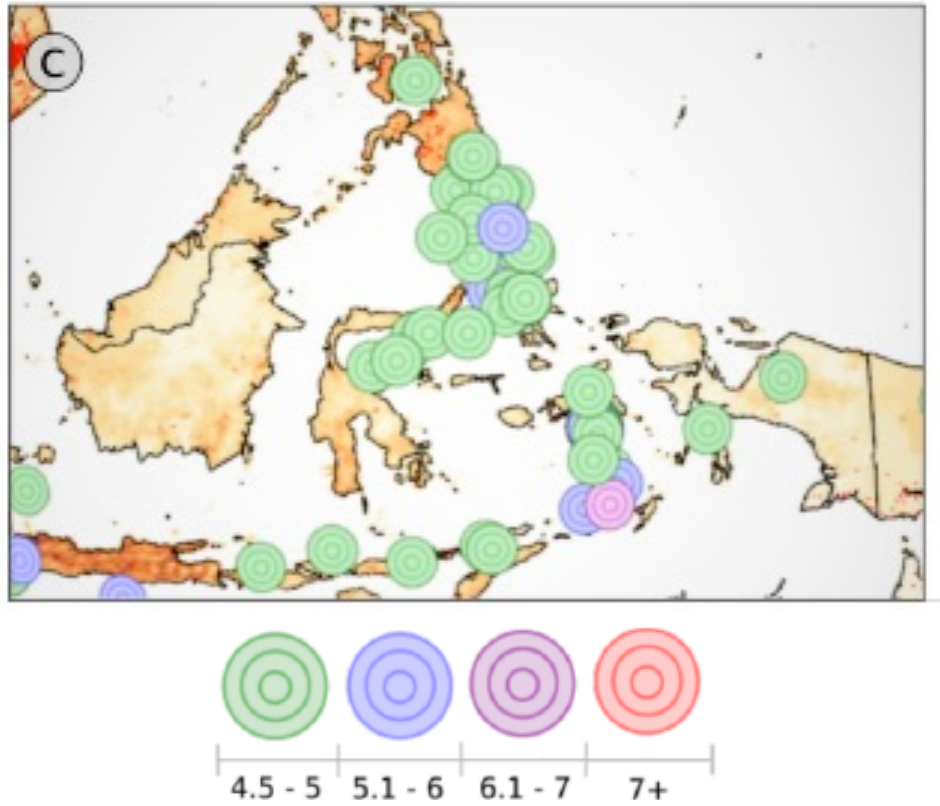


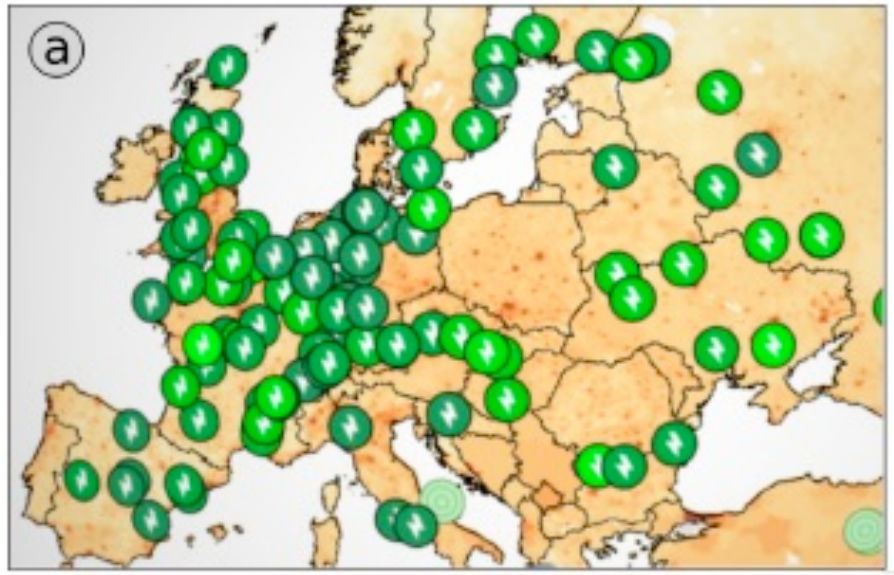
Earthquake decal-map

Results – Layering on Surfaces

Multivariate Geographic Visualization

- Visualization design

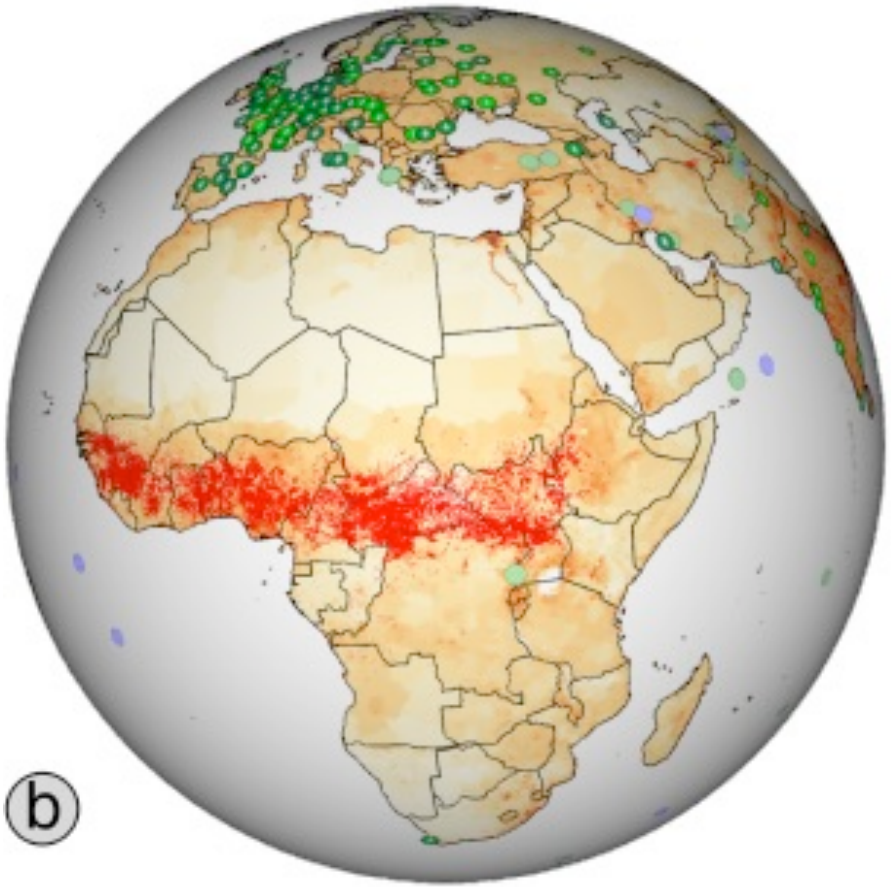
geographic data	visual mapping
population density	sequential colormap (one hue)
earthquake location	earthquake decal placement
earthquake magnitude	earthquake decal-map
NP location	NP decal placement
number of nuclear reactors	color saturation
fire detection	point placement



Nuclear plant decal-map

Results – Layering on Surfaces

Multivariate Geographic Visualization

- Visualization design

geographic data	visual mapping
population density	sequential colormap (one hue)
earthquake location	earthquake decal placement
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