Mid-term Review

What is visualization?

What are the goals of visualization?

What is visualization?

Techniques and tools that convert the given data into certain visual representation that enables the user insights of the data.

What are the goals of visualization?

Represent
Analyze
Explore

What is the visualization pipeline? What does each step do?

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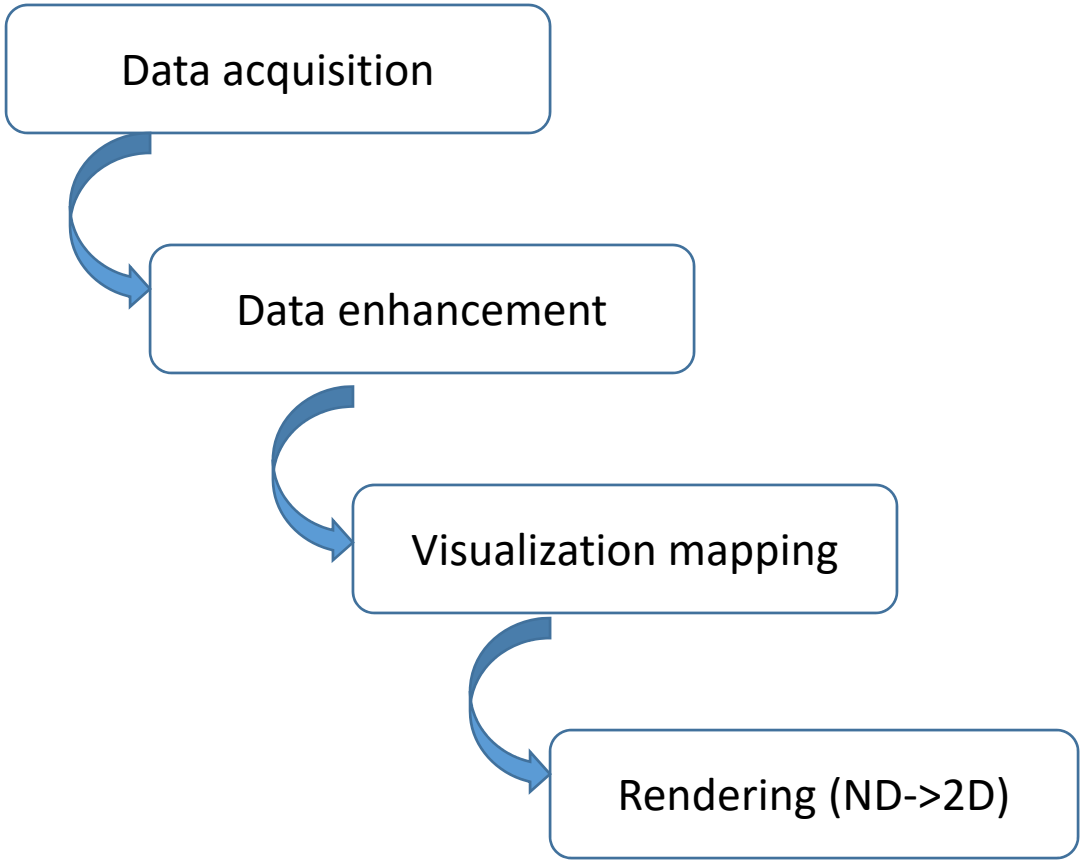

Data are generated.

Data are processed.

Data are mapped to visual primitives, e.g. colors, geometry, etc.

Images are generated.

What is the difference between scientific data and information data? How does this difference affect the selection of the visualization techniques?

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Scientific data are

- 2, 3, 4 dimensional, spatial or spatio-temporal
- Continuous in the nature but stored in a discretized fashion

Information data are

- In higher-dimensional space, abstract
- Discrete in the nature

Considering scientific data, how can we classify them?

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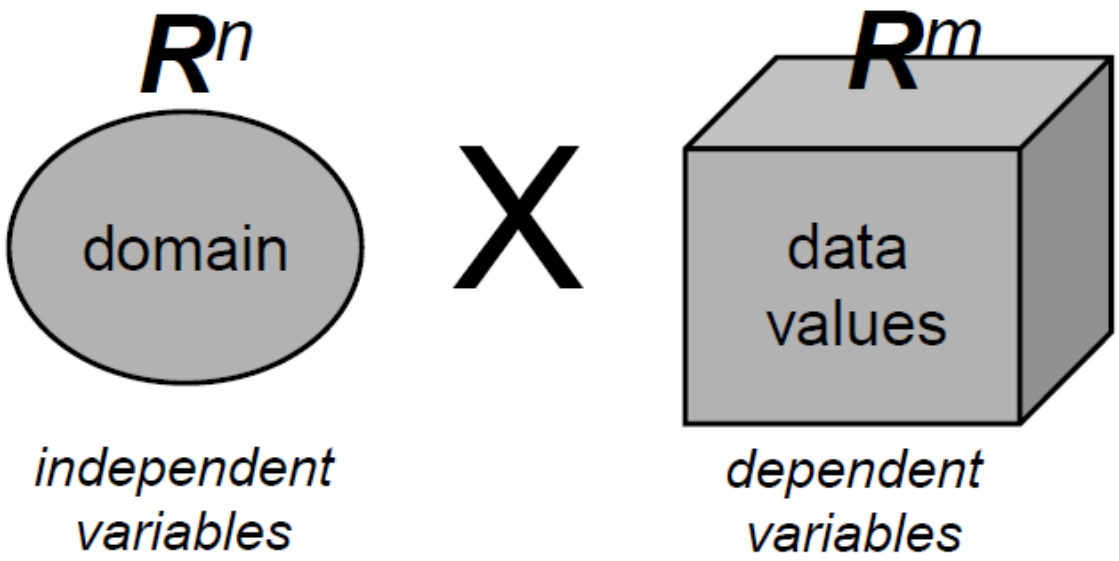


scientific data $\subseteq R^{n+m}$

1D
2D
3D
+time

scalar
vector
tensor

How do people typically represent a scientific data?

How do people typically represent a scientific data?

Scatter data
Data on grids (or meshes)
    structured grids
    unstructured grids
Deterministic versus uncertain

What information is needed to store a grid?

What are the Gestalt Principles?

What are the Gestalt Principles?

proximity	We tend to think of objects that are physically close together as belonging to part of a group.
Similarity	Objects that are of similar color, shape, size, or orientation are perceived as related or belonging to part of a group.
Enclosure	We think of objects that are physically enclosed together as belonging to part of a group.
Closure	People like things to be simple and to fit in the constructs that are already in our heads.
Continuity	When looking at objects, our eyes seek the smoothest path and naturally create continuity in what we see even where it may not explicitly exist.
Connection	We tend to think of objects that are physically connected as part of a group.

What are the principles of making elementary plots?

What are the principles of making elementary plots?

Improve vision

1. Reduced clutter, Make data stand out
2. Use visually prominent graphical elements
3. Use proper scale lines and a data rectangle
4. Reference lines, labels, notes, and keys
5. Superposed data set

Improve understanding

1. Provide explanations and draw conclusions
2. Use all available space
3. Align juxtaposed plots
4. Use log scales when appropriate
5. Bank to 45^o

Can you name a number of plotting techniques and when they will be useful?

Can you name a number of plotting techniques and when they will be useful?

- Connected symbol plots
  - For 1D time-series data
- Dot plots
  - 1D data that do not have sequential relation
- Scatter plots
  - Used to see how one variable is affected by another
- Histograms, bar charts
  - For plotting distribution
- Box plots
  - For representing statistical variation in the data
- Many others

In your eyes, which sensors, rods or cones, sense intensity and which sensors sense color?

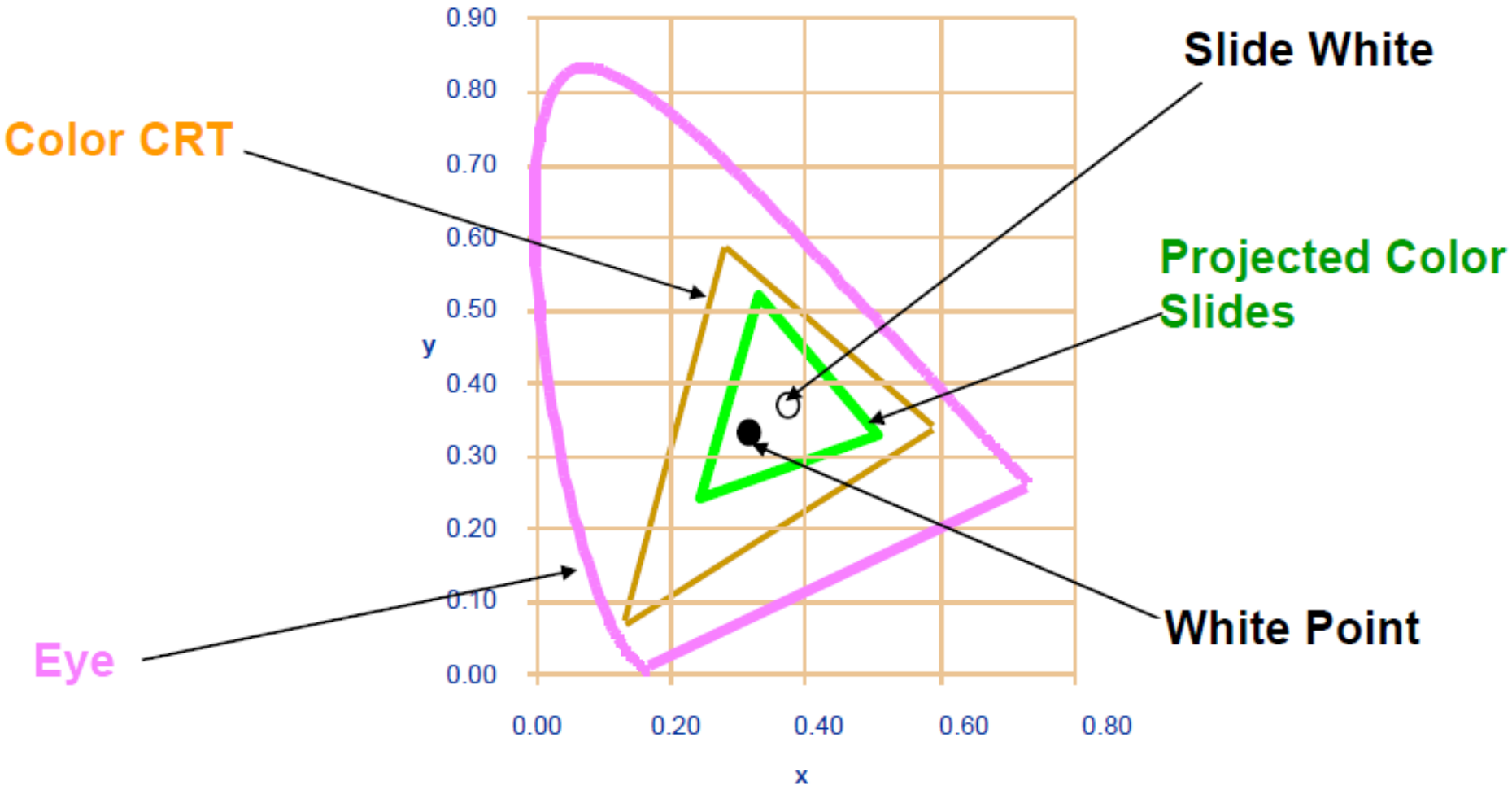
In your eyes, which sensors, rods or cones, sense intensity and which sensors sense color?

Rods (periphery) for intensity
Cones (center) for color

What is the difference between additive and subtractive color models? Where are they applied, respectively?

Can you explain the meaning of the three parameters of the **HSV** color space? Can you map the scalar value to one or more of these parameters to produce the desired color coding schemes, such as rainbow, blue-white-red, intensity, saturation, etc.?

Do you understand the color gamut? What does it tell us?



Can you compute the luminance of a given color?

How can you choose pairs of colors that will make good contrast?

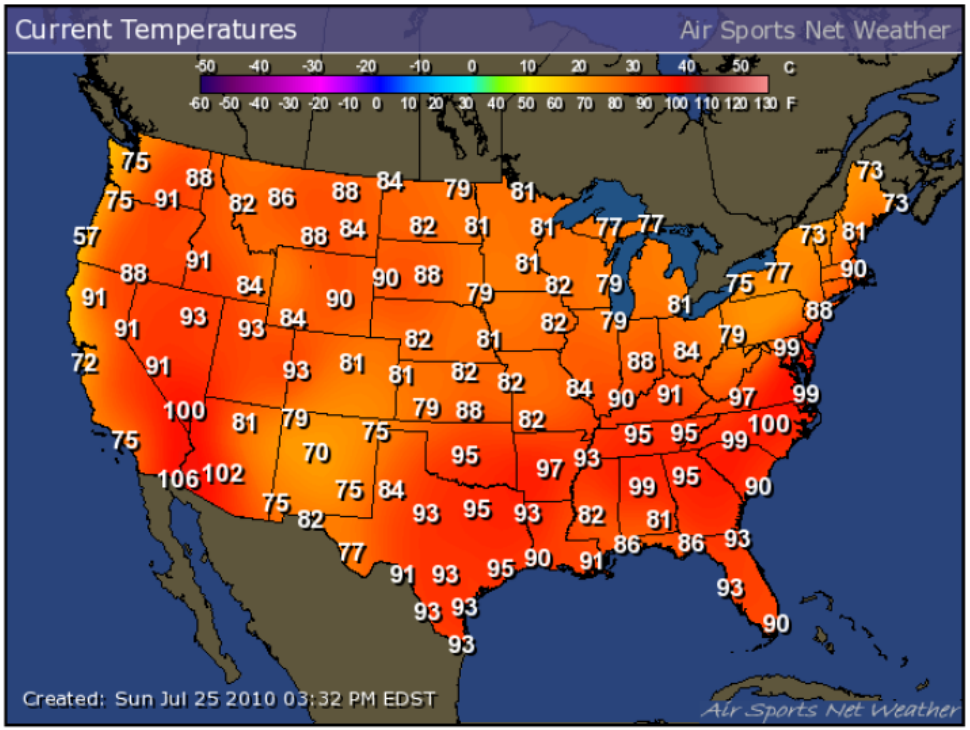
Can you compute the luminance of a given color?

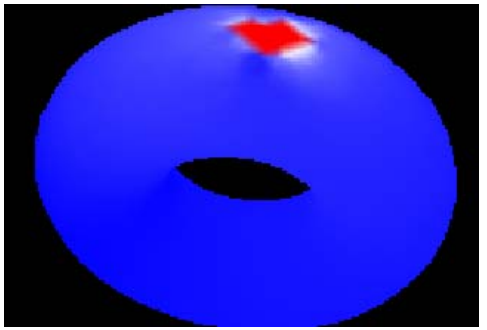
$$Y = 0.3 \times Red + 0.59 \times Green + 0.11 \times Blue$$

How can you choose pairs of colors that will make good contrast?

- Colors whose luminance values have more that 0.4 difference will make a good contrast.

Do you know how to correct the following issue in the color transfer function design?

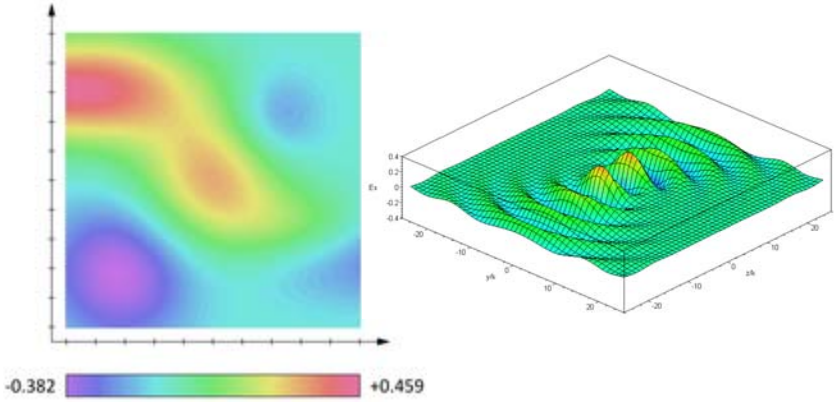


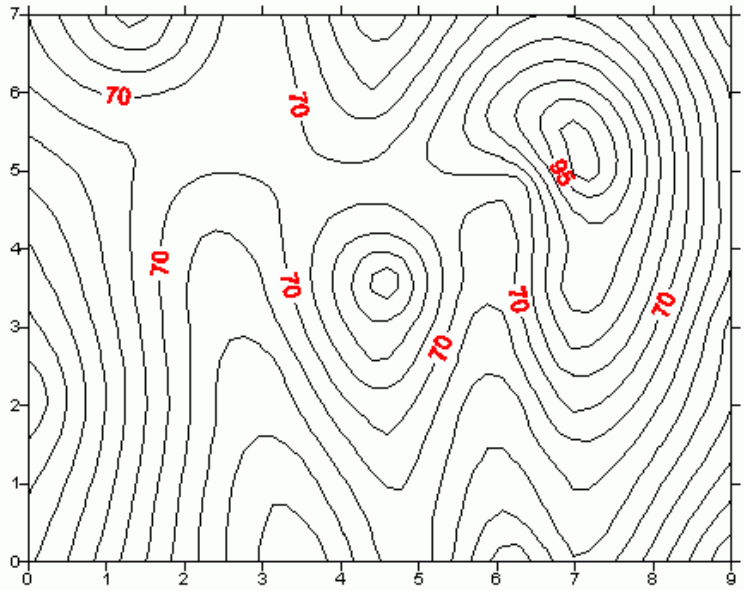


What is a scalar field? Can you give a few examples of it?

What is a scalar field? Can you give a few examples of it?

- The approximation of certain scalar function in space *f(x,y,z).*
- Each data point has a single numeric value.





For a 2D scalar field, how is the color plot accomplished?

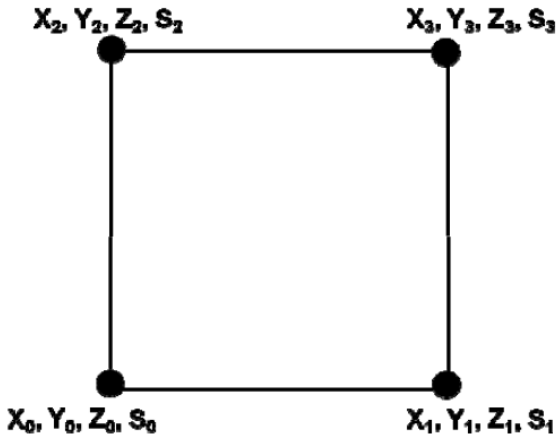
For a 2D scalar field, how is the color plot accomplished?

```
// compute color at V0
glColor3fv (rgb0);
glVertex3f (x0, y0, z0);

// compute color at V1
glColor3fv (rgb1);
glVertex3f (x1, y1, z1);

// compute color at V3
glColor3fv (rgb3);
glVertex3f (x3, y3, z3);

// compute color at V2
glColor3fv (rgb2);
glVertex3f (x2, y2, z2);
```



For each scalar value at a vertex

```
float hsv[3], rgb[3];
```

$\text{hsv}[0] = 240. - 240. \frac{S - S_{min}}{S_{max} - S_{min}}$;

```
HsvRgb (hsv, rgb);
```

What is **Marching Squares** for?

Do you know how to perform Marching Squares?

What is **Marching Squares** for?
Do you know how to perform Marching Squares?

# of intersections = 0	Do nothing
# of intersections = 2	Draw a line connecting them
# of intersections = 1	Error
# of intersections = 3	Error
# of intersections = 4	Saddle case

For **Marching Cubes**, how many possible configurations can we encounter? And how many of them are topologically distinct?

For **Marching Cubes**, how many possible configurations can we encounter? And how many of them are topologically distinct?

there are **only 15** topologically distinct configurations

What is a **direct volume rendering**?
Under what situations, direct volume rendering is more suitable than iso-surfacing?

What is the difference between direct and indirect methods for scalar data visualization?

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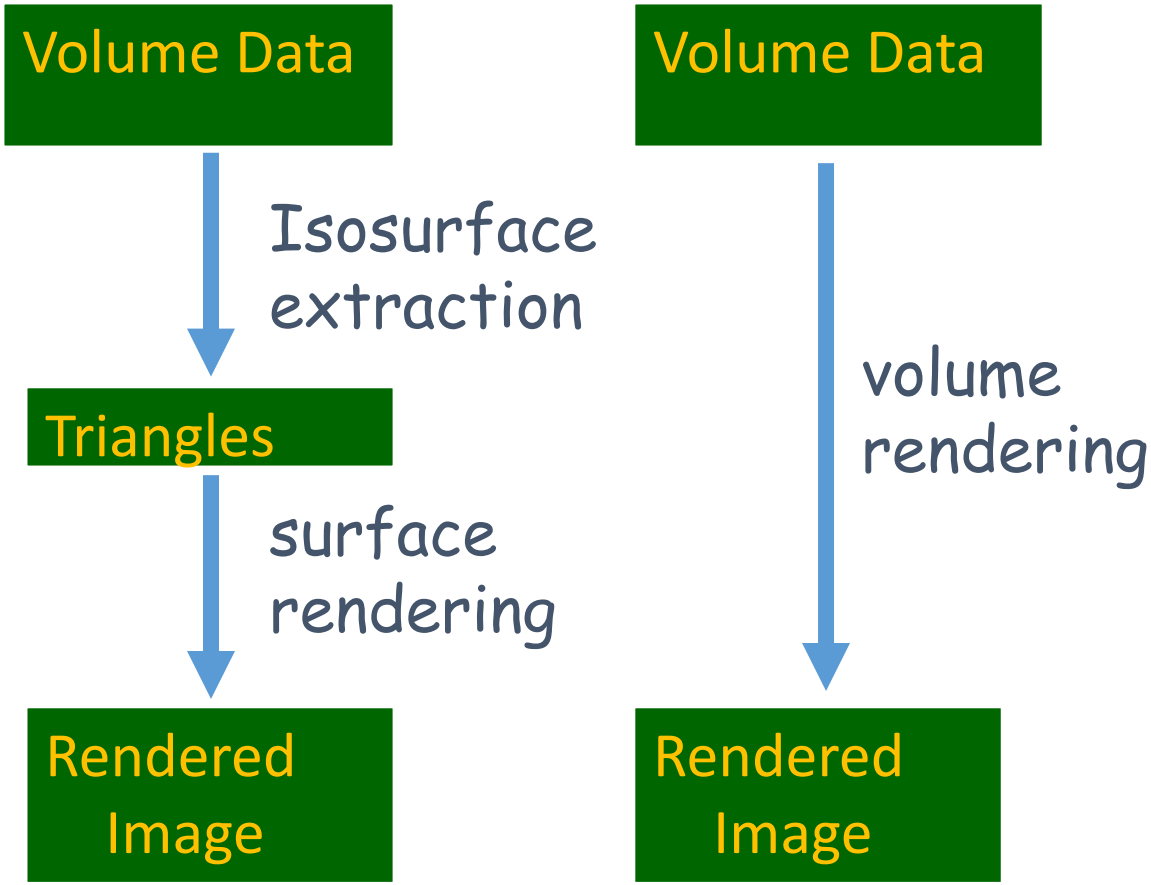

What is the difference between the image-order and object-order direct volume rendering methods? Can you briefly describe their respective pipeline?

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For each pixel …
- cast ray
- sampling along ray
- interpolate
- get colors/opacity
- composite

for **each voxel** …
- get color/opacity
- determine image contribution
- composite

For the Raycasting, under what condition can we use the ray template? What does it do and why it is useful?

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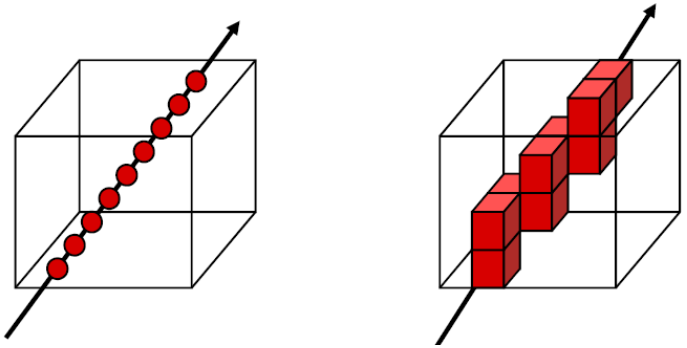


Algorithm:

- Rename volume axes such that z is the one "most orthogonal" to the image plane.
- Create ray template with 3D version of **line pixelized** algorithm, giving 26-connected rays which are functional in z coordinate (have exactly one voxel per z-layer)
- Translate ray template in **base plane**, not in image plane

Color composition is an important step in volume rendering. What are the techniques of conducting color composition introduced in the class?

Color composition is an important step in volume rendering. What are the techniques of conducting color composition introduced in the class?

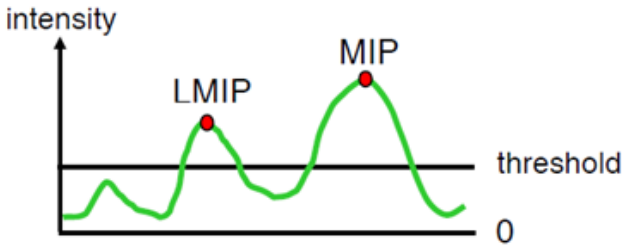
Maximum intensity projection (MIP):

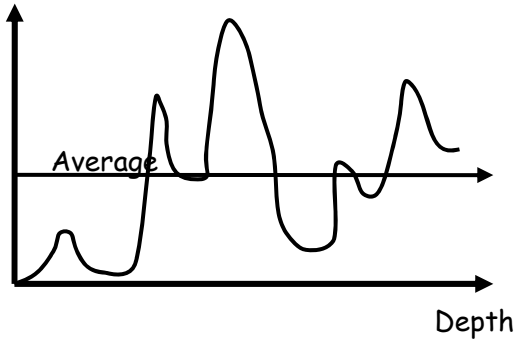
maximum of sampled values
result resembles X-ray image

Local maximum intensity projection (LMIP):

first local maximum which is above a prescribed threshold
approximates occlusion
faster & better(!)

Average:





Do you know how to perform α-composition?

Do you know how to perform α-composition?

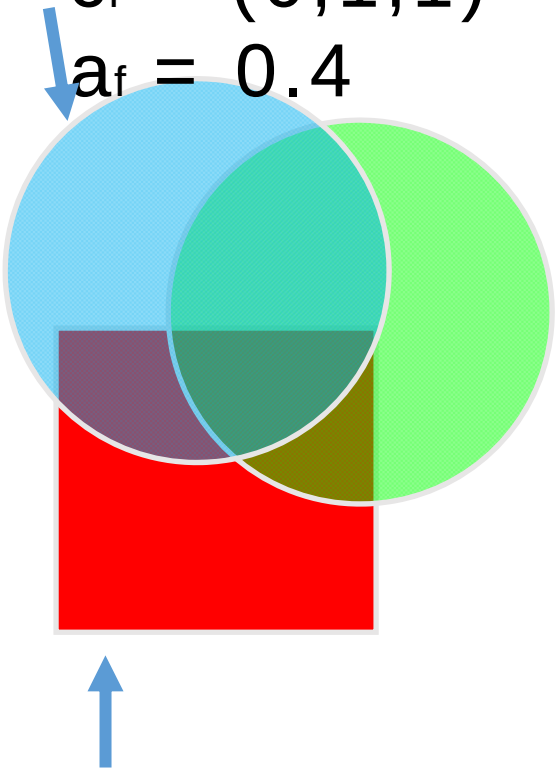
It is an iterative process that composite colors in order via linear blending.

How about the detailed process?

Compositing Example (back to front)

$c_f = (0,1,1)$

$a_f = 0.4$



$c_b = (1,0,0)$

$a_b = 0.9$

$$c = a_f * c_f + (1 - a_f) * a_b * c_b$$

$$a = a_f + (1 - a_f) * a_b$$

$c_f = (0,1,0)$

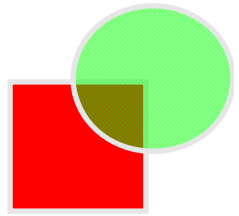
$a_f = 0.4$

$c_{red} = 0.4*0 + (1-0.4)*0.9*1 = 0.6*0.9 = 0.54$

$c_{green} = 0.4*1 + (1-0.4)*0.9*0 = 0.4$

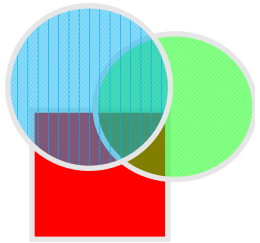
$c_{blue} = 0.4*0 + (1-0.4)*0.9*0 = 0$

$a = 0.4 + (1 - 0.4)*(0.9) = 0.4 + 0.6*0.9)$



$c_b = (0.54,0.4,0)$

$a_b = 0.94$



$c_{red} = 0.4*0 + (1-0.4)*0.94*0.54 = 0.6*0.94*.54 = 0.30$

$c_{green} = 0.4*1 + (1-0.4)*0.94*0.4 = 0.6*0.94*.4 = 0.23$

$c_{blue} = 0.4*1 + (1-0.4)*0.94*0 = .4$

$a = 0.4 + (1 - 0.4)*(0.94) = 0.4 + 0.6*0.94) = .964$

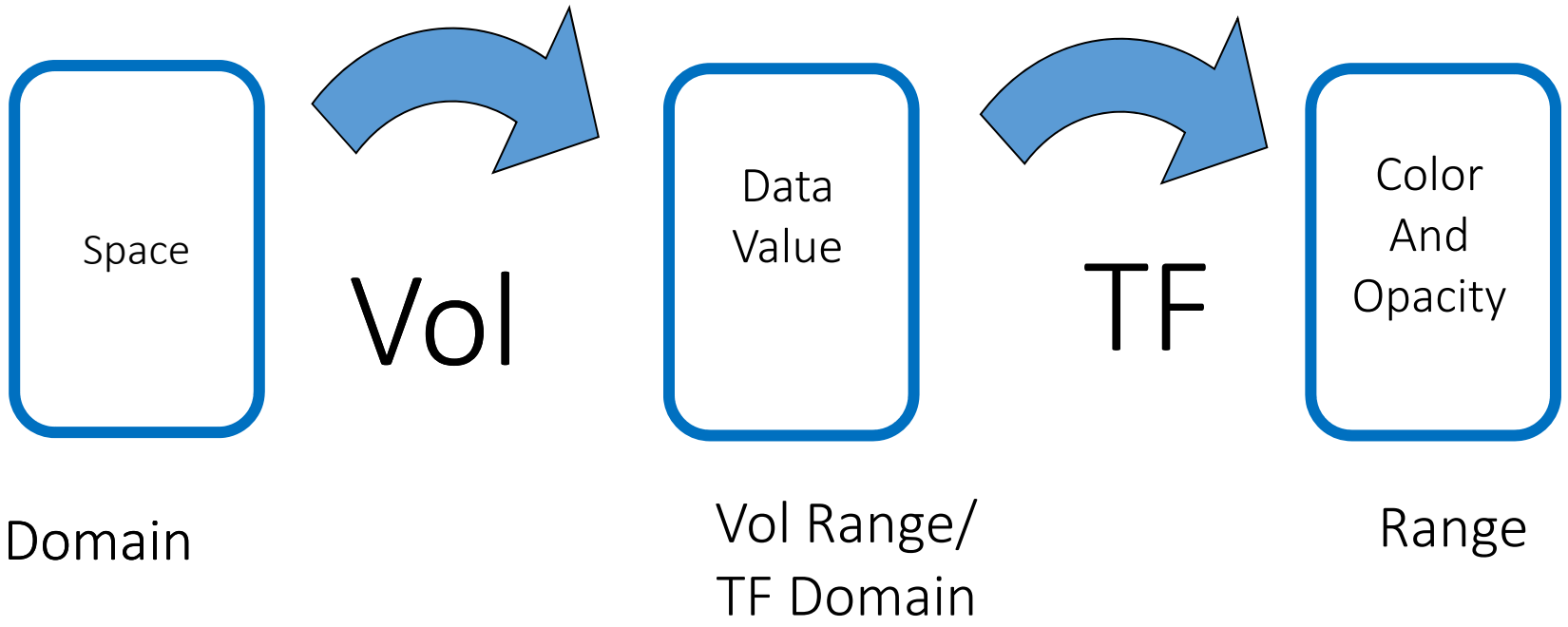
$c = (0.3,0.23,0.4)$

$a = 0.964$

What is the role of transfer functions in direct volume rendering? Why they are difficult to specify?

What is the role of transfer functions in direct volume rendering? Why they are difficult to specify?

Make data visible by mapping data value to color and opacity



How to perform 2D texture-based volume rendering?

How to perform 2D texture-based volume rendering?

Generate axis aligned texture planes based on the specified transfer functions (3 families of planes)
[Need to pay attention to the ordering of the indices for the texture arrays]

Perform texture mapping by selecting a family of texture planes to render in order (i.e., back to front or front to back) based on the current view point
[Need to pay attention to the texture environment setting]

What is a vector field? Can you provide a few examples to show why it is useful?

What are the typical visualization techniques for vector fields that we have introduced so far? What are the advantages and disadvantages of these methods, respectively?

What is a vector field? Can you provide a few examples to show why it is useful?

A vector-valued function that assigns a vector to any give point

What are the typical visualization techniques for vector fields that we have introduced so far? What are the advantages and disadvantages of these methods, respectively?

Direct
Geometric-based
Texture-based
Feature-based

How to define and compute a streamline? In practice, how can one trace out a streamline from a given position?

What is the Euler integration and what is the Runge-Kutta integration? How accurate are they?

How to define and compute a streamline? In practice, how can one trace out a streamline from a given position?

A streamline is a solution of the initial value problem of the vector field.

In practice, numerical integration is used to compute a streamline step by step.

What is the Euler integration and what is the Runge-Kutta integration? How accurate are they?

Euler integration - first order integration
Runge-Kutta integration – higher-order integration

What are the termination conditions for streamline tracing?

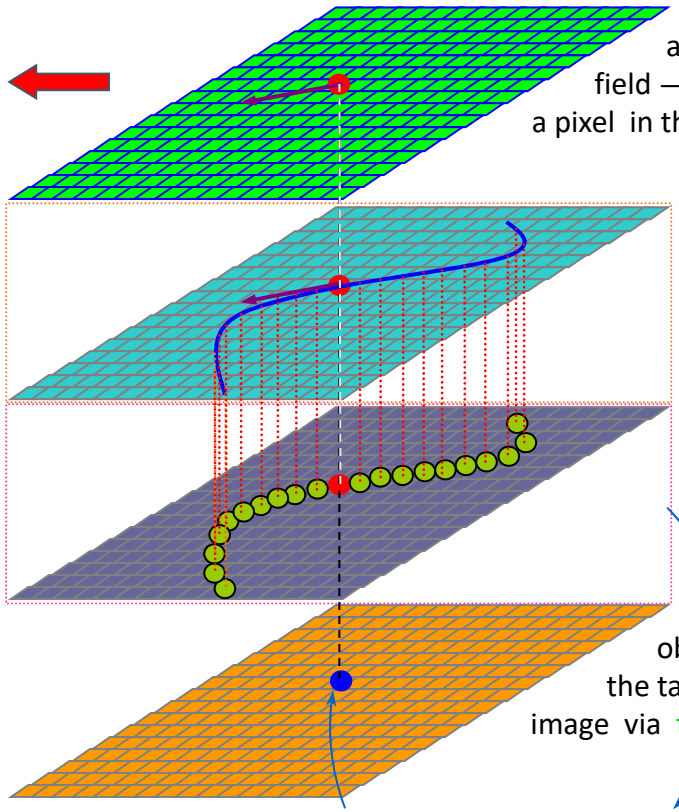
What are the termination conditions for streamline tracing?

- when streamline leaves flow domain
- when streamline runs into fixed point (**v** = 0)
- when streamline gets too near to itself (loop)
- after a certain amount of maximal steps

What is the difference between streamline placement and texture-based visualization?

How to compute a LIC image?

How to compute a LIC image?



a point in the flow field — the counterpart of a pixel in the output LIC image

locate a set of pixels hit by the streamline

index the input noise for the texture values

obtain the value of the target pixel in the LIC image via texture convolution

$$\frac{\sum (\text{texture}[i] \times \text{weight}[i])}{\sum \text{weight}[i]}$$

weighting is governed by a low-pass filter

What are the ingredients of steady vector field topology?

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- Fixed points
- Periodic orbits
- AND their connectivity

Do you know how to extract fixed points?

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Do you know how to extract fixed points?

- Using Gaussian map and winding number/Poincare index!

Do you know how to construct the Gaussian map?

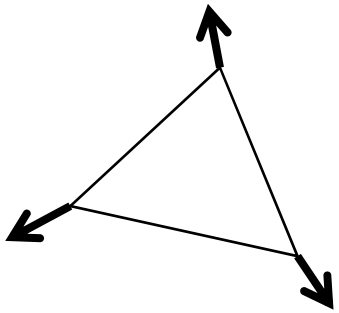
What are the ingredients of steady vector field topology?

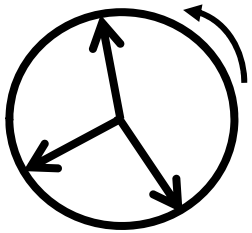
- Fixed points
- Periodic orbits
- AND their connectivity

Do you know how to extract fixed points?

- Using Gaussian map and winding number!

Do you know how to construct the Gaussian map?





How to classify a fixed point?

How to classify a fixed point?

- Based on the eigenvalues of its Jacobian!

How to compute the Jacobian of a vector field?

How to classify a fixed point?

- Based on the eigenvalues of its Jacobian?

How to compute the Jacobian of a vector field?

$$\nabla V = \begin{bmatrix} \frac{\partial f_x}{\partial x} & \frac{\partial f_x}{\partial y} & \frac{\partial f_x}{\partial z} \\ \frac{\partial f_y}{\partial x} & \frac{\partial f_y}{\partial y} & \frac{\partial f_y}{\partial z} \\ \frac{\partial f_z}{\partial x} & \frac{\partial f_z}{\partial y} & \frac{\partial f_z}{\partial z} \end{bmatrix}$$

Assuming $V = [f_x \quad f_y \quad f_z]$

How to classify a fixed point?

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How to compute the Jacobian of a vector field?

How to use the eigenvalues to classify fixed points?

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How to compute the Jacobian of a vector field?

How to use the eigenvalues to classify fixed points?

The eigenvalues of the Jacobian matrix $\lambda J = \lambda \boldsymbol{x}$ are

$$\lambda = Re_{1,2} + iIm_{1,2}$$

If both $Re_{1,2} > 0$, the fixed point repels flow locally (e.g., source-like).
If both $Re_{1,2} < 0$, the fixed point attracts flow locally (sink-like).
If $Re_1 Re_2 < 0$, it does both and is a saddle

What do curl and divergence of a vector field measure?

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- Curl- describes the infinitesimal rotation around a point
- Divergence- measures the magnitude of outward flux through a small volume around a point

How to compute curl and divergence of a vector field?

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- Curl- describes the infinitesimal rotation around a point
- Divergence- measures the magnitude of outward flux through a small volume around a point

How to compute curl and divergence of a vector field?

Divergence is the trace of the Jacobian
Curl is the difference of the off-diagonal entries in 2D case