Computer Graphics

Visualization I

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SAPIENZA
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Exercises

- Mesh and point cloud data structures
- `calc_tri_areas` , `calc_normals`

Visualizing shapes

Throughout this course we deal with manifold triangle meshes and images

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How can we visualize our shapes in the "best" possible way?

Visualizing shapes

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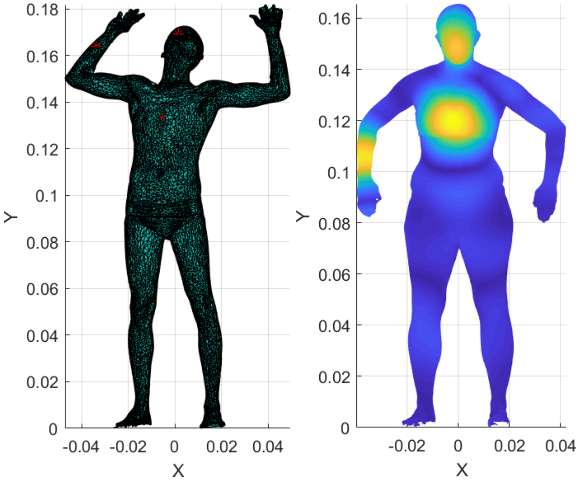

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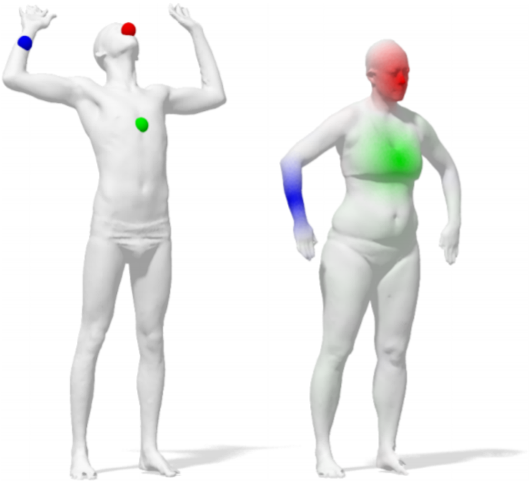

Visualizing shapes

Throughout this course we deal with manifold triangle meshes and images

Good visualization brings several benefits:

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- Puts the emphasis on the relevant aspects
- Sidesteps technical clutter and makes for a pleasant reading

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- Might convey no message at all
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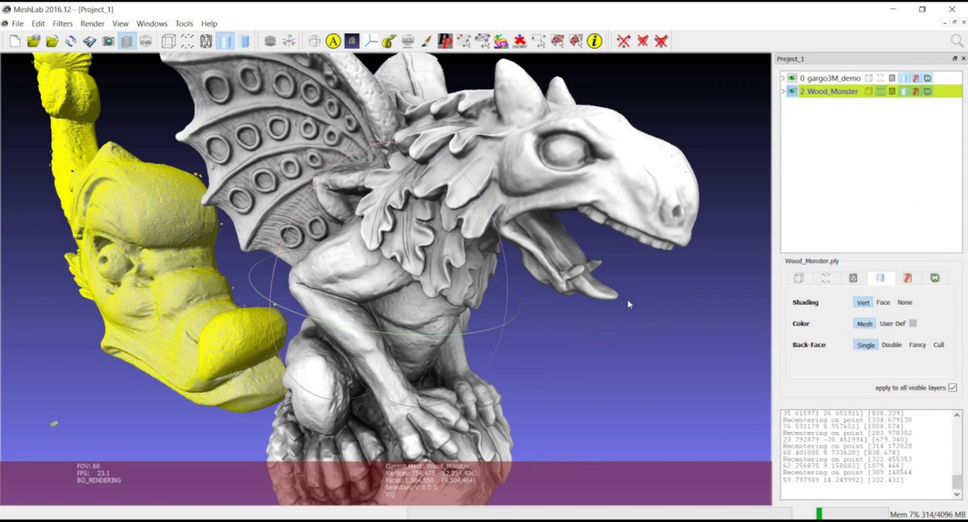
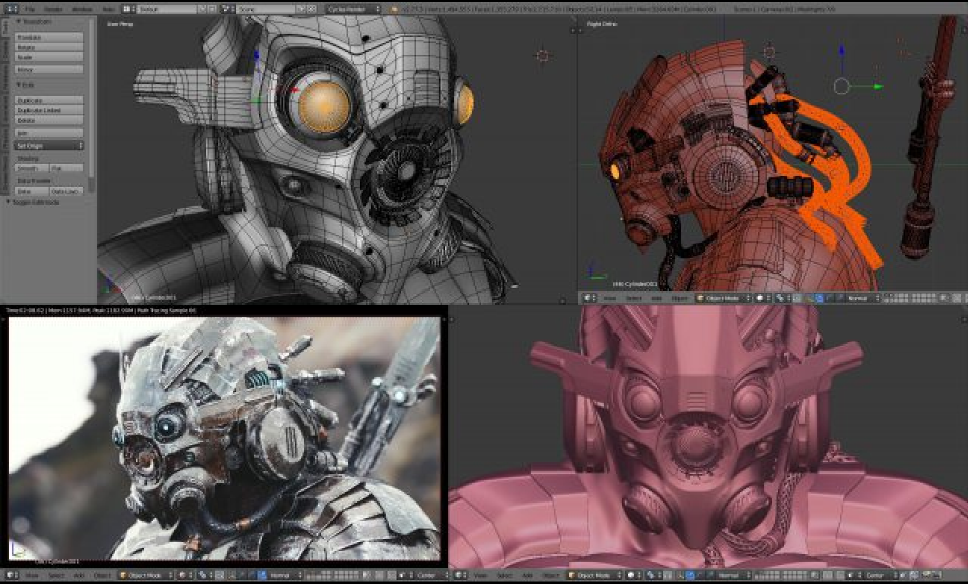
Scientific visualization is a research area by itself!

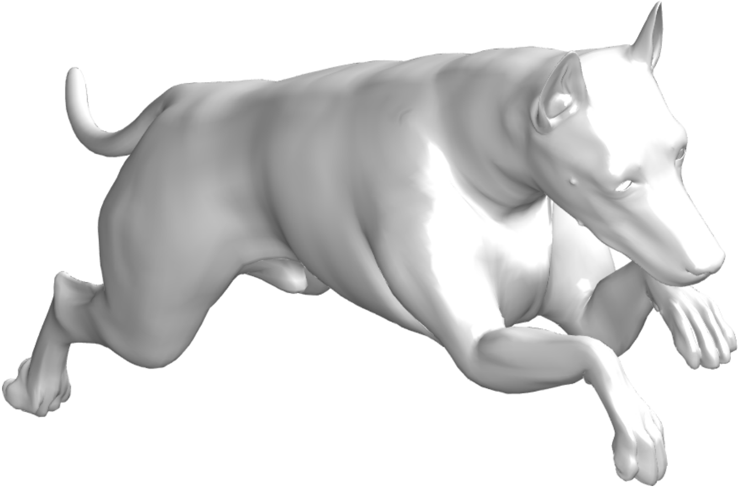
MeshLab (www.meshlab.net)



Blender (www.blender.org)



Plotting scalar functions



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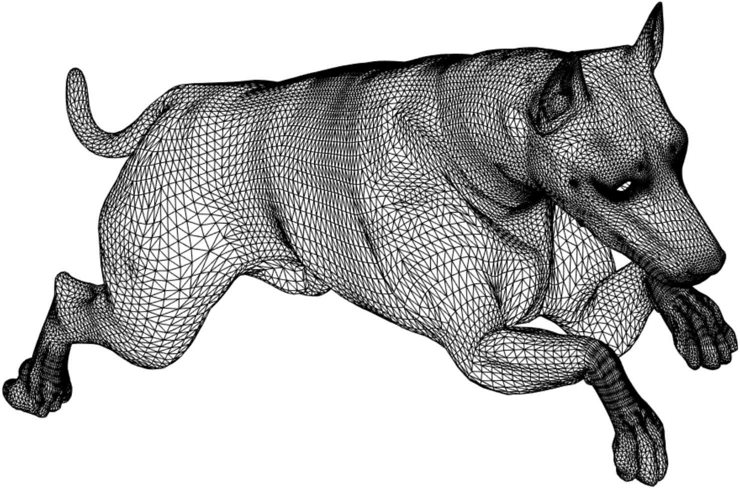

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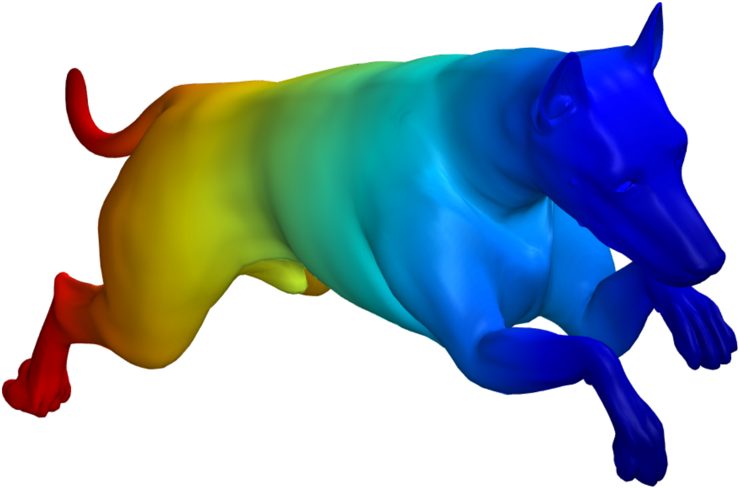
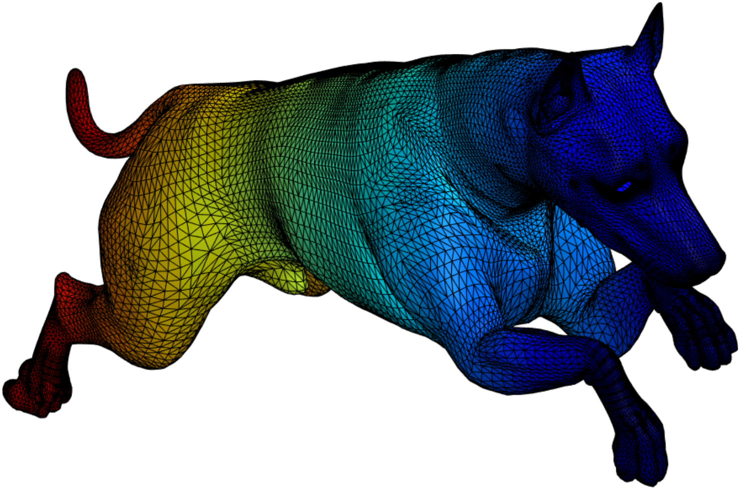


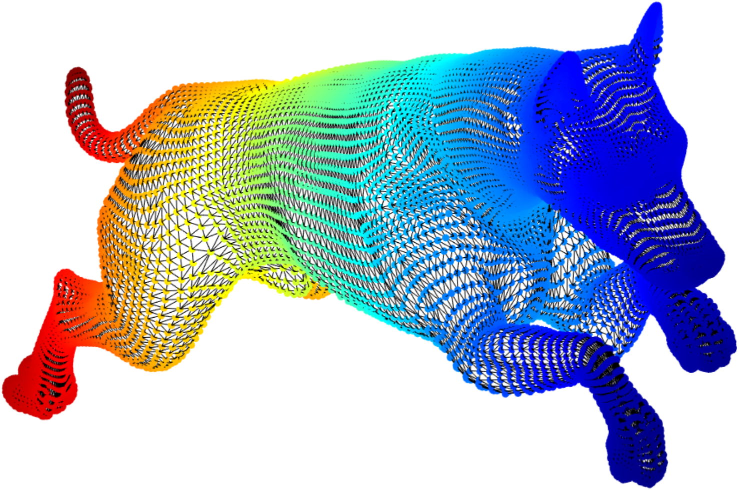
In Matlab: `trisurf (TRIV, X, Y, Z, f ); shading interp ;`
where $\mathbf{f}$ is a $n \times 1$ vector with a number per vertex

Plotting scalar functions



Matlab is actually coloring the triangles, not the vertices!

Plotting scalar functions

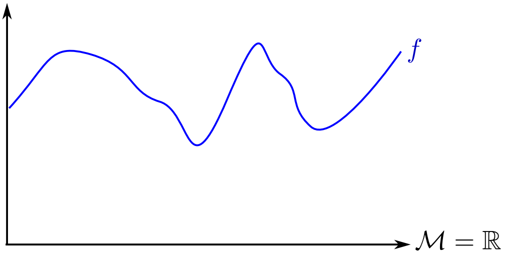


So what is happening inside the triangles?

Piecewise-linear approximation

Let us take one step back.

Consider a scalar function $f : \mathcal{M} \to \mathbb{R}$, which we want to represent on some discrete domain



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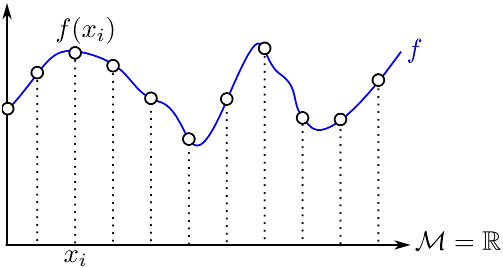

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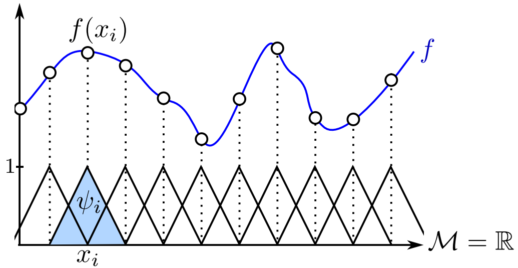
To do so, we approximate f by some other function $\tilde{f}$ using linear combinations of basis functions:

$$f \approx \tilde{f}$$
$$\tilde{f} = \sum_i f(x_i)\psi_i$$

Here, ψ_i are "hat" basis functions and $f(x_i)$ are approx. coefficients



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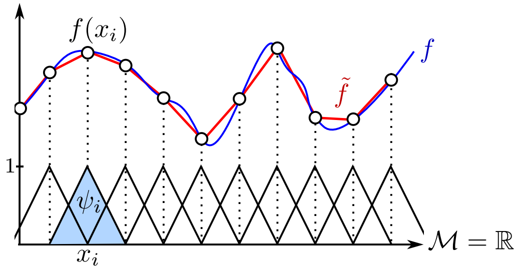
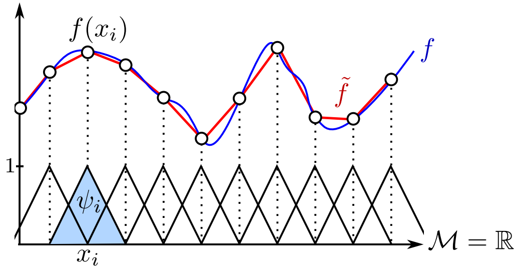
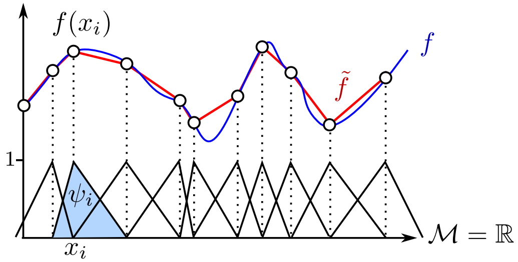


Piecewise-linear approximation



The vector $\mathbf{f} \in \mathbb{R}^n$ contains the approximation coefficients $\mathbf{f}_i = f(x_i)$ wrt the hat basis.

Piecewise-linear approximation



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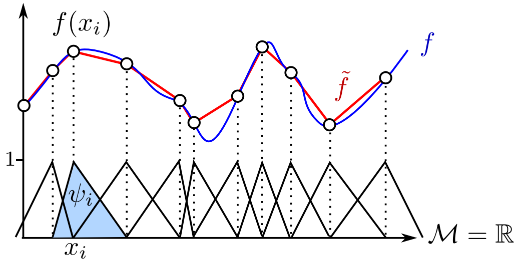
Note that:

- The domain could also be non-uniformly sampled while keeping a piecewise-linear approximation

Piecewise-linear approximation



The vector $\mathbf{f} \in \mathbb{R}^n$ contains the approximation coefficients $\mathbf{f}_i = f(x_i)$ wrt the hat basis.

Note that:

- The domain could also be non-uniformly sampled while keeping a piecewise-linear approximation
- Piecewise-linear is not the only option: other basis functions can be chosen (quadratic, cubic, ...)

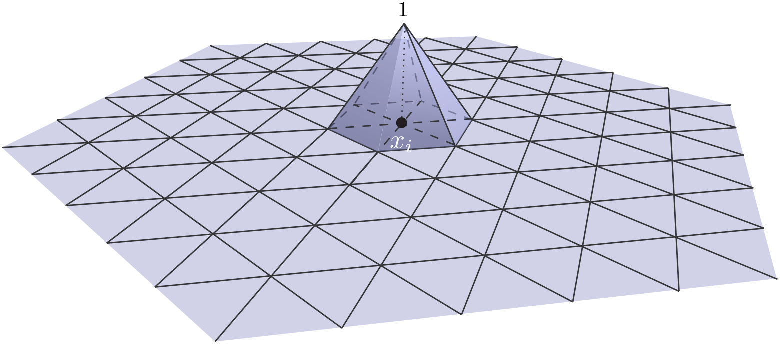
Piecewise-linear approximation on meshes

Triangle meshes discretize an underlying surface domain $\mathcal{M}$

Piecewise-linear approximation on meshes

Triangle meshes discretize an underlying surface domain $\mathcal{M}$

Hat basis functions can be defined just as before:



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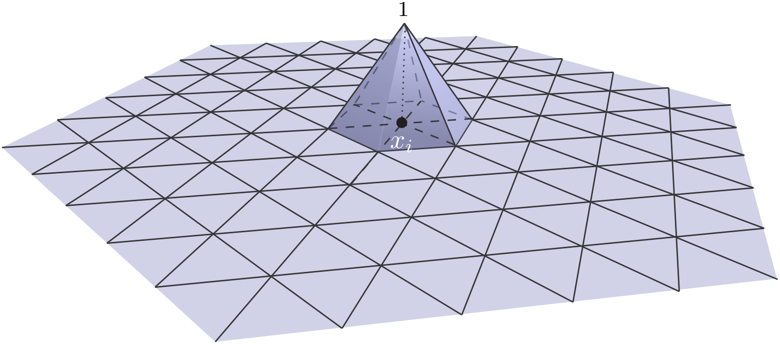
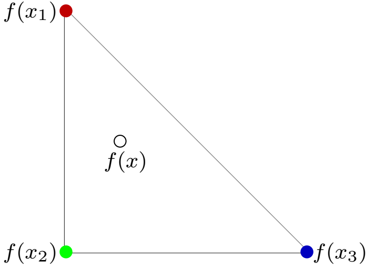


With this choice, we look at piecewise-linear approximations of functions on our triangle meshes (this will be a key assumption in future lectures!)

Piecewise-linear approximation on meshes

Piecewise-linear clearly means linear behavior within each triangle:



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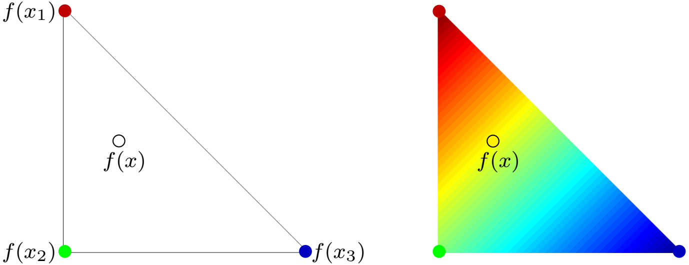

Given function values $f(x_1), f(x_2), f(x_3)$ at the 3 vertices, the function values $f(x)$ inside the triangle are obtained by barycentric coordinates

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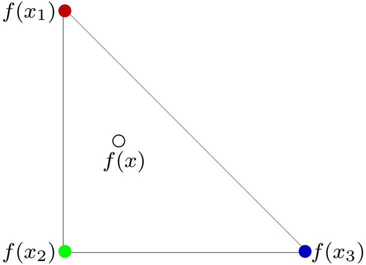
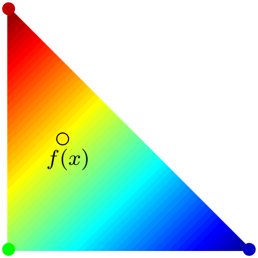


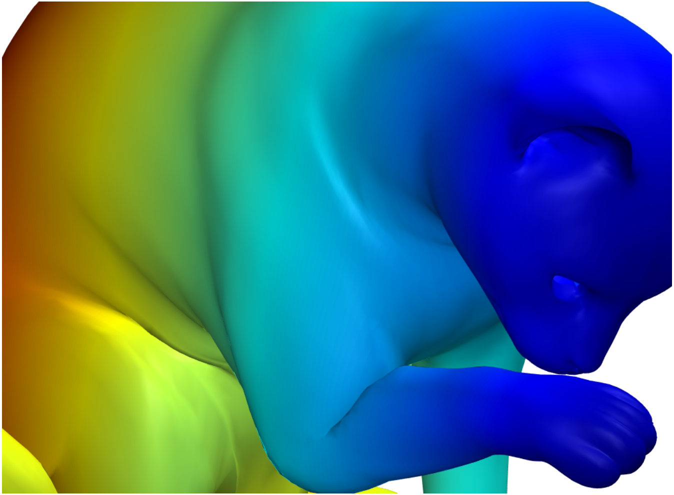


Given function values $f(x_1), f(x_2), f(x_3)$ at the 3 vertices, the function values $f(x)$ inside the triangle are obtained by barycentric coordinates

With Matlab's shading interp command, vector values are therefore interpreted as approximation coefficients wrt the hat basis

Shading in Matlab: interp

The choice of shading depends on what we want to visualize.



shading interp is good for scalar functions

Shading in Matlab: flat

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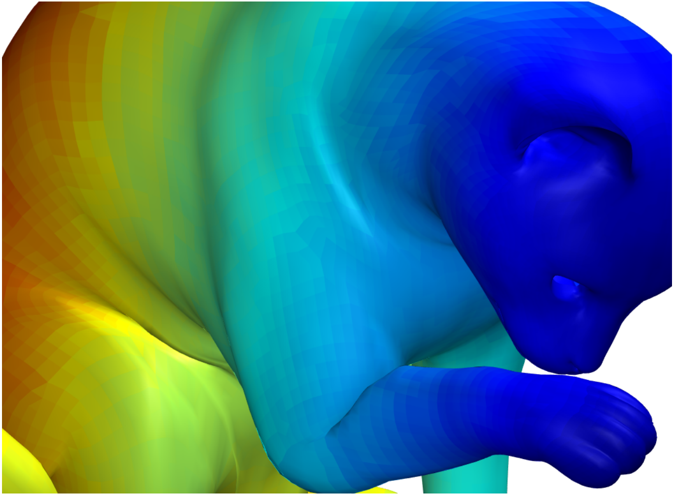

shading flat does not apply any interpolation

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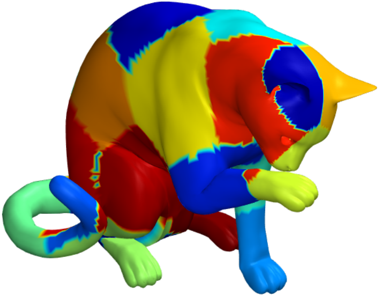

shading interp

shading flat

shading flat does not apply any interpolation (good for segmentations)

Shading in Matlab: faceted

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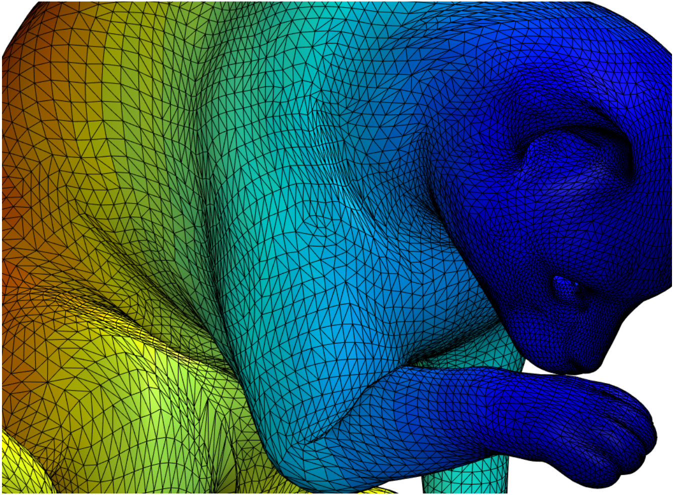

shading faceted is flat with visible mesh edges

Lighting and materials

Shape appearance is affected by lights and how the surface reacts to them

no light

light

Lighting and materials

Shape appearance is affected by lights and how the surface reacts to them

no light

light

lighting gouraud

- lighting gouraud interpolates linearly across the triangles

Lighting and materials

Shape appearance is affected by lights and how the surface reacts to them

no light light ×2 lighting gouraud

- lighting gouraud interpolates linearly across the triangles
- lights add up (two lights are brighter than one)

Lighting and materials

Several surface properties interact with lights and affect appearance

- Ambient light intensity: a nondirectional light that illuminates the scene

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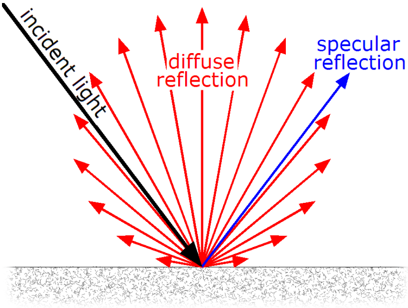
- Diffuse reflection: the nonspecular reflectance (think of non-shiny wood or chalk)



Lighting and materials

Several surface properties interact with lights and affect appearance

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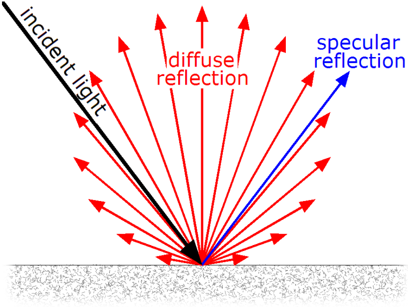
- Specular reflection: the bright spots on the surface



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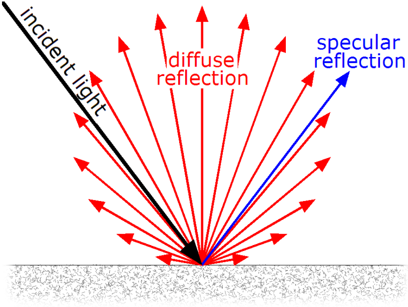


A specific set of these property values make up a material

Ambient light

Ambient light mainly affects shadows:

In Matlab: Change trisurf's 'AmbientStrength' property from 0 to 1

Diffuse reflection

Diffuse reflection mainly affects color brilliance:

In Matlab: Change trisurf's 'DiffuseStrength' property from 0 to 1

Specular reflection

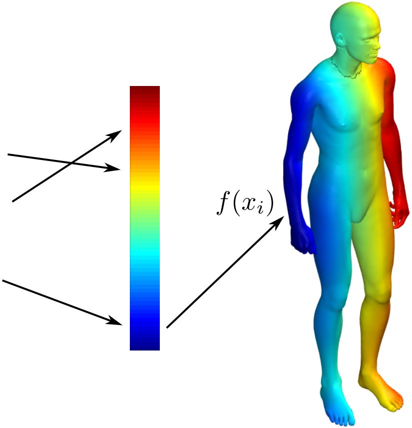
Specular reflection directly affects specularities:

In Matlab: Change trisurf's 'SpecularStrength' property from 0 to 1

Colormaps

Colormaps are used to determine which color corresponds to which value:

$$\mathbf{f} = \begin{array}{r} \\ \\ \\ i: \end{array}\begin{bmatrix} 0.1 \\ 0.15 \\ \vdots \\ 0.03 \end{bmatrix}$$



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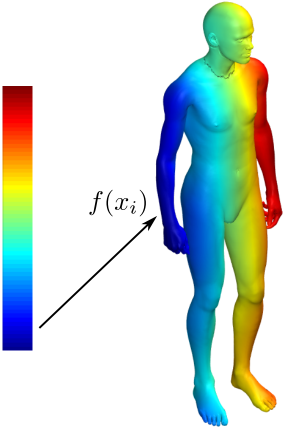
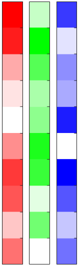


Scale does not matter: $\alpha\mathbf{f}$ will look the same as $\mathbf{f}$ for any $\alpha \neq 0$

Colormaps as range quantization

Colormaps are usually represented as $n \times 3$ matrices with values in $[0, 1]$:



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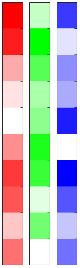
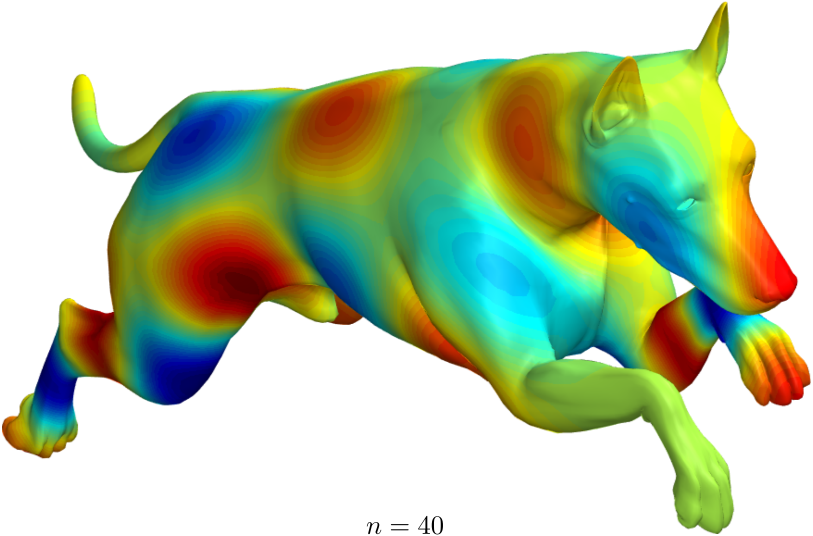


The number n of colors in a colormap doesn't have anything to do with the size of $\mathbf{f}$

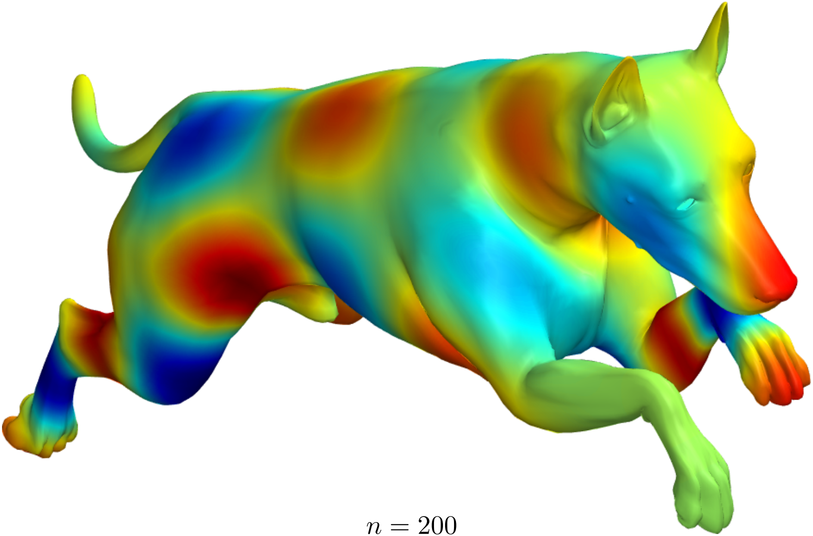
Rather, the colormap represents a quantization of the range of $f : \mathcal{M} \to \mathbb{R}$ into a discrete number (n) of "color bins"

Example: Quantization



$n = 40$

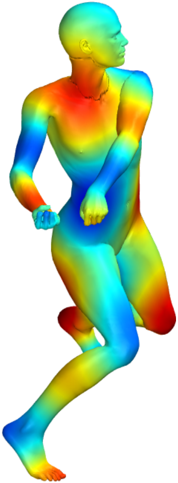
Example: Quantization



$n = 200$

Standard colormaps

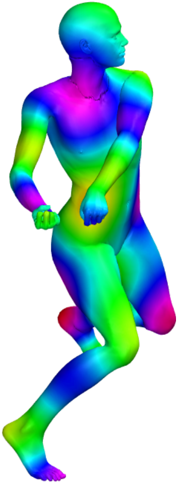
- jet



Standard colormaps

- jet

- hsv



Standard colormaps

- jet

- hsv

- spring

Standard colormaps

- jet

- hsv

- spring

- hot

Standard colormaps

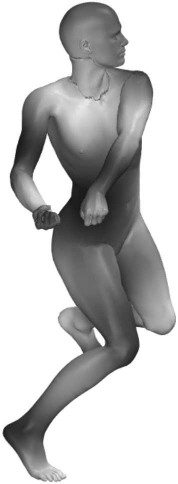
- jet

- hsv

- spring

- hot

- gray



Standard colormaps

- jet

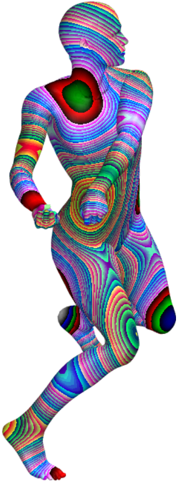
- hsv

- spring

- hot

- gray

- colorcube



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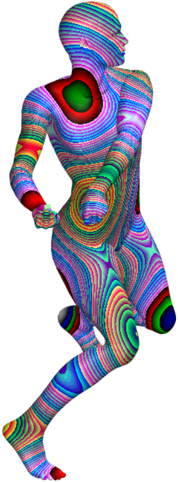


Custom colormaps may also be defined as needed

- By modifying an existing colormap (e.g. reverse color order)
- By creating a new one from scratch

Example: whitered

Create a colormap that linearly grows from white to red in n steps:

$n = 10$

Example: whitered

Create a colormap that linearly grows from white to red in n steps:

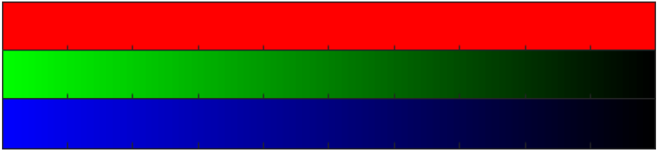
$n = 100$

Example: whitered

Create a colormap that linearly grows from white to red in n steps:

$n = 100$

Simply fix the red channel to constant value 1, and linearly decrease the blue and green channels from 1 to 0 in n discrete steps:



Exercise: Blue-white-red colormap

For the human shape `tr_reg_000.off`, compute the average Euclidean distance at each point:

$$f(x_i) = \sum_j \|x_i - x_j\|$$

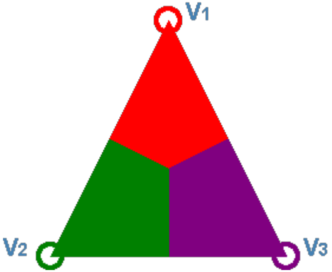
Then:

- Create a new colormap 'bluewhitered' growing linearly from blue to white to red
- Render f as a colored mesh using the bluewhitered colormap

Use materials and lights as you like.

Exercise: Nearest-neighbor colors

Given a triplet of vertices (v_1, v_2, v_3) with colors (c_1, c_2, c_3), write code that colors the interior points as in the following figure:



Note: The vertices should not necessarily form an equilateral triangle