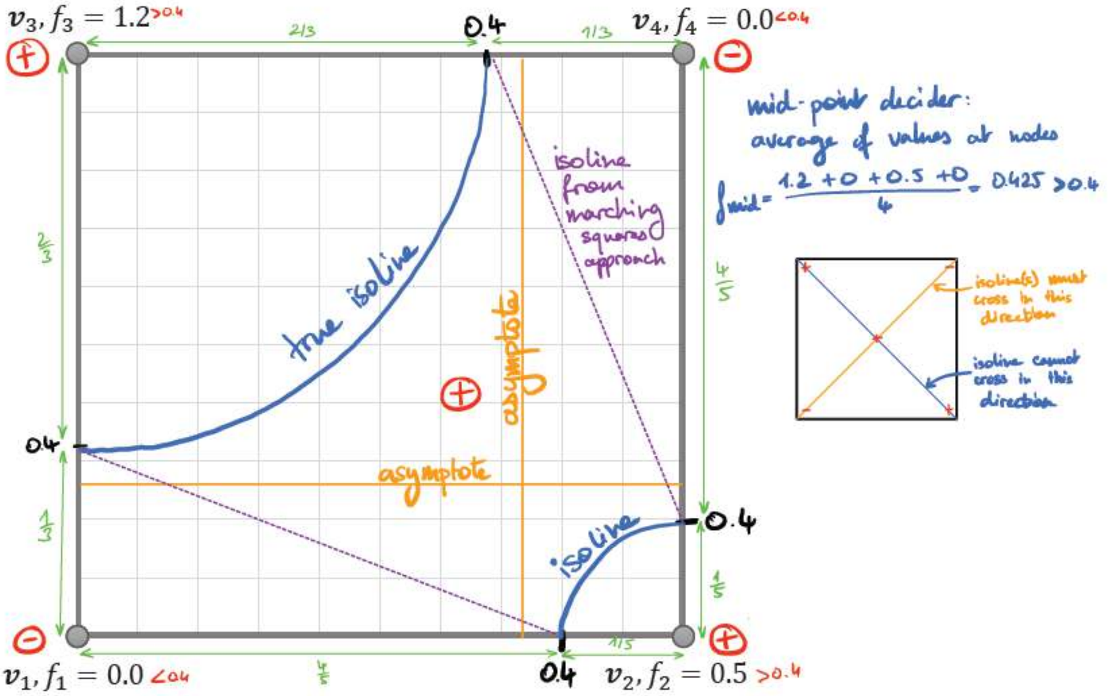
Sample questions Lecture 5 Solution

Visual Data Analytics (Technische Universität München)

Lecture 5 – Isolines & Isosurfaces

Isolines & Isosurfaces

a) Given is the following quadrilateral cell with its four vertices $\boldsymbol{v_1}, \boldsymbol{v_2}, \boldsymbol{v_3}, \boldsymbol{v_4}$ and the corresponding scalar values f_1, f_2, f_3, f_4. A grid is shown for orientation purpose, i.e., it does not affect the interpolation.
Draw the approximated **iso-lines** (dashed) for the iso-value 0.4 into the illustration using the **marching squares algorithm**. Use the **mid-point decider** for ambiguous cases.
Also, draw the true iso-contour (bold) for the iso-value 0.4 into the same illustration, i.e., all points in the interior of the cell which have a value equal to 0.4. Bi-linear interpolation is assumed for interpolation.



b) Name the three components of the **Phong illumination model**.
Ambient light, specular reflector, diffuse reflector.

c) How can a **perfect mirror** be simulated via the Phong illumination model?
If the shininess coefficient $n \rightarrow \infty$.

d) Let L be an incoming light ray and M a **diffusely reflecting material**. Complement the illustration on the right in Figure 7 according to the illustration on the left. Hint: Take into account the direction and strength of the reflection.

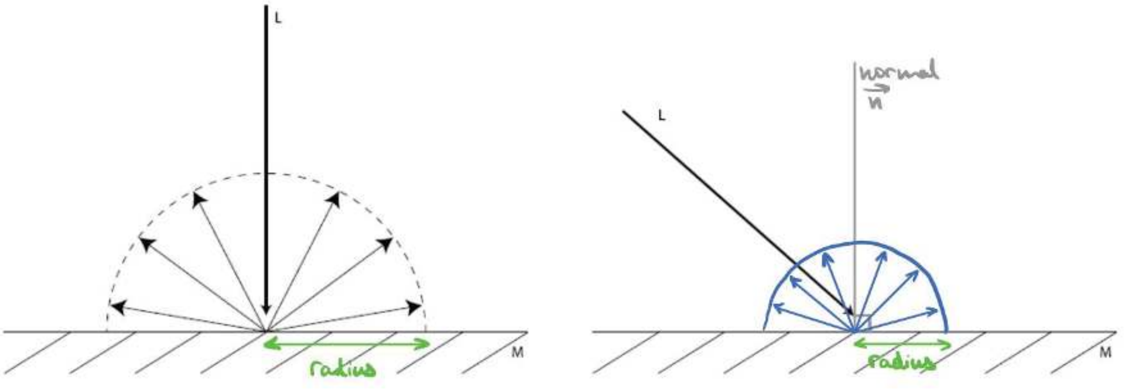


Figure 7

The radius is smaller in the RHS of Figure 7 because the reflection is weaker.

e) Let L be an incoming light ray and M a **specular reflecting material**. The viewer is positioned at the light source and is looking along L. Complement Figure 8 according to Figure 7.

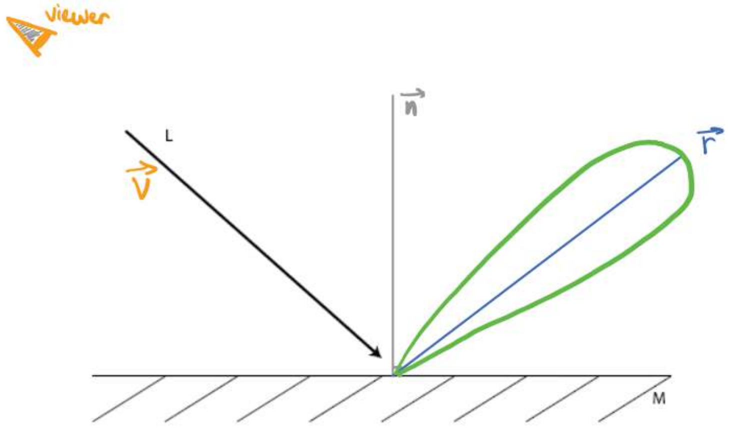
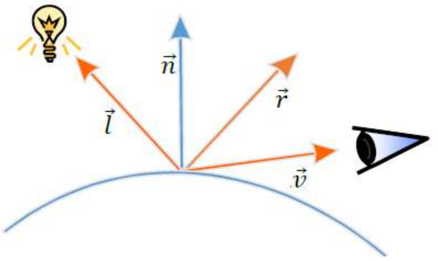


Figure 8

f) Below is an illustration of the **Phong illumination model**. All indicated vectors are normalized (i.e., their length is one). Answer whether the following statements are true or false:



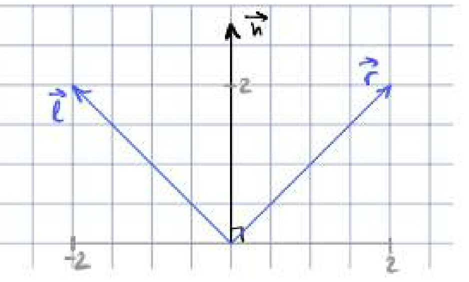
$\vec{n}$ ... Normal vector of the surface
$\vec{l}$ ... Vector pointing to the light source
$\vec{r}$ ... Reflected light ray
$\vec{v}$ ... Vector pointing to the viewer (view vector)

The specular reflection is based on the scalar/dot product of $\vec{\boldsymbol{n}}$ and $\vec{\boldsymbol{v}}$.	False: depends on $\vec{\boldsymbol{r}}$ and $\vec{\boldsymbol{v}}$, not $\vec{\boldsymbol{n}}$.
The diffuse reflection is based on the scalar/dot product of $\vec{\boldsymbol{n}}$ and $\vec{\boldsymbol{l}}$.	True.
The ambient light is based on the scalar/dot product of $\vec{\boldsymbol{l}}$ and $\vec{\boldsymbol{r}}$.	False: ambient light is always constant.
The specular reflection is independent of the view vector $\vec{\boldsymbol{v}}$.	False: depends on angle between on $\vec{r}$ and $\vec{v}$.

g) Compute the **specular reflection** at a surface point $P = (3,1,-2)^T$ using the Phong lighting model. The normal at the point is $\vec{n} = (0,1,0)^T$. Moreover, the specular reflection coefficient of the surface is $k_s = 0.5$ and the specular exponent is $n = 2$. The position of a point light source is $L_{pos} = (1,3,-1)^T$ and the camera position is at $E_{pos} = (5,2,-2)^T$. Both the point light source and the surface color are white with RGB-values $(1,1,1)$.

Hint: You can compute the reflected light ray as $\vec{r} = 2(\vec{n} \cdot \vec{l})\vec{n} - \vec{l}$, where $\vec{n}$ and $\vec{l}$ need to be normalized.

$$C = \underbrace{k_s}_{\text{specular reflection coef.}} \cdot \overset{\text{color}}{O_c} \cdot (\underset{\text{reflection}}{\vec{r}} \cdot \overset{\text{viewing}}{\vec{v}})^{n}$$ shininess factor



Light vector:

$$\underset{L_{pos}}{\begin{pmatrix}1\\3\\-1\end{pmatrix}} - \underset{P}{\begin{pmatrix}3\\1\\-2\end{pmatrix}} = \begin{pmatrix}-2\\2\\1\end{pmatrix} \quad \sqrt{(-2)^2+(2)^2+(1)^2} = 3 \quad \therefore \vec{l} = \underbrace{\frac{1}{3}}_{\text{normalisation factor}}\begin{pmatrix}-2\\2\\1\end{pmatrix}$$

Reflection vector:

$$\vec{r} = \underbrace{\frac{1}{3}}\begin{pmatrix}2\\2\\-1\end{pmatrix}$$

Check:

$\vec{r} = 2(\vec{n}\cdot\vec{l})\vec{n} - \vec{l}$ with $\vec{n}$ and $\vec{l}$ normalised:

here, $\vec{n} = \begin{pmatrix}0\\1\\0\end{pmatrix}$ $\quad |\vec{l}| = \sqrt{2^2+2^2+1^2} = 3$ $\therefore$ take $\vec{l} = \frac{1}{3}\begin{pmatrix}-2\\2\\1\end{pmatrix}$

$$\Rightarrow \vec{r} = 2\left[\begin{pmatrix}0\\1\\0\end{pmatrix}\frac{1}{3}\begin{pmatrix}-2\\2\\1\end{pmatrix}\right]\begin{pmatrix}0\\1\\0\end{pmatrix} - \frac{1}{3}\begin{pmatrix}-2\\2\\1\end{pmatrix} = \frac{2}{3}[2]\begin{pmatrix}0\\1\\0\end{pmatrix} - \frac{1}{3}\begin{pmatrix}-2\\2\\1\end{pmatrix}$$

$$= \frac{4}{3}\begin{pmatrix}0\\1\\0\end{pmatrix} - \frac{1}{3}\begin{pmatrix}-2\\2\\1\end{pmatrix} = \frac{1}{3}\begin{pmatrix}2\\2\\-1\end{pmatrix}$$

View vector:

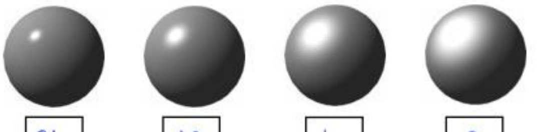
$$\underset{E_{pos}}{\begin{pmatrix}5\\2\\-2\end{pmatrix}} - \underset{P}{\begin{pmatrix}3\\1\\-2\end{pmatrix}} = \begin{pmatrix}2\\1\\0\end{pmatrix} \quad \sqrt{2^2+1^2+0^2} = \sqrt{5} \quad \therefore \vec{v} = \underbrace{\frac{1}{\sqrt{5}}}_{\text{normalisation factor}}\begin{pmatrix}2\\1\\0\end{pmatrix}$$

Specular reflection:

$$C = k_s\, O_c\, (\vec{r}\cdot\vec{v})^n = 0.5 \cdot O_c \cdot \left[\frac{1}{3}\begin{pmatrix}2\\2\\-1\end{pmatrix} \cdot \frac{1}{\sqrt{5}}\begin{pmatrix}2\\1\\0\end{pmatrix}\right]^2 = \frac{1}{2} O_c \left[\frac{1}{3\sqrt{5}}(6)\right]^2 = \frac{1}{2} O_c \frac{4}{5} = \frac{2}{5} O_c$$

$$\therefore C = \frac{2}{5}\underbrace{\begin{pmatrix}1\\1\\1\end{pmatrix}}_{\text{RGB values}} = \begin{pmatrix}0.4\\0.4\\0.4\end{pmatrix}$$

h) In the four images below, a sphere is rendered using the Phong illumination model. Four different specular exponents (2, 4, 16, and 64) were used to create the specular reflection. Write the **specular exponent** that was used to create the rendering below each image.



64	16	4	2

From $C = k_s \cdot C_p \cdot O_d \cos^n \varphi$, larger $n \rightarrow$ smaller $\cos^n \varphi \rightarrow$ smaller C, thus the larger the exponent (=shininess factor), the smaller the specular highlight.