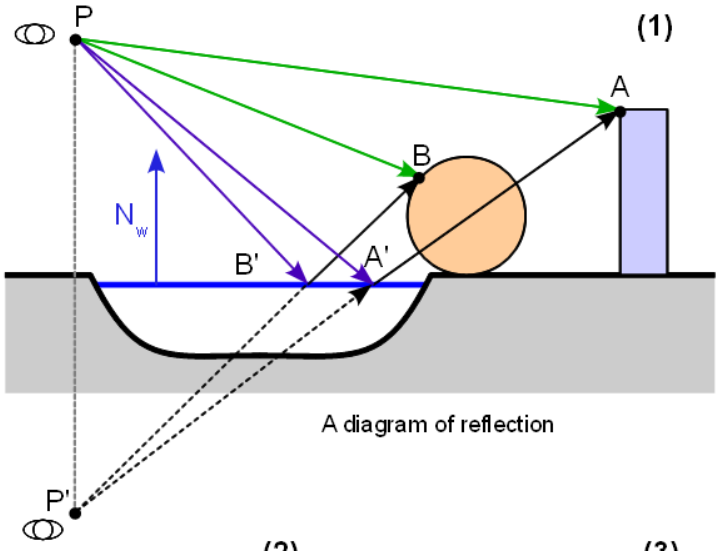
Real-Time Water Surface Rendering

Computer Graphics Seminar
Maarja Lepamets
October 9th, 2014

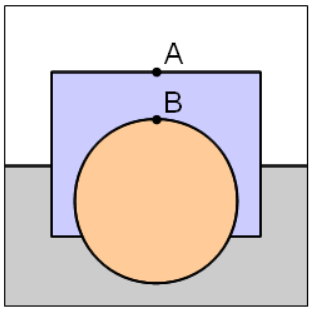
Physical properties of water

- Reflection and refraction (incl. caustics)
- Light attenuation
- Transparency/opacity
- Surface tension
- Ripples and waves
- Sprinkles and foam

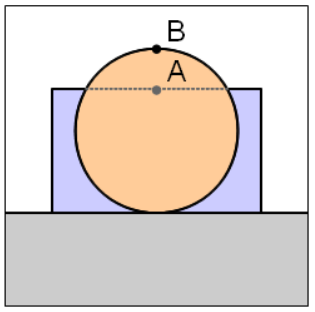
Reflection



A diagram of reflection



The original image



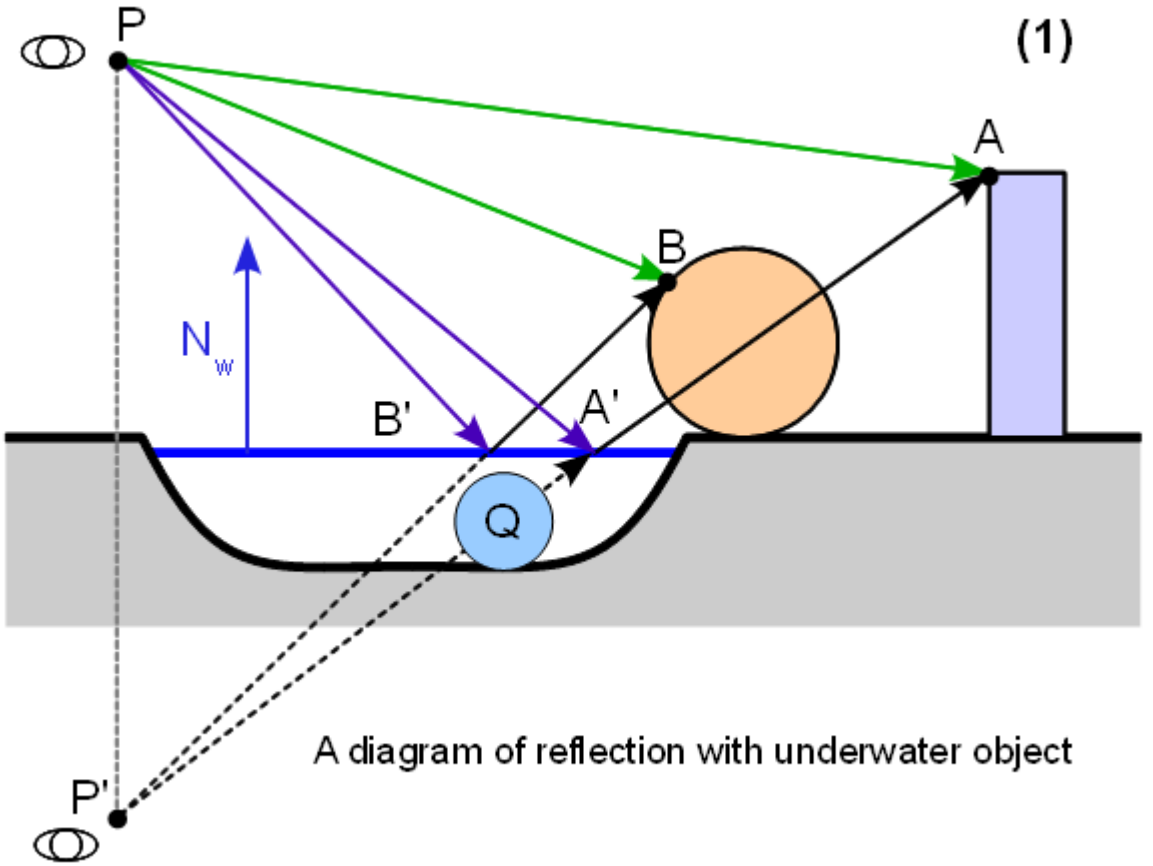
Reflected image

$$M'_{camera} = M_{reflection} * M_{camera}$$

$$N_x x + N_y y + N_z z + D = 0$$

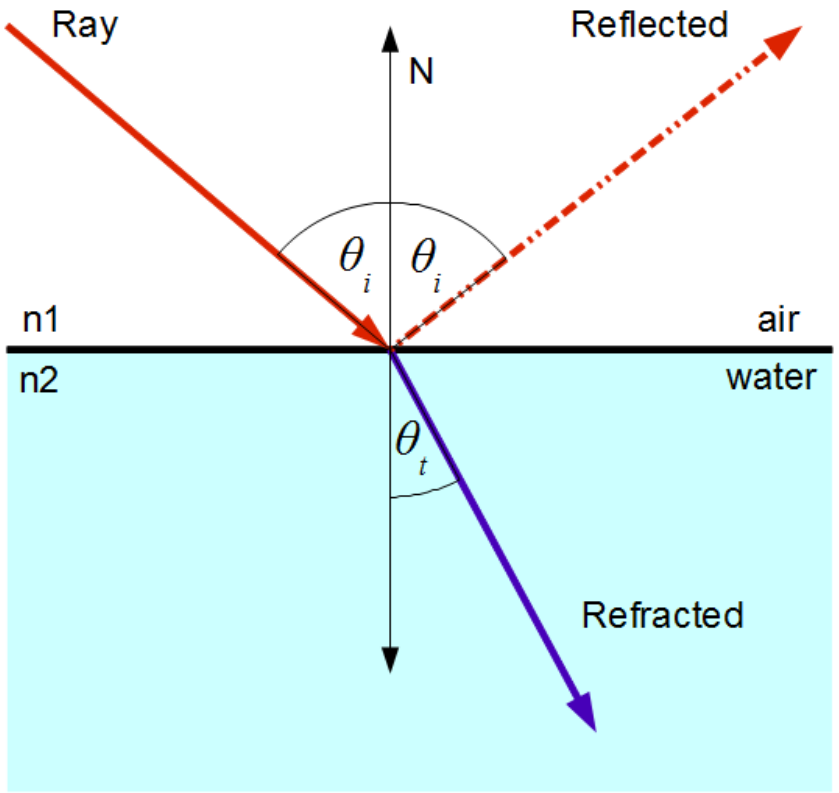
$$M_{reflection} = \begin{pmatrix} 1-2N_x^2 & -2N_xN_y & -2N_xN_z & -2N_xD \\ -2N_xN_y & 1-2N_y^2 & -2N_yN_z & -2N_yD \\ -2N_xN_z & -2N_yN_z & 1-2N_z^2 & -2N_zD \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

Underwater clipping



A diagram of reflection with underwater object

Reflection and viewing angle

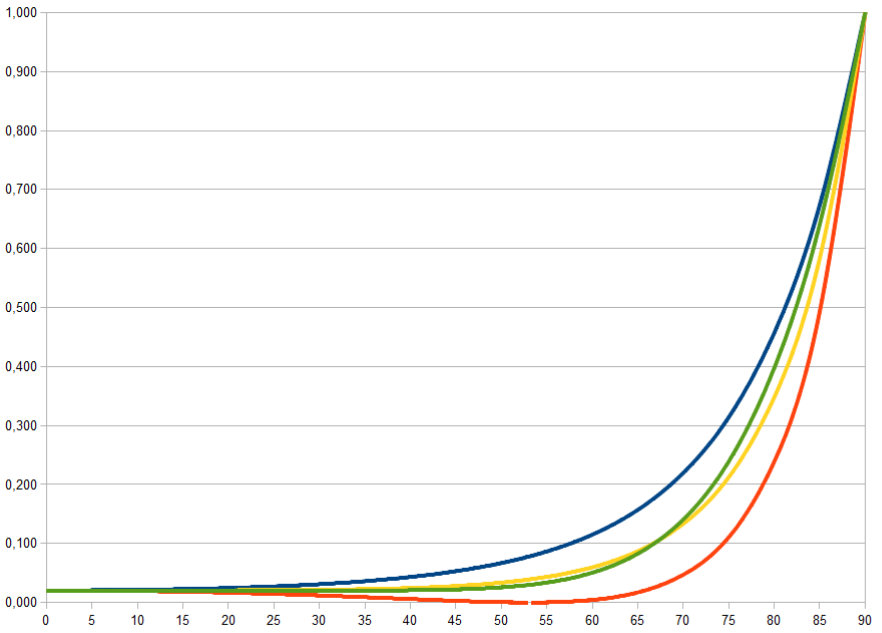


Fresnel equations:

$$R_s = \left(\frac{n_1 \cos\theta_\mathrm{i} - n_2 \cos\theta_\mathrm{t}}{n_1 \cos\theta_\mathrm{i} + n_2 \cos\theta_\mathrm{t}} \right)^2 = \left[\frac{n_1 \cos\theta_\mathrm{i} - n_2 \sqrt{1 - \left(\frac{n_1}{n_2} \sin\theta_\mathrm{i} \right)^2}}{n_1 \cos\theta_\mathrm{i} + n_2 \sqrt{1 - \left(\frac{n_1}{n_2} \sin\theta_\mathrm{i} \right)^2}} \right]^2$$

$$R_\mathrm{p} = \left(\frac{n_1 \cos\theta_\mathrm{t} - n_2 \cos\theta_\mathrm{i}}{n_1 \cos\theta_\mathrm{t} + n_2 \cos\theta_\mathrm{i}} \right)^2 = \left[\frac{n_1 \sqrt{1 - \left(\frac{n_1}{n_2} \sin\theta_\mathrm{i} \right)^2} - n_2 \cos\theta_\mathrm{i}}{n_1 \sqrt{1 - \left(\frac{n_1}{n_2} \sin\theta_\mathrm{i} \right)^2} + n_2 \cos\theta_\mathrm{i}} \right]^2$$

Reflection and viewing angle



Fresnel equations:

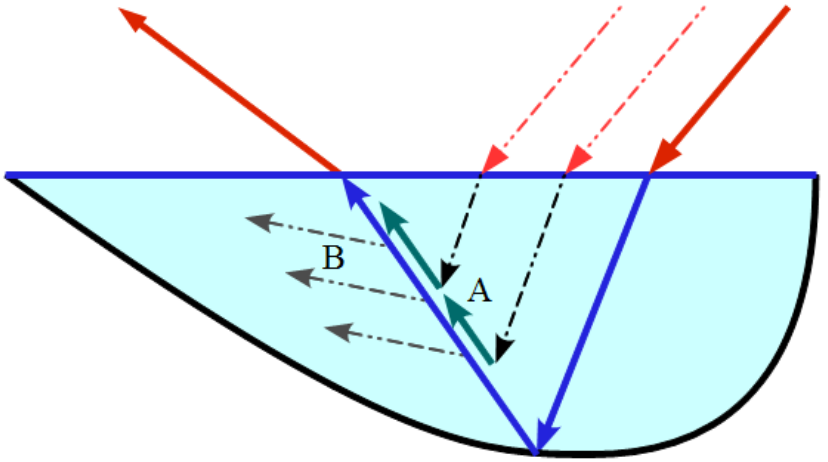
$$R_s = \left(\frac{n_1 \cos\theta_i - n_2 \cos\theta_t}{n_1 \cos\theta_i + n_2 \cos\theta_t} \right)^2 = \left[\frac{n_1 \cos\theta_i - n_2 \sqrt{1 - \left(\frac{n_1}{n_2} \sin\theta_i \right)^2}}{n_1 \cos\theta_i + n_2 \sqrt{1 - \left(\frac{n_1}{n_2} \sin\theta_i \right)^2}} \right]^2$$

$$R_p = \left(\frac{n_1 \cos\theta_t - n_2 \cos\theta_i}{n_1 \cos\theta_t + n_2 \cos\theta_i} \right)^2 = \left[\frac{n_1 \sqrt{1 - \left(\frac{n_1}{n_2} \sin\theta_i \right)^2} - n_2 \cos\theta_i}{n_1 \sqrt{1 - \left(\frac{n_1}{n_2} \sin\theta_i \right)^2} + n_2 \cos\theta_i} \right]^2$$

$$R = (R_s + R_p)/2$$

$$R = R_{min} + (1 - R_{min}) * (1 - \cos\theta_i)^5$$

Light scattering

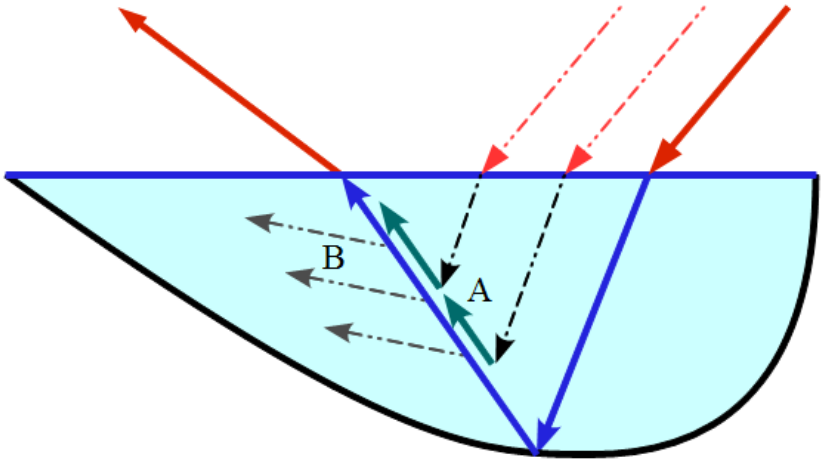


A – in-scattering
B – out-scattering

Rayleigh scattering:

$$I = I_0 \frac{1 + \cos^2\theta}{2R^2} \left(\frac{2\pi}{\lambda}\right)^4 \left(\frac{n^2 - 1}{n^2 + 2}\right)^2 \left(\frac{d}{2}\right)^6$$

Light scattering

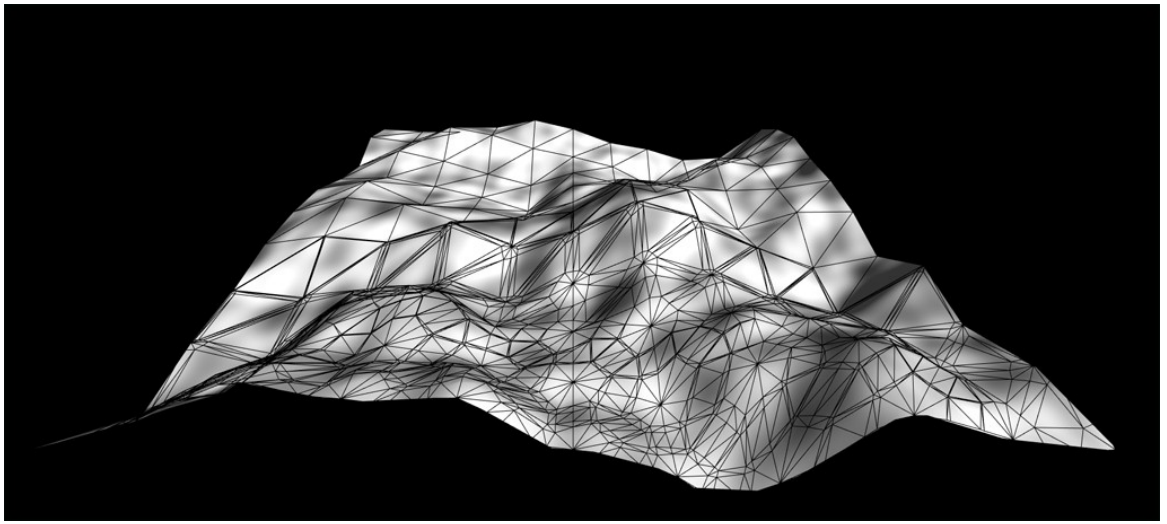


A – in-scattering
B – out-scattering

$$C_{tint} = C_{water} * (O_{min} + (1 - O_{min}) * \sqrt{\min(thickness / D_{opaque}, 1)})$$

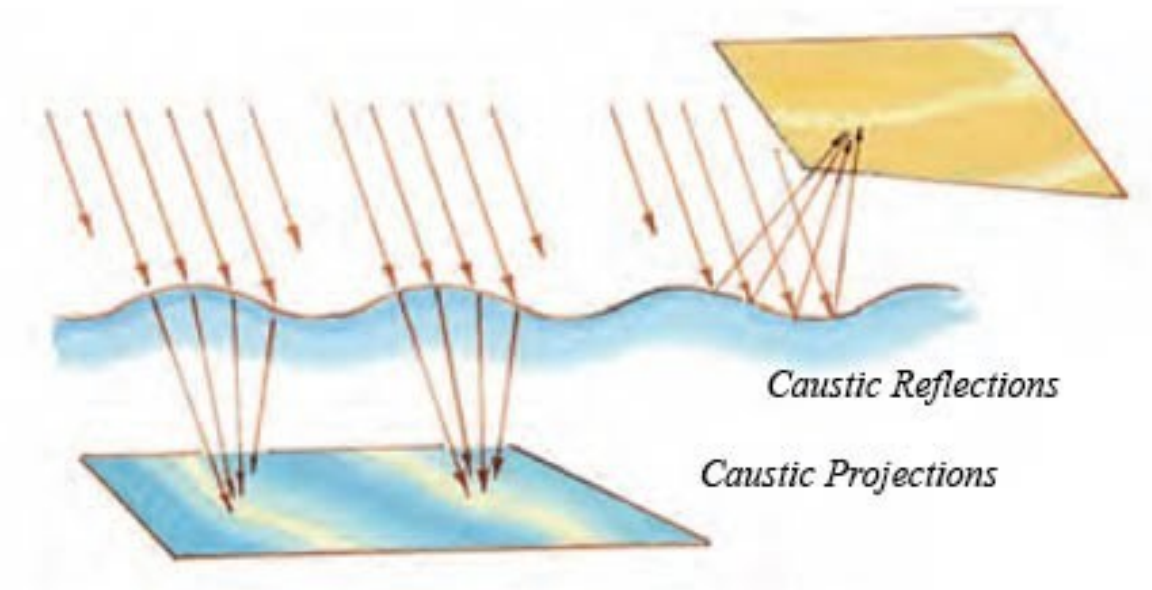
Ripples and waves

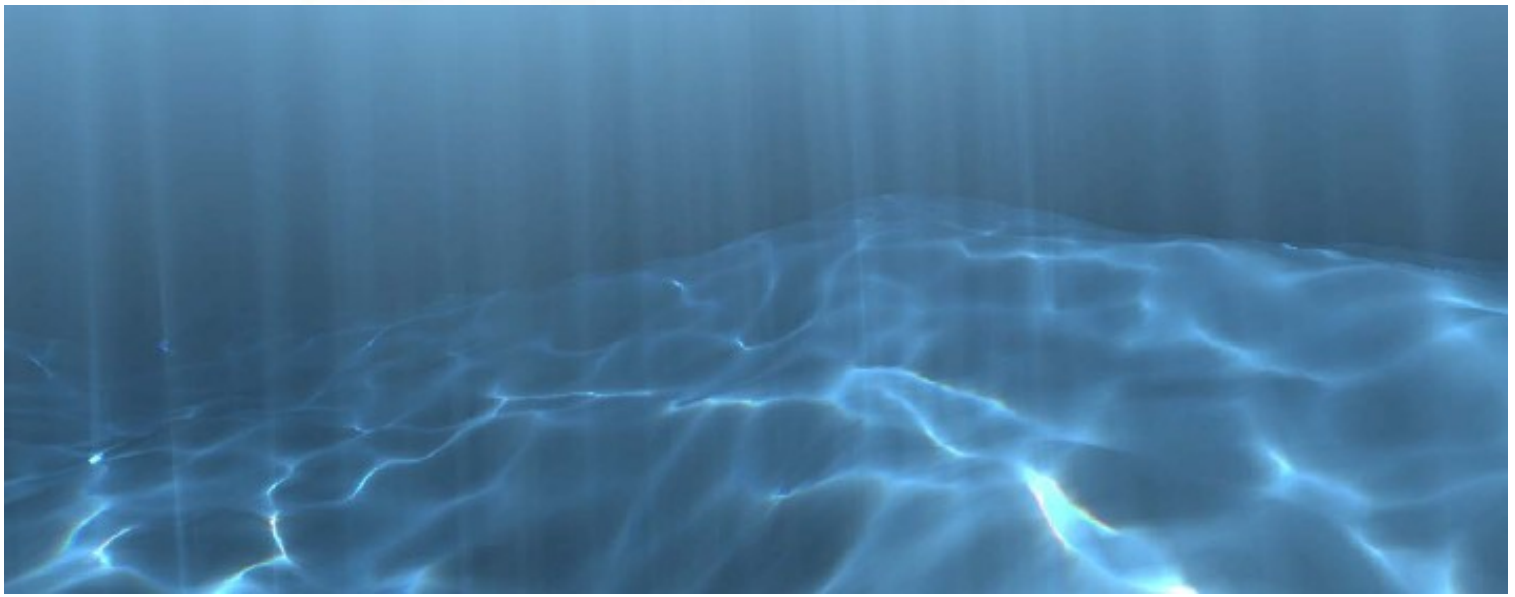
- Sum of simple sine waves
- Two methods:
  - Displacing vertices
  - Manipulating normals
- Adaptive tesselation



http://scrawkblog.files.wordpress.com/2013/10/proceduraltessellation0.jpg

Caustics





Thank you for your attention!