Diplomarbeitspräsentation

Extending Separable Subsurface Scattering to Arbitrary Materials

Masterstudium:
Visual Computing

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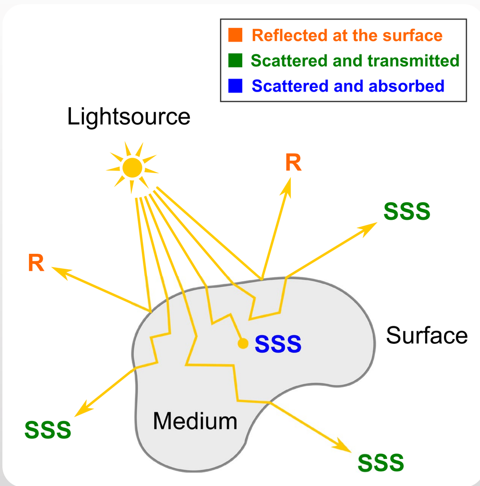
PROBLEM STATEMENT

In the context of real-time rendering it is common to ignore or simplify certain physical effects in order to increase rendering performance.

On example is **Subsurface Scattering (SSS)**, which refers to the transmittance of light through materials with low translucency, and is **important for the realistic appearance of many materials**, e.g. human skin, marble, milk or wax. SSS simulation and rendering is in general difficult and time consuming, and **often approximated by simpler models**.



Light transmittance and scattering

Real-world SSS

MOTIVATION & GOAL

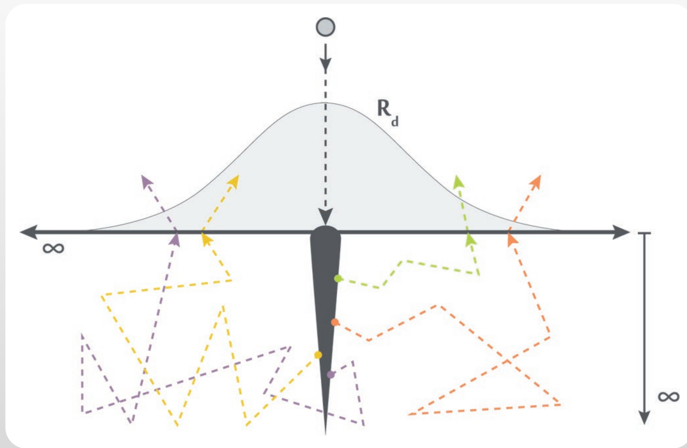
A recent algorithm called **Separable Subsurface Scattering (SSSS)** enables the approximation of Subsurface Scattering in real-time. It is in principle a **post-processing effect** that takes less than **1 ms per frame**. Unfortunately, the SSS model used in this method is specifically designed to approximate SSS in human skin.

GOAL:
Since SSSS is specifically tuned for human skin only, the goal of this thesis is to extend this method to support arbitrary materials.

REAL-TIME SSS APPROXIMATION

Most common real-time methods **approximate SSS by filtering of irradiance** on the surface of the material being rendered.

The used filters are based on so called **diffuse reflection profiles**, which capture and represent the SSS characteristics of a material. Such profiles are usually generated by simulation of a thin light beam hitting the surface of an infinite half-cube of a material volume. The light distribution on the surface represents the diffuse reflection profile, and subsequent the **ground-truth 2D filter**.



1D illustration of a diffuse reflectance profile

SSSS EXTENSIONS

Several filter models were developed as an **extension of Separable Subsurface Scattering**, which enable the approximation of SSS for materials other than human skin. They build upon the SSSS idea of a separable filter approximation based on the ground-truth 2D filter, but provide **more general models in order to support arbitrary materials**. The different models offer varying levels of filter computation speed, controllability and approximation quality.

SINGULAR VALUE DECOMPOSITION

A low rank approximation can be generated via **singular value decomposition of the ground-truth** 2D filter. Rank-1 (separable) approximations are of low quality, but higher rank approximations converge quickly to the ground truth, and can be applied via multiple convolution passes (two per rank).

SVD-based approximations

rank-1 (separable) *rank-3* *rank-5*

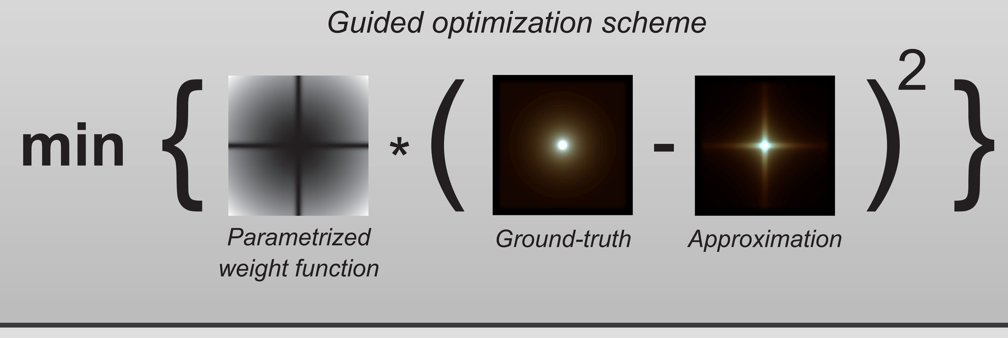
PRE-INTEGRATION

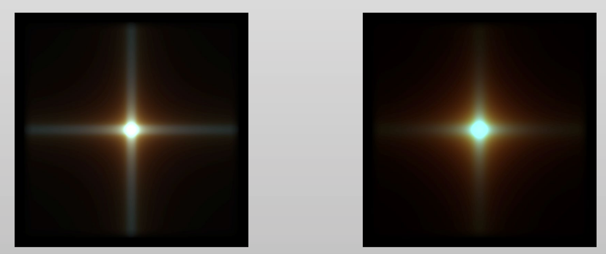
Via **pre-integration of the ground-truth 2D filter** along one axis, a separable approximation can be derived that is exact for additively separable irradiance signals. Moreover, the results indicate that this model is also applicable for arbitrary irradiance signals.

GUIDED OPTIMIZATION

The custom optimization scheme is based on the **minimization of a weighted error term**. The parametrized weight function makes it possible to shift the approximation quality between the center and falloff regions of the filter.

Guided optimization scheme



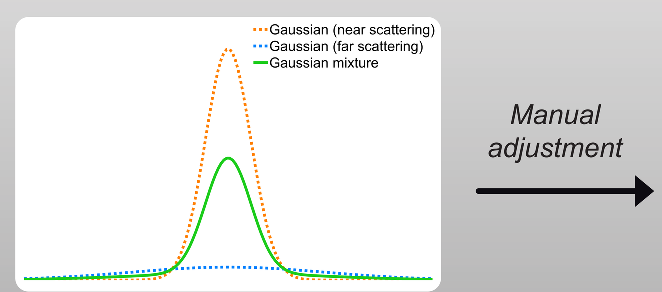


Emphasized center approximation *Emphasized falloff approximation*

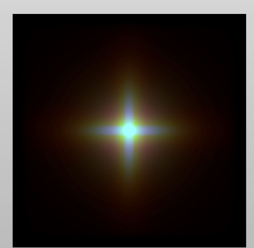
MANUAL APPROXIMATION

Full artistic control over the separable approximation filter can be achieved by usage of a **parametrized filter function, which is tweaked by the user** to generate the desired approximation filter. The function builds upon a mixture of two Gaussian as the 1D component of the separable filter.

1D component of the separable filter



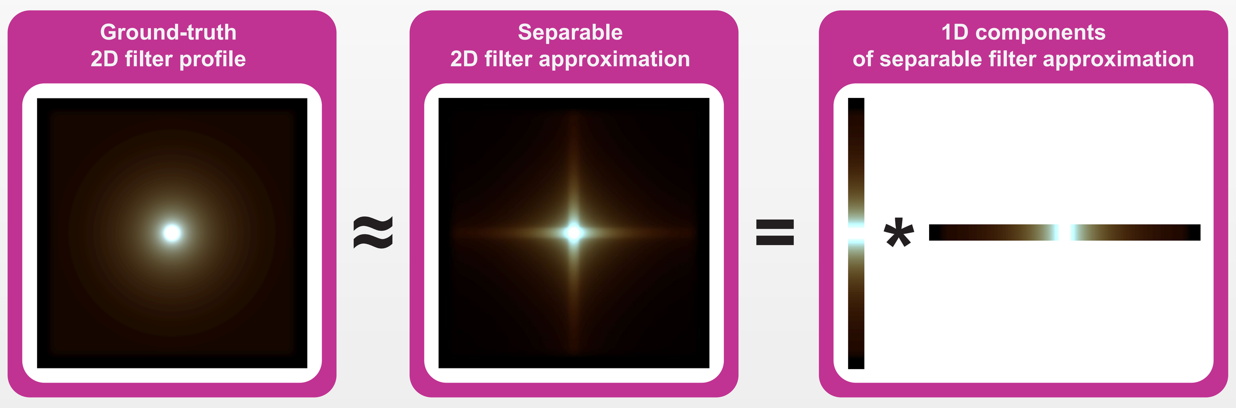
Approximation



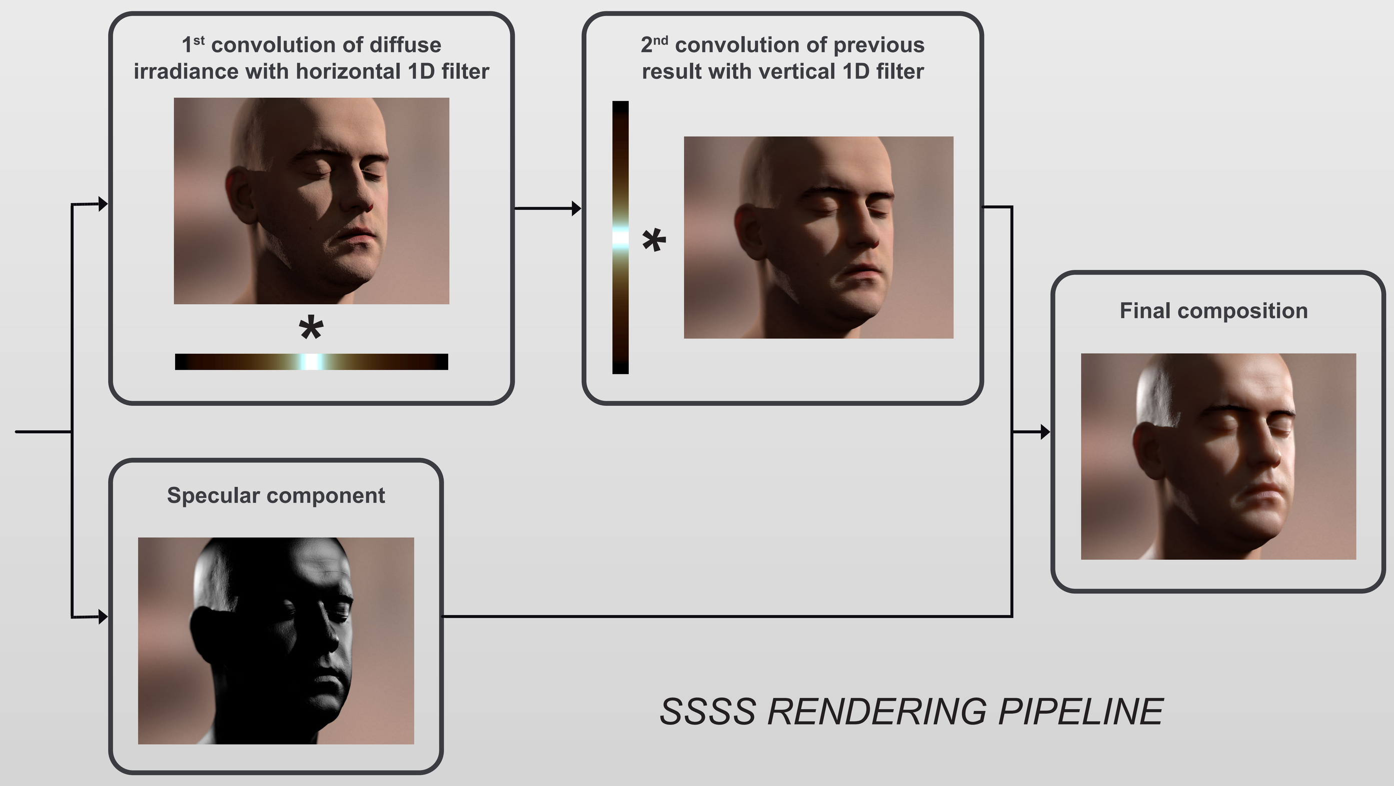
SEPARABLE SUBSURFACE SCATTERING

The basic idea of SSSS is to **approximate the ground-truth 2D filter by a separable filter** which can be applied much faster using only two 1D convolutions. The original SSSS algorithm only provides a very limited approximation model which was tuned for SSS in human skin.

The developed **extensions which support arbitrary materials are presented on the left**.



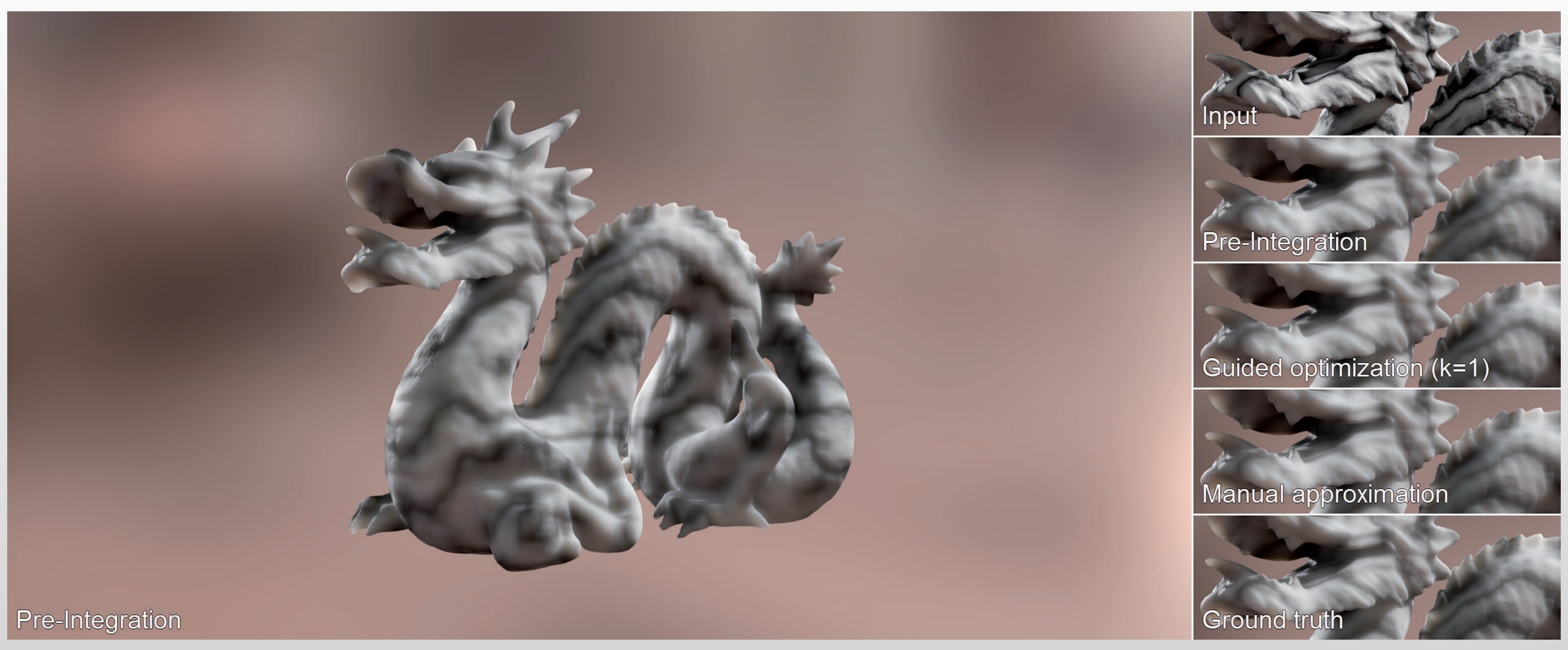
The SSSS algorithm applies the separable approximation filter as a **post-processing step in screen-space** on the diffuse illumination of the scene.



SSSS RENDERING PIPELINE

RESULTS

The extensions enable real-time SSS for **arbitrary materials and fully dynamic scenes**.



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