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Advanced Importance Sampling Techniques for Virtual Ray Lights

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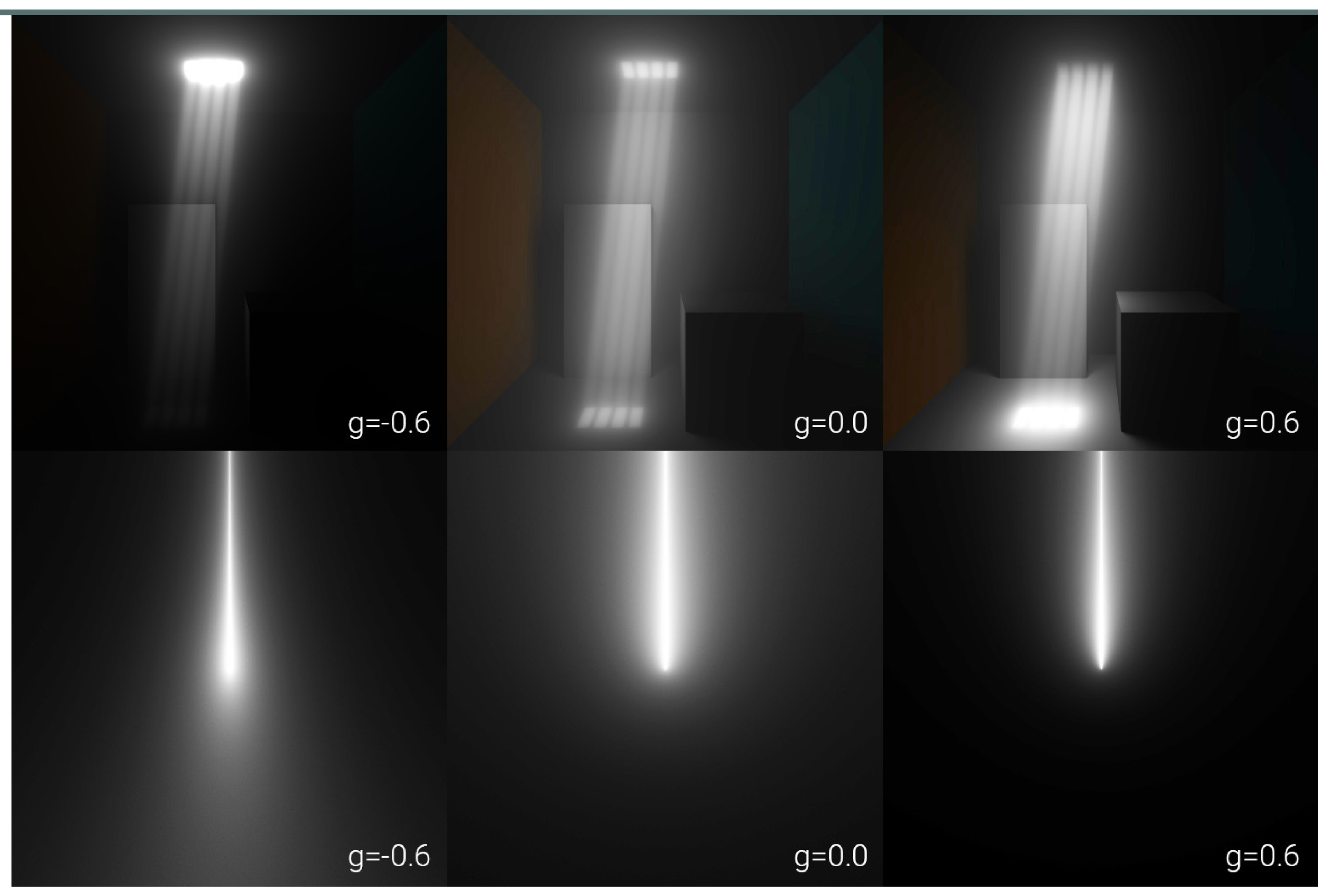
Problem Statement and Motivation

The aim of this work is to provide a new importance sampling technique that solves the anisotropic case of Virtual Ray Lights (VRL). As the original technique already creates a highly accurate approximation of the target function, the idea is to find representations that may approximate the target functions slightly worse, but are easier and faster to calculate. Therefore, more samples can be taken within the same time frame, as a result of performance improvements with an easier methodology. Additionally, the new importance sampling approach should also be less complex than the original approach. For these goals, there are three rules that we have set ourselves as guidelines.

1. The new approach has to be simpler than the original one.
2. All cases that were solved by the original approach, also have to be solved by the new approach.
3. The new approach has to be faster than the old one when comparing the time it takes to take a single sample.

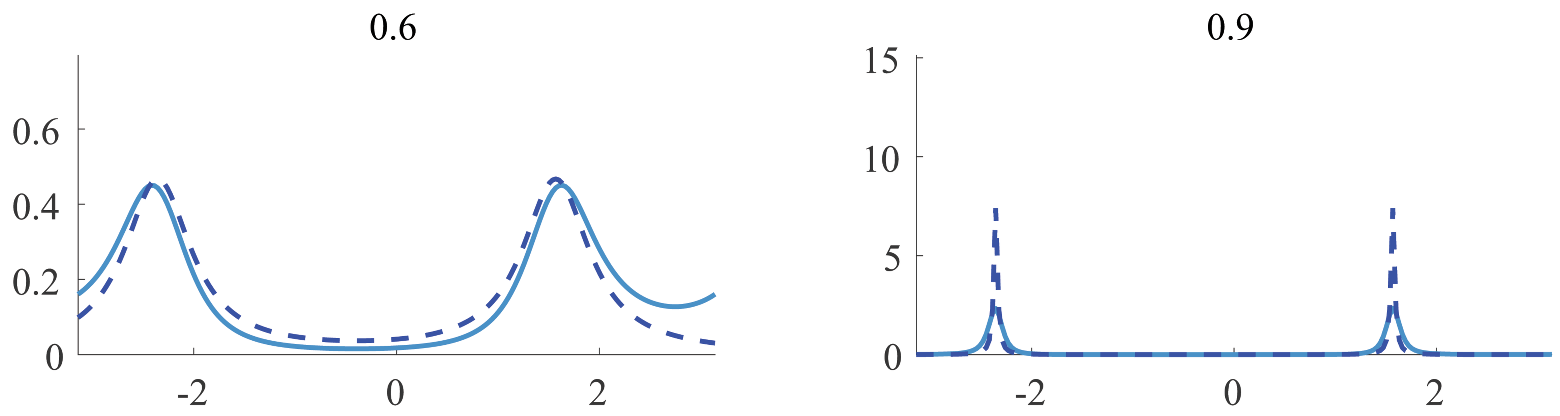


In the image above, two example scenes can be seen with varying anisotropic values. The used values are displayed within the images.

Solution 1 - Sum of Cauchy Distributions

In our first solution we use the sum of two Cauchy distributions to approximate the product of the phase functions, which is our target function. We first match two Cauchy distributions to the two phase functions by matching the location and adjusting the scale so that the distributions match the peak of the corresponding phase functions.

The sum of two Cauchy distributions can be integrated and then inverted, which is necessary when being used in Monte Carlo importance sampling approach. Therefore, this approach provides a solution that can be directly sampled from.

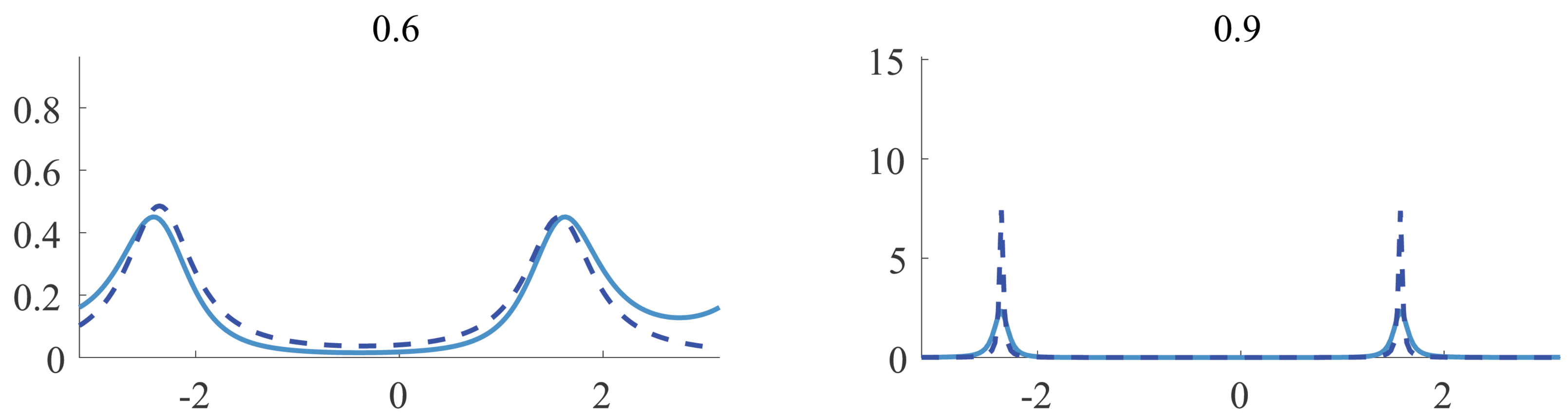


In the image above, two examples of this approximation can be seen with the target function as as solid line and our approximation as a dashed line.

Solution 2 - Mixture Model

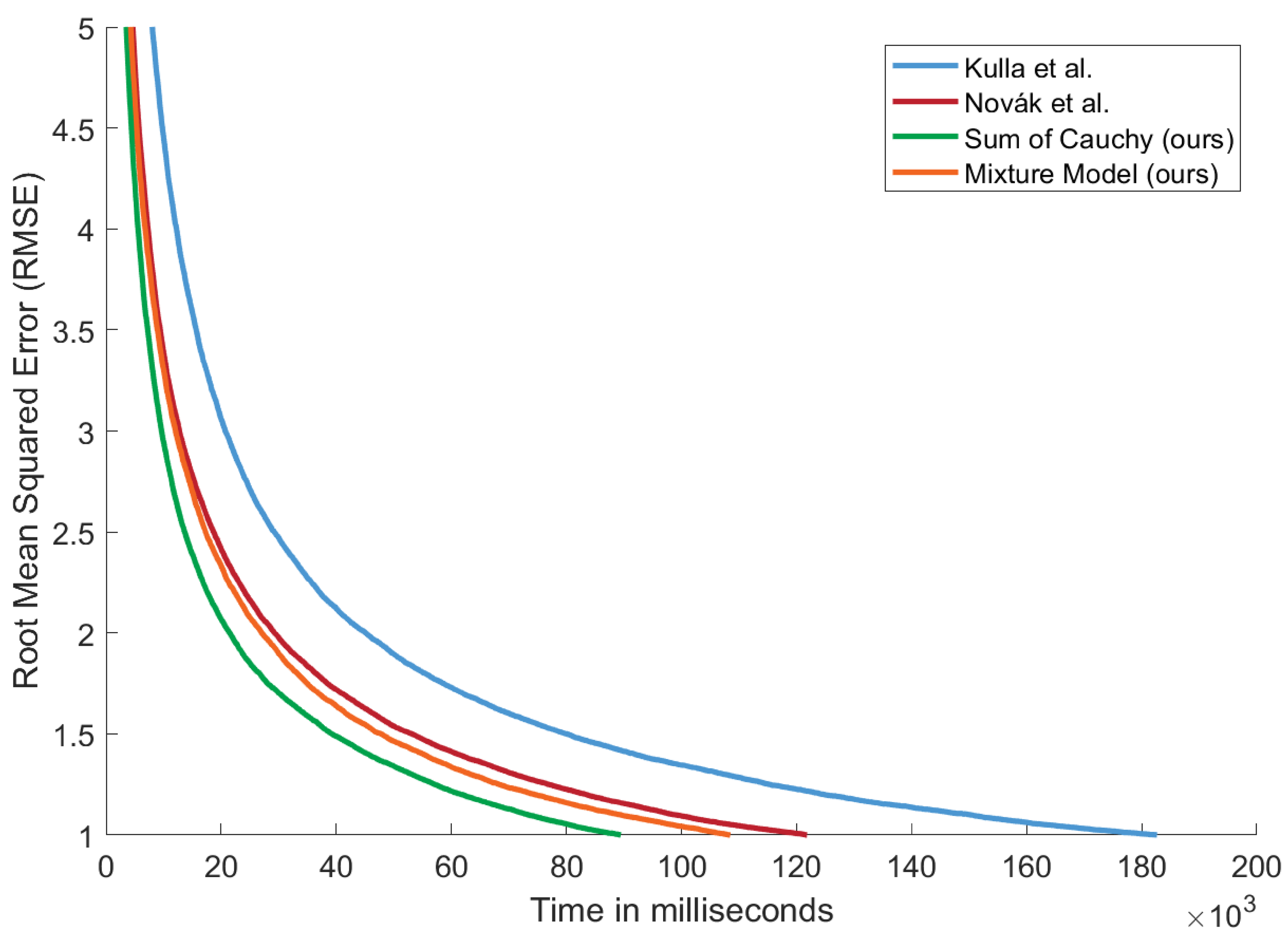
In our second approach we use a mixture model with two Cauchy distributions. Again, we first match two Cauchy distributions to the two phase functions. Although similar to the approach of the first solution, this approach differs from the first approach as the two Cauchy distributions have to be normalized when used in the mixture model. This therefore leads to different results and accuracy when comparing it to the target function.

The advantage of this approach is its mathematical simplicity as the Cauchy distributions only need to be integrated and inverted individually.



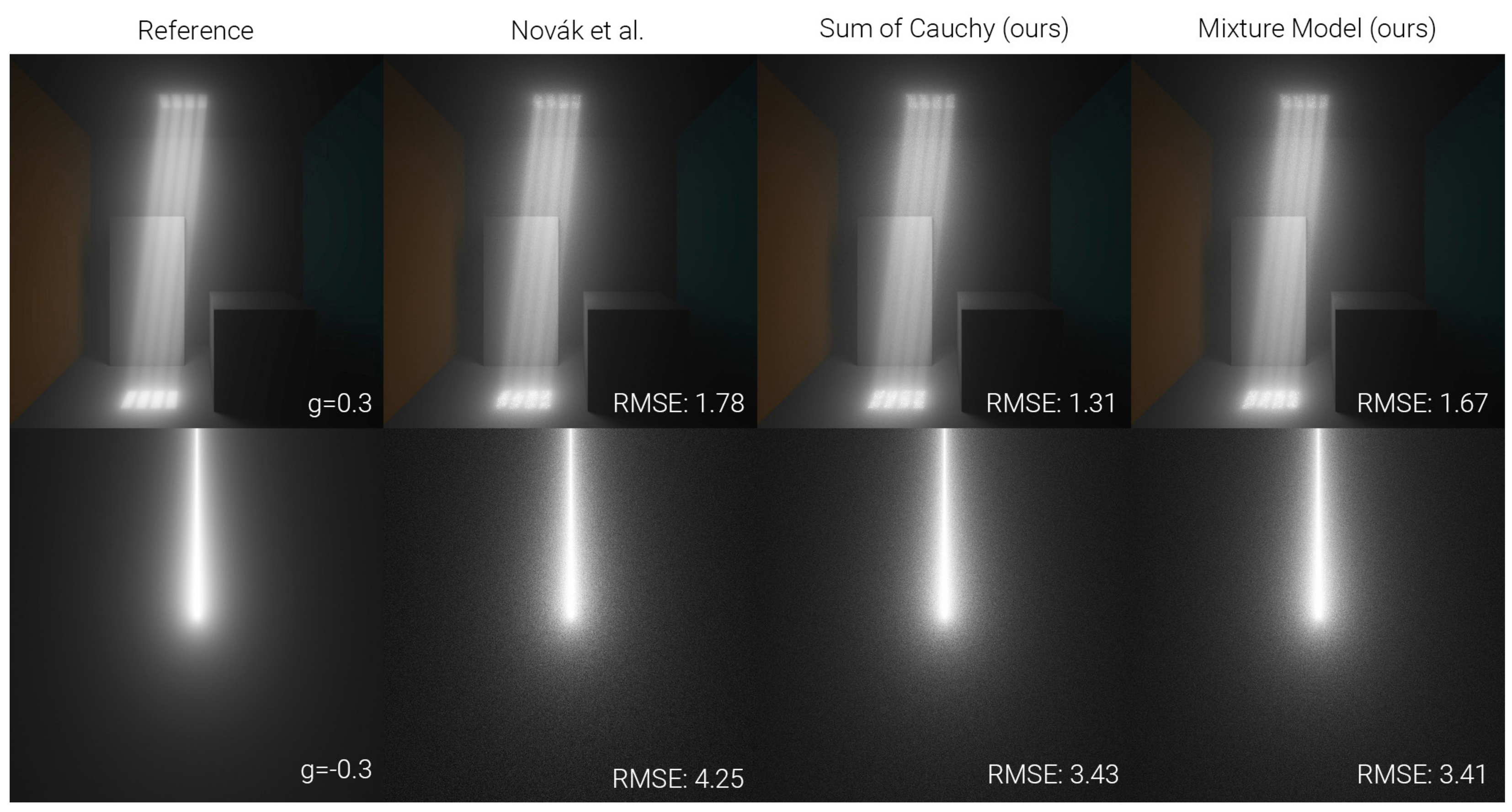
In the image above, two examples of this approximation can be seen with the target function as as solid line and our approximation as a dashed line.

Results



Both of our approaches outperform the original approach by Novák et al. in most of our test cases. Only for high forward scattering media (g = 0.9 for the Henyey-Greenstein phase function), Novák et al. still maintain a better performance. Not only do our approaches outperform Novák et al. in most of our tests, the mathematical formulation is less complex and can therefore be evaluated easier for future adaptations.

In the image to the left, the progression of the Root-Mean-Square Error (RMSE) is plotted on the y-axis for the corresponding time in milliseconds on the x-axis. This plot contains the data from the bidirectional light scene with a g-value of −0.9 for the Henyey-Greenstein phase function.



In the image on the right, examples cases are presented with scenes that were rendered for 60 seconds. The corresponding RMSE values are provided within the image and the approach that was used can be seen on top of the image.