Radiopropa: Hybrid minimizer

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Abstract

This is an alternative module to the iterative raytracer to make use of the radiopropa module. It succeeds in more rapidly tracing the path from the event to the detector and also arrives closer to the detector as the final result is not limited by the final drawn sphere size but by a given tolerence.

I. Introduction

The Hybrid ray tracer, in the source code called the "hybrid minimizer" is the result of the first semester of my masters thesis. Upon learning that more complex ice models where needed and after seeing the work that has been done to iteratively ray trace a path [1], I checked out the source code to try and understand the workings. In the source code I saw that a clever but unsuccesful attempt was made to implement the scipy.optimize module as an alternative to the iterative ray tracer. I came up with a way to implement this that succeeded as will be explained below.

II. How it works

The hybrid minimizer can be seen as an extension of the iterative raytracer, it checks after the first loop (as explained in the paper by B. Oeyen et al. [1]) if there are 2 distinct launch regions, if this is the case it breaks out of the loop as is visually explained using a modified version of B. Oeyen et al. their figure in figure 1. It then goes on to use the scipy.optimize.minimize module to find the solutions in the respective angle intervals as shown in figure 2 (minimizing Δz). If it doesn't find 2 distinct regions after the first loop, it falls back on the iterative ray tracer.

III. random number generator

To test the hybrid minimizer the numpy random module was used to generate random , the considered square (as there is only a z component to the ice model the 3D problem is essentially only a 2D problem) is x:0.1km,4km and z:-0.1km,-3km.[1]

IV. Performance Optimalisation

i. Length of the normal vector

As visually explained in figure 5, the size of the normal vector influences how big the ray tracer's step size is taken close to the detector. This thus influences the convergence and time taken. The results of varying this are shown in figures 6 and 7. The first optimization conclusion is thus: take the normal vector length to be 1 meter.

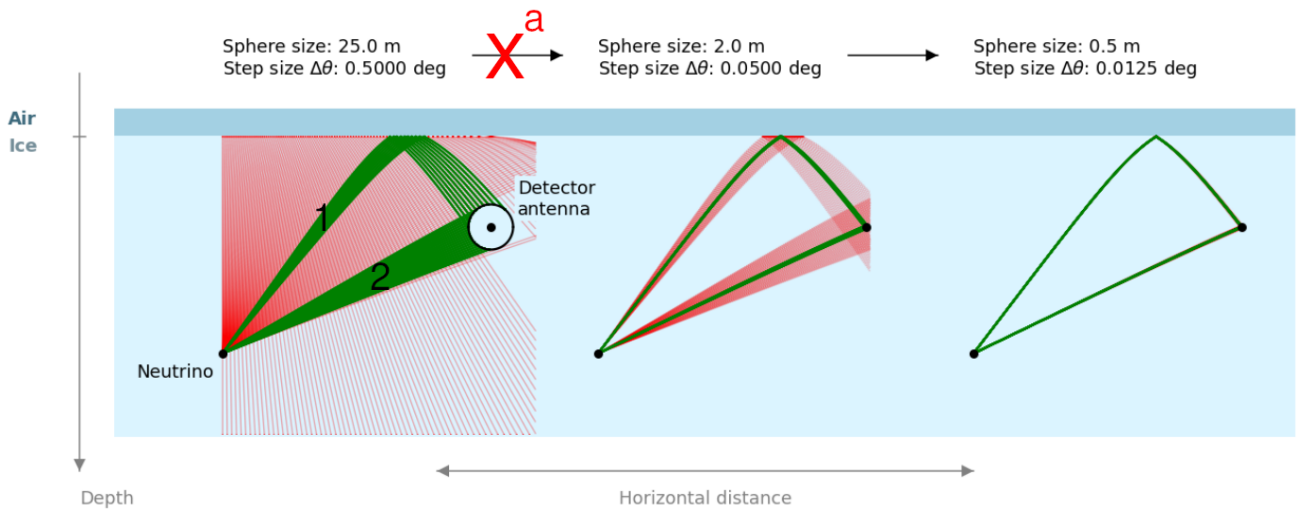
ii. ztol

We'll now change the tolerence on the vertical distance away from the detector which is deemed accepted i.e in figure 5 if Δz is below this threshold it's accepted. The results are shown in figures 8 and 9. From which we can conclude the second optimization conclusion: take ztol to be 0.05 m.

iii. Sphere Size & Step Size

As explained in Oeyen et al.'s work, the initial rays are sent out in steps of a certain angle and with a sphere around the detector (as can also be seen in figure 1, but for clarification I again refer to their paper). The sphere size and step size weren't jet optimized. But as this is the slowest step in the

[1]This was to get around issues concerning events that won't even trigger in a full simulation



[a] process is broken out of as 2 distinct launch regions (region 1 & 2) are found.

Figure 1: *explanation of the hybrid method*

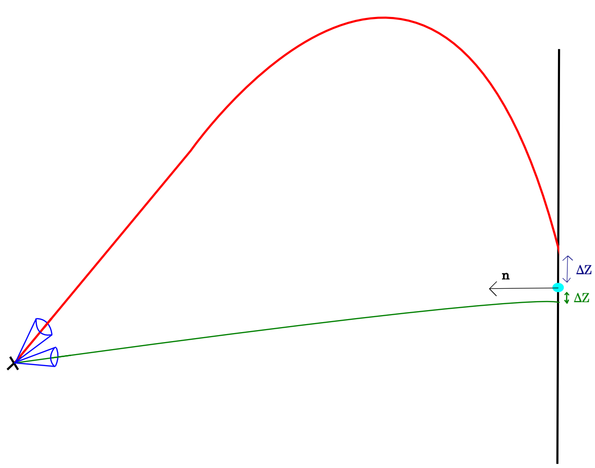


Figure 2: *explanation of scipy.optimize.minimize*

hybrid ray tracer this was optimized here (only the initial sphere and step size as those are relevant for the hybrid raytracer) as seen in figure .

References

[1] B. Oeyen, I. Plaisier, A. Nelles, C. Glaser, and T. Winchen. Effects of firn ice models on radio neutrino simulations using a RadioPropa ray tracer. In *37th International Cosmic Ray Conference. 12-23 July 2021. Berlin*, page 1027, March 2022.

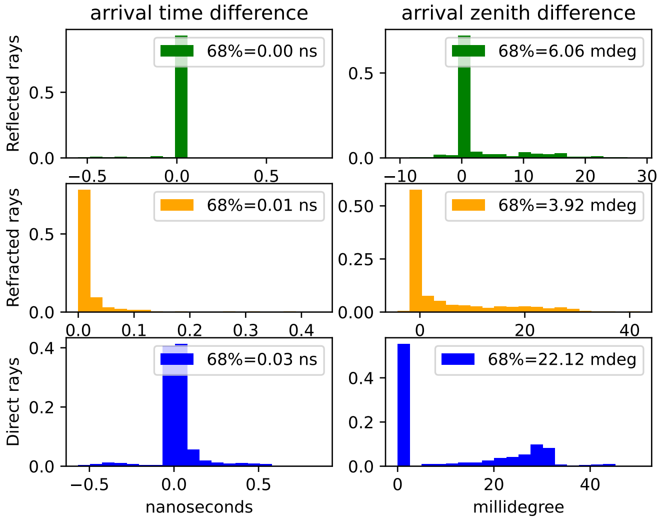


Figure 3: *Hybrid*

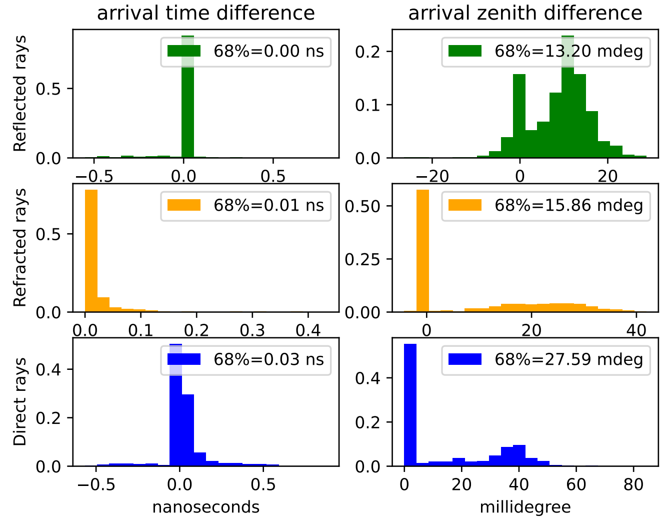


Figure 4: *Iterative*

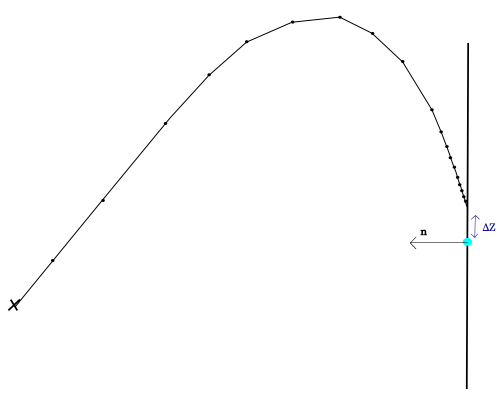


Figure 5: *how normal vector size influences the stepsize*

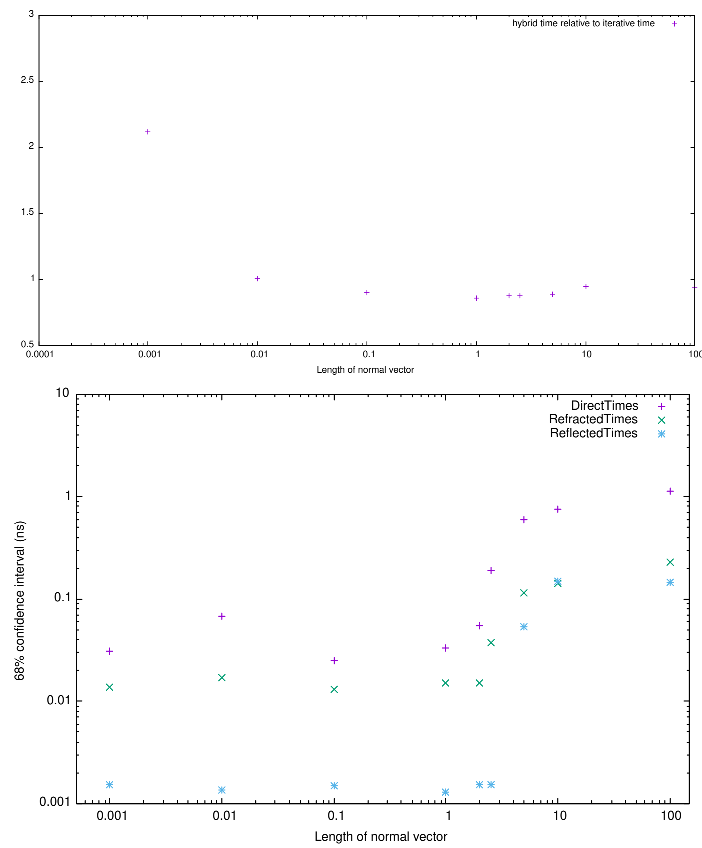


Figure 6: *influence of the lenth of the normal vector*

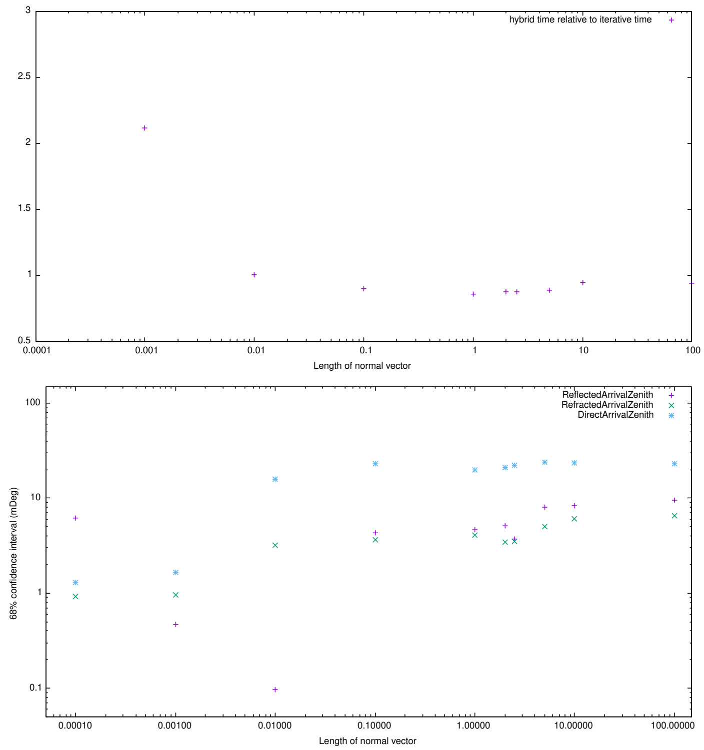


Figure 7: *influence of the lenth of the normal vector*

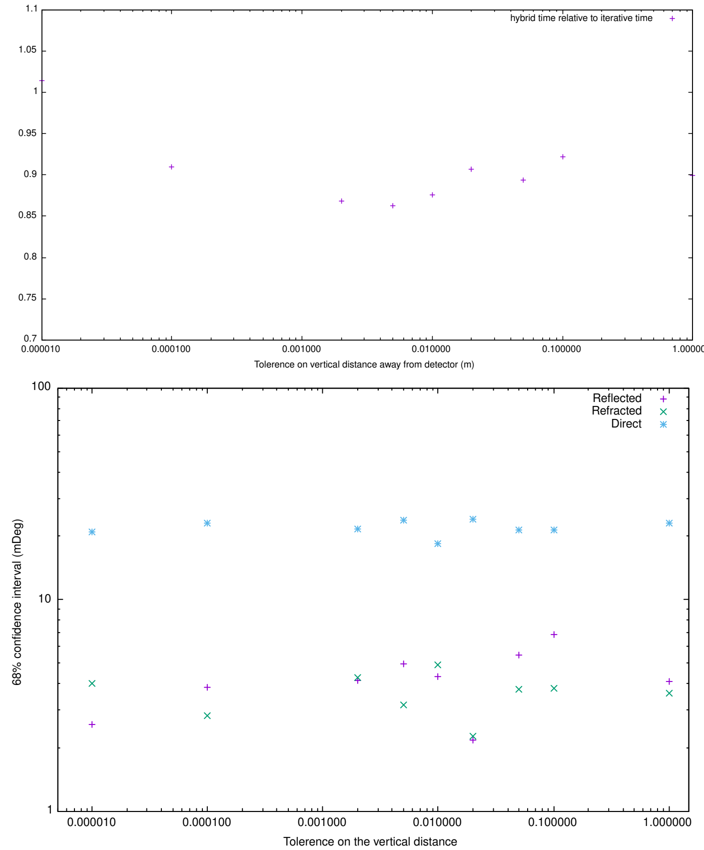


Figure 9: *influence of the tolerence on vertical distance*

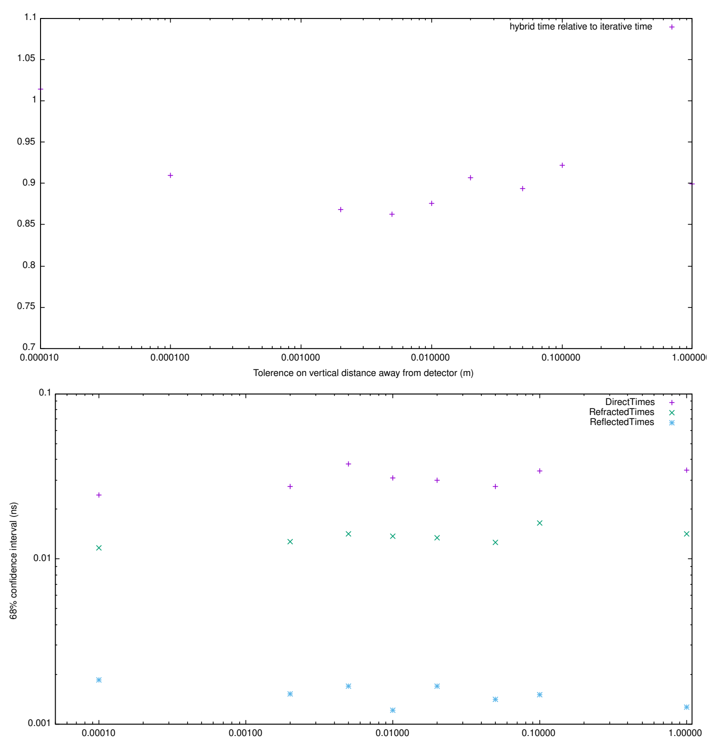


Figure 8: *influence of the tolerence on vertical distance*

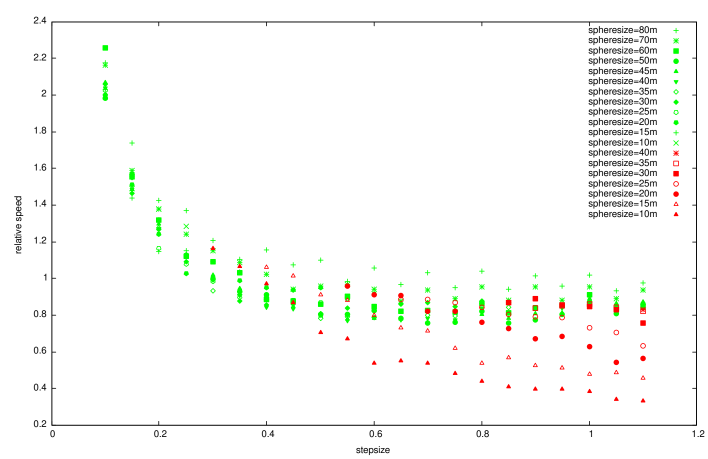


Figure 10: *Variation in Sphere and Step size with report on relative time.*