Hybrid radiopropa ray tracer

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1 random number generator

We'll use the numpy random module to generate the random numbers, 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:-4km,+4km and z:0,-3km. A good test to see if the generator is both random and uniform is to plot the next element to the previous element, shown in figure 1 for the generated z coordinates, in figure 2 for the generated x coordinates. This clearly is a good random number generator and is the one we'll be using for the testing of the hybrid ray tracer. As a counter-example, a bad random number generator's expected output is shown in figure 3
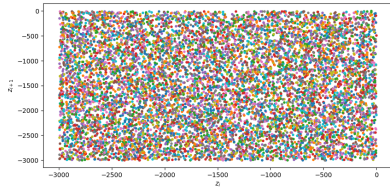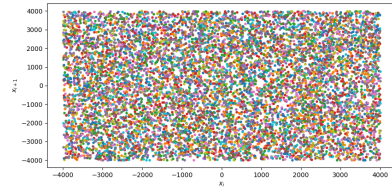

Figure 1: z_{i+1} i.f.o z_i

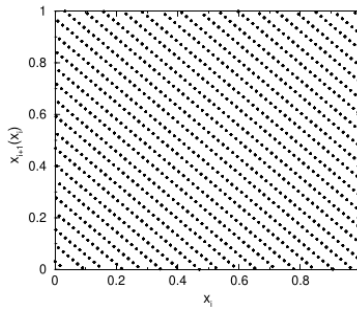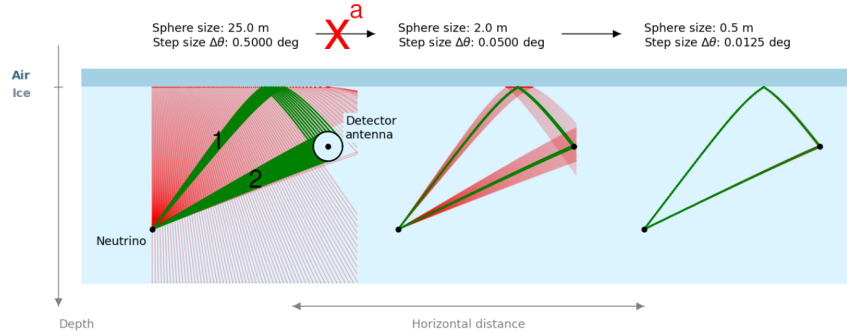Figure 2: x_{i+1} i.f.o x_i

Figure 3: bad random number generator

2 How it works

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

Figure 4: explanation of the hybrid method

The hybrid minimizer can be seen as an extension of the iterative minimizer, 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 and uses the scipy.optimize.minimize module to find the solutions in the respective angle intervals. If it doesn't find 2 distinct regions after the first loop, it checks again the next loop. This is visually explained using a modified version of B. Oeyen et al. their figure in figure 4.

3 performance

3.1 speed

I did a test with 10000 coordinates who were randomly generated (as mentioned above) and each ray tracer was used on these 10000 coordinates, checking the time it took per solution to check the speed of this algorithm and compare it with the iterative ray tracer. It turns out that on average we get (for my HP ProBook with an i5-6200U at 2.8GHz):

- a hybrid solution time of 7.69 seconds

- an iterative solution time of 1.538 seconds

So it takes ≈ 5 times as long.

3.2 accuracy

Now happily it's not just slower, it's actually a more accurate ray tracer:

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.