Developing a model for the “moving train illusion”

Problem: Write down a Bayesian model for the illusory self-motion phenomena: Imagine you are sitting in a train, and you see relative movement of another train out the window. For a moment you feel like you are moving backwards - you experience self motion in the direction opposite to the perceived relative motion. Then you realize you haven’t moved at all - it’s the other train that moved.
What are the variables needed to describe the phenomena? How are the variables related? Specify the variable which represents the percept and measurements.

Watch https://www.youtube.com/watch?v=F4xenIulg_8 for an intro to the problem.
Look through Lappe, Bremmer, & van der Berg 1999, for overview on self-motion, and Seno & Fukuda 2012 for use of the train illusion in an experimental context.

Most of the steps for developing a Bayesian model can be found in Chapter 2 (Building a Bayesian Model) of [Bayesian perception - an introduction]() by Wei Ji Ma, Konrad Kording, Daniel Goldreich, and we will use them here. For any bayesian models, you need to first create a generative model before reversing it and develop the inference process. Here we need to consider what physical environment the observer is in to determine what information they have access to.

Step 1: The generative model
When you are looking at a train and the train moves, this induces a flow pattern on the retina. What is the flow pattern or flow field?

Start with a cartesian frame centered on the head: the train can be described by a line in space, $ax + by + cz = d$, with an (x,y,z) reference where: x is left/right, y is up/down, and z is forward/back. The train is moving towards you, so in direction of -z. Translate this motion into the retina’s frame of reference to understand the flow.

Look at Figure 2 in [Longuet-Higgins & Prazdny 1979]() (and accompanying text, Sec 2) for information on projection.

Remember that this is for a single patch on the retina. We actually get measurements across the retina on many patches, each with their own measurement noise.

What are the variables needed to describe this illusion (hint: there are 4)?

Step 2: The inference process
Sketch a bayesian net indicating the direction of information flow between the relevant variables. Determine which variables we have information for (what data does the observer

have) and which they want to infer. Write down the likelihood, prior, and posterior for this inference (assuming Gaussian noise).

Step 3. Maximum a posteriori (MAP)
Solve for the MAP. What does the distribution of the MAP tell you about the nature of the illusion?

Some other videos with examples:
Spinning room: https://www.youtube.com/watch?v=pjdVLRyTrZw
Practical use of the motion illusion: https://www.youtube.com/watch?v=VSBRG1_5s2E
Examples from virtual reality: https://www.youtube.com/watch?v=7rm3Yk89gjk