

Variational Autoencoders and the wave equation

K.Rivkin^a

a. RKMAG Corporation, 651 N. Broad St. Suite 205 462 Middletown Delaware 19709

Self-nomination for invited talk

At the heart of every generative AI algorithm lies a principle that different classes of objects can be represented as groups of elements within a relatively low dimensional, so called “latent”, space. Selecting an element (vector) within the latent space and applying to it a predetermined operator generates an output belonging to one of the classes encoded, depending on the location of the input vector. Moreover, the output does not exactly replicate the data used to design either the latent space or the decoding operator, but represents a new, “generated” data which however possesses all the key properties of the respective class.

In many practical cases the latent space can be two dimensional, which brings forward a question whether there could be an actual physical representation where each input vector corresponds to an actual physical location. For example, if a wave is excited at this point by an external source, the decoding operator acts as a set of transformations applied to the excited wave as it propagates from the source to the output screen.

In this work we’ll first demonstrate that as long as the material properties related to wave propagation, both linear and nonlinear, can be adjusted within a relatively wide range, it is possible to use wave propagation to encode very sophisticated generative AI algorithms. For example, exciting waves in different parts of a two dimensional physical “latent” layer can generate images of cats or dogs on the output screen. The images themselves are confirmed to be different compared to the ones supplied to the system when the physical layers corresponding to the “latent” space and the projection operator are designed, which confirms that the system’s functionality is that of a generative AI algorithm. We demonstrate that adding to such system a thermal excitation greatly expands its functionality, as now the “source point” defines the general properties of the output image, without deterministically setting the minor details; near infinite number of different images can be produced using a relatively small physical latent space layer.

The analysis is applicable to any propagation phenomenon governed by the wave equation, however it appears that only in magnetics the propagation properties can be practically adjusted to the extent required. Therefore, in the second part of our work we present a micromagnetic-like analysis of a specific magnetic system here an spin waves in a specific point generates a large set of output datapoints belonging to a specific class, whose identity is determined by the physical location of the excitation point or the initial magnetic state of the system. We further demonstrate how the procedure can be used to construct an AI system where the input is a complex set of datapoints which need to undergo a desired transformation, similar to a competitive Generative Adversarial Network (GAN).

This represents the next step in complexity compared to Deep Neural Networks and Convolution Neural Network, but at the same time demonstrated that Generative AI algorithms are uniquely predisposed to being implemented using physical phenomena, with multiple orders of magnitude advantages in terms of operating power, speed and chip manufacturing costs.