Frame Interpolation of Smoke Simulation with Neural Network

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Abstract

We propose a new method of generating more detailed frame pictures of **smoke simulation**. By using the existing smoke's frames, the **interpolation** result between the frames can be obtained. For the simulation of the smoke, some constraints of the equation can be used to simplify the procedure. We can get the density and the temperature from the **velocity field**. Therefore,we just need to process the velocity field. The **auto-encoder** is used to encode the velocity field into a lower-dimension space,which we call latent space, where interpolation will be done. A **neural network** is trained using the existing frames, and the corresponding interpolation results are obtained.

Introduction

The modeling of natural phenomena such as smoke remains a challenging problem in computer graphics. Visual smoke models have many obvious applications in the industry including special effects and interactive games. Ideally, a good CG smoke model should be easy to use and produce highly realistic results. Unfortunately, current CG smoke models are either too slow or suffer from too much numerical dissipation. If we can use the existing video frames to get the medium frame between frames, it will be a very meaningful work. Here are main steps we need to do.

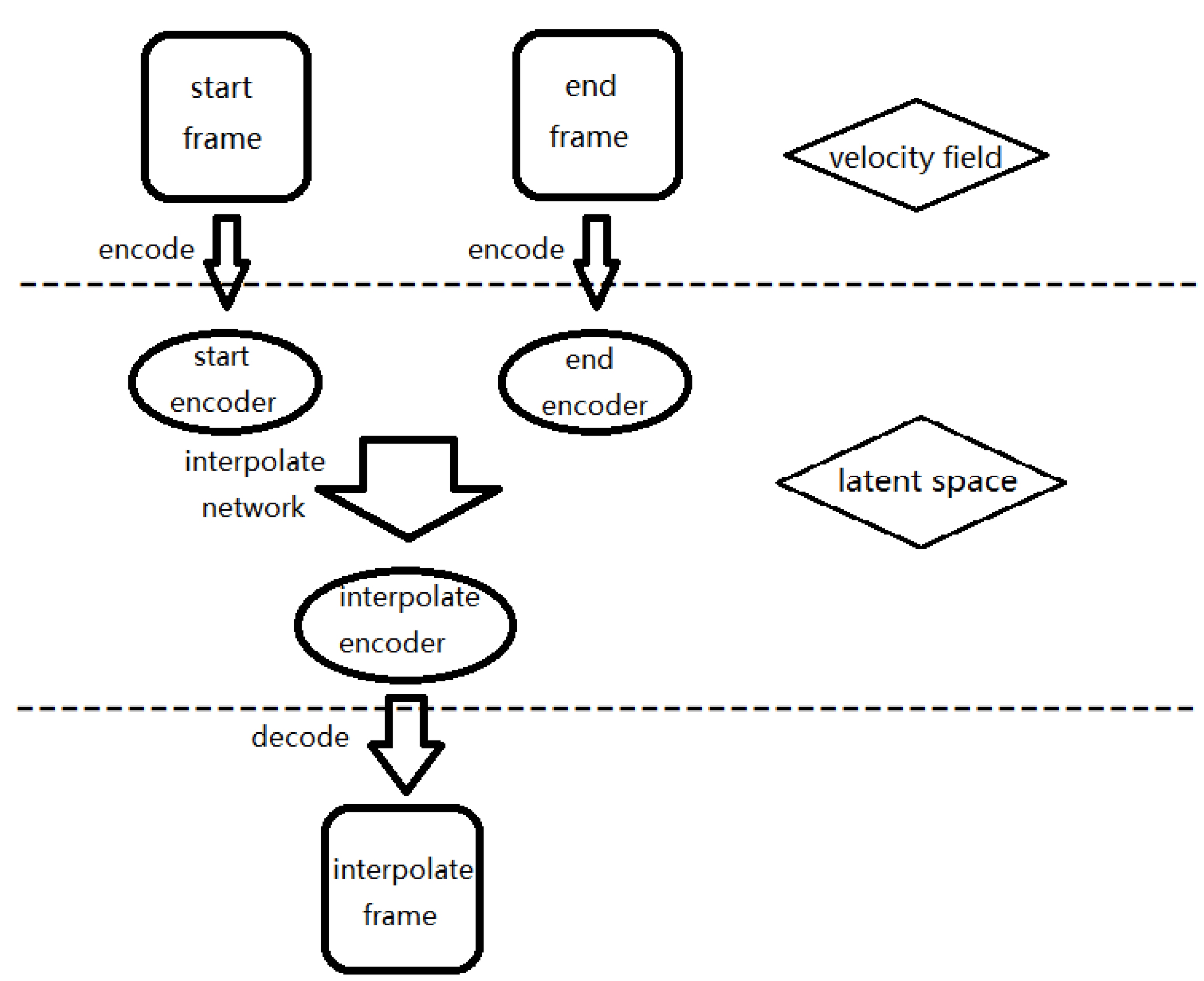
1. generate the velocity field of each frames via c++
2. encode and decode velocity field by auto-encoder to reduce the dimension of the input velocity
3. train a neural network to interpolate the frame we want
4. use the interpolate velocity field to get the temperature and density field, finally we get the visual smoke

Visual Simulation of Smoke

In the inviscid Euler equations, the effect of viscosity is negligent in assuming that gases can be modeled as inviscid, incompressible, constant density fluids. The equations that model the smokes's velocity are given by the incompressible Euler equations. We also conclude equations for the evolution of both temperature T and density ρ assuming that these two scalar quantities are simply moved along the smoke's velocity. Besides, the density and temperature affect fluid's velocity by defining external forces directly proportional to them. In this way, we can simulate the spread of smoke by calculating the velocity of each frame.

Figure 1:several frames of smoke simulation

Flowchart



Autoencoder

Now we want to train a neural network so that it can produce each frame of the simulating result between these frames. However, the velocity field $(100 * 256 * 1024)$ is too large for a neural network's input. Therefore, we use the auto-encoder techniques. It is sufficient and convenient to encode them to a latent space. We can reduce the amount of data hundred times smaller $(400 * 15 * 63)$. When we finish the interpolation in latent space, the decoder will push back the original result. As a result, we get the precise frame of velocity field.

Interpolation training

We train a fully connected neural network with two hidden layers by the auto-encoder interpolation data. The data processed by the neural network is on latent space. We process the velocity in two directions separately, and import the frames of the latent space as the training data. Use the data of the animation itself to train a network that can interpolate it. At present, our training can low the loss error to 1%.

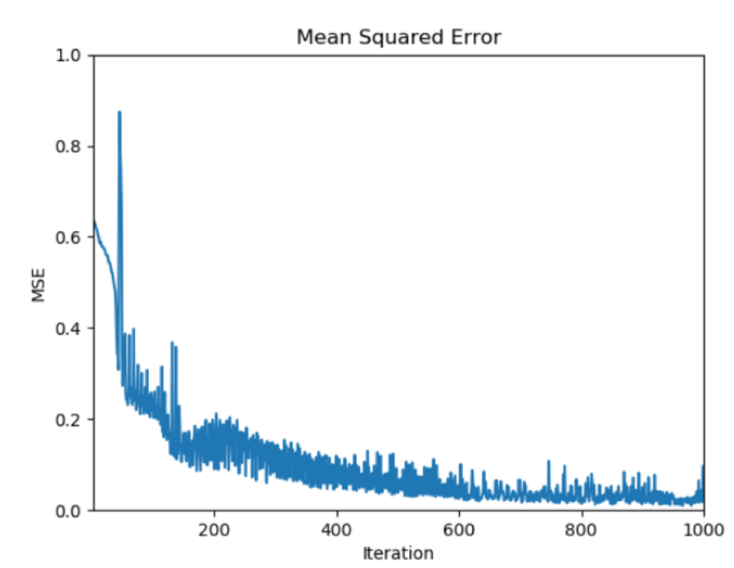


Figure 2:MSE changes with iterations

Future Work

1. Adjust interpolation network parameters for higher accuracy
2. Combine the velocity in the two directions, and interpolate 1000 frames of data to generate 2000 frames of data
3. Extend 2D results to 3D scenarios

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