Brain Tumor Modeling

Background:

1. Glioblastoma multi frome (GBM) is a malignant brain tumor.
2. Modern treatment of GBM involve combinations of susogerry, chemotherapy and radiation therapy.
3. Despite of the aggressive therapies survival of GBM is slightly over a year.

The common model to simulate GBM progression is a partial differential equation (PDE) called the proliferation_invasion (PI) model.
In the PI model GBM progression is governed by two process: diffusion and proliferation.

The pde for brain tumor

$$\frac{\partial n}{\partial t} = D\nabla^2 n + rn\left(1 - \frac{n}{n_{max}}\right)$$ —— Equation (1)

The n denotes density Cellular tumor density at time t
The D denotes the prolifenation rates
The r denotes the reaction diffusion rates

n_{max} is the biologically feasible tumor size at a location

To generate synthetic tumors, intial conditions are first selected. Let Gaussian initial cellularity given by

$$n_0 = Ae^{\frac{-||\vec{r}||^2}{2\sigma^2}} \qquad \text{Equation (2)}$$

From the literature, we will define the following parameters to simulate the PDE.

$n_{max} = 1$

Standard deviation, $\sigma = 2$ mm

PI model parameters,

$D = 0.001\ mm^2/day$

$r = 0.03/day$

we are going to simulate the PI model with initial conditions over 50 days with 1500 time points.

The initial and final cellularity profiles are 3D arrays with size of (31,31,31).

$x \quad y \quad z$

In the following figures we are visualizing only three slices or z dimension.

As we are following gaussian distribution that's why most variations will be observed in the middle slices.

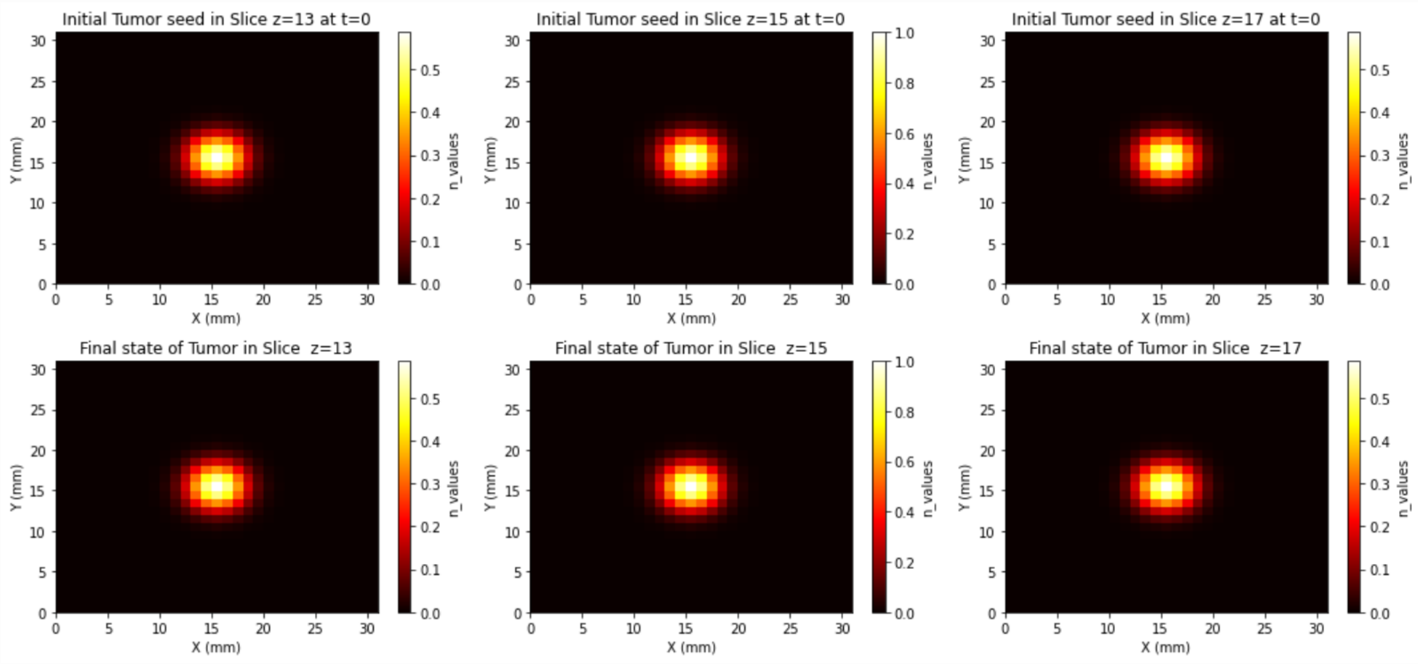

Figure 1: The initial tumor state at t=0 and d final tumor state at t=0. The first now is the initial state and the second row is the final state at t=0.

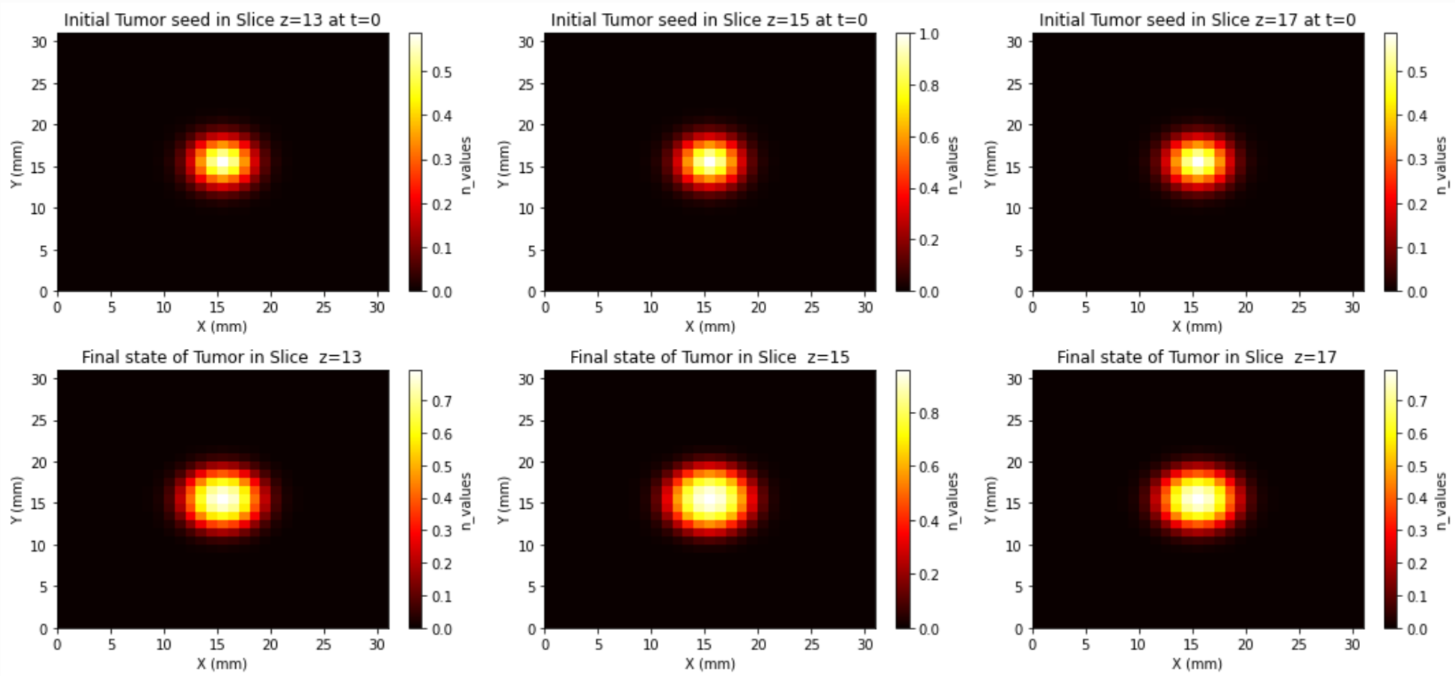

Figure 2: The initial tumor state at t=0 and d final tumor state at t=750. The first now is the initial state t=0 and the second row is the final state at t=750.

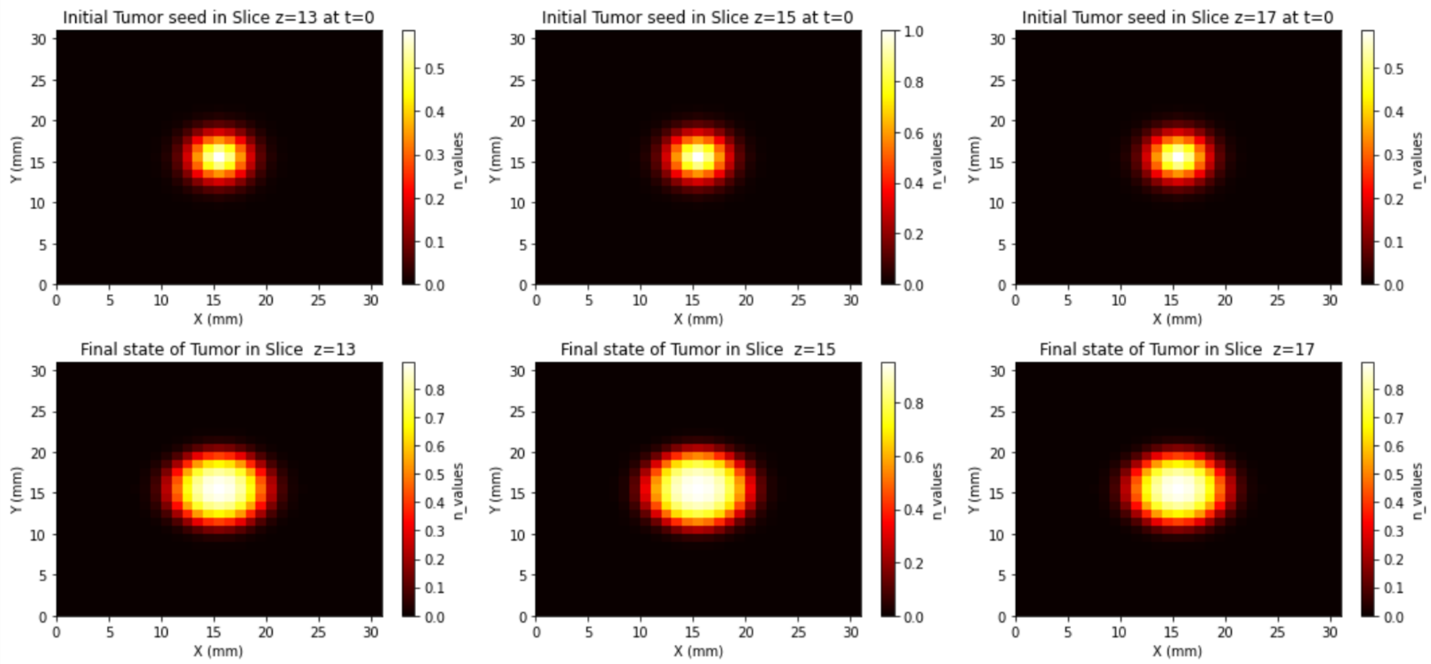

Figure 3: The initial tumor state at t=0 and d final tumor state at t=1500. The first now is the initial state t=0 and the second row is the final state at t=1500.

Implications of the simulated tumors with PDE:

I. Use initial and Final celluraity profile in the deep learning model to estimate D and r.
2. Estimate celluraity progression between two time points.
3. Tumor Inverse modeling.

Reference Papers Title:

1. Deep learning characterization of Brain Tumors with Diffusion weighted Imaging.
2. Learn-Morph-Infer: a new way of solving the inverse problem of brain tumor modeling.