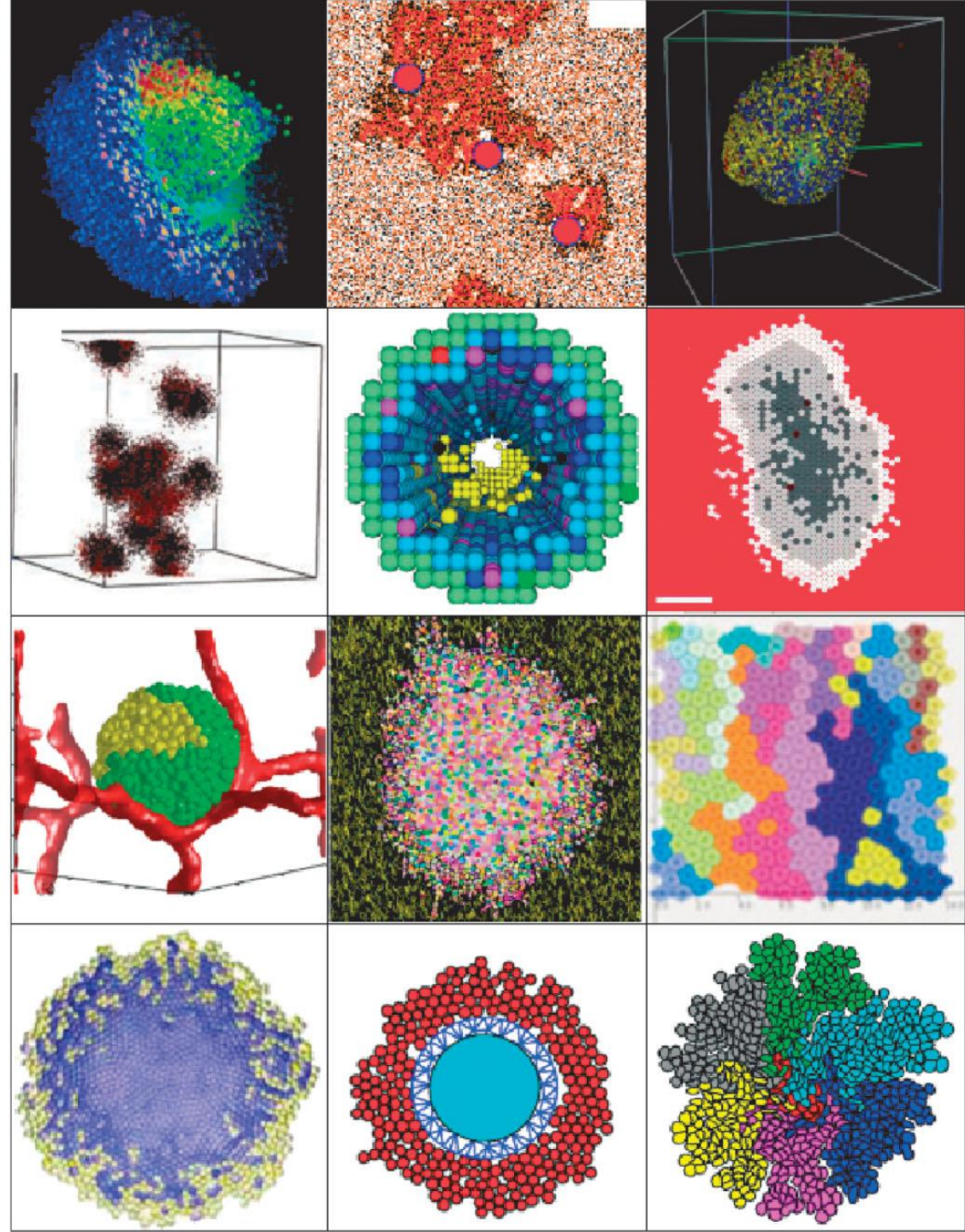


# Hybrid Modeling Framework

# What is Hybrid Modeling?

## Agents (cells) + PDEs (chemicals)

- Agents as cells is useful because cells are discrete entities with complex behaviors
- PDEs allow realistic flow simulation of drugs/endogenous chemicals
- Hybrid models allow chemicals to affect cells and vice versa
- The Framework is designed to help facilitate hybrid modeling



Example 1:

Division Death Mutation

Legend:

Cells colored by number of mutations

## Example 2: Stem Cell Model

Legend:

Stem cells are Red

Differentiated Cells are Blue

# Example 3:

## Contact Inhibition

Legend:

**Pink** cells divide rapidly but are sensitive to contact inhibition

**Purple** cells divide slowly but ignore contact inhibition

# Example 4:

## Vessel Occlusion

### Legend:

Live Squares are Red

Dead Squares are Black

### Elements:

Single Grid2D, on-lattice agents

# Example 5:

## Spreading And Metastasis

Legend:

Vessels are Red

Tumor Cells colored by local  
oxygen concentration

# Example 6:

## Competitive Release

Legend:

Drug sensitive cells are Blue

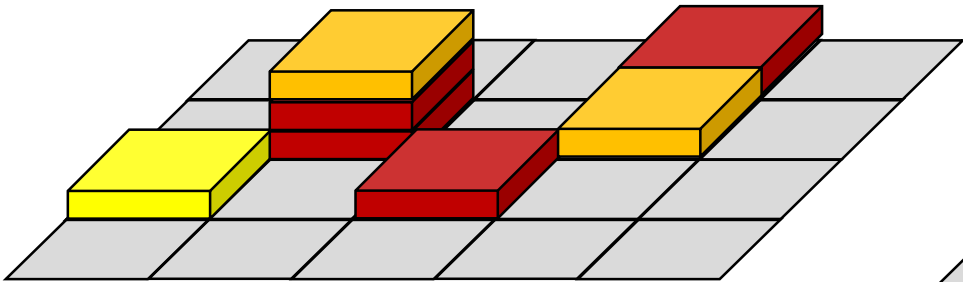
Drug resistant cells are Green

Background colored by Drug  
concentration

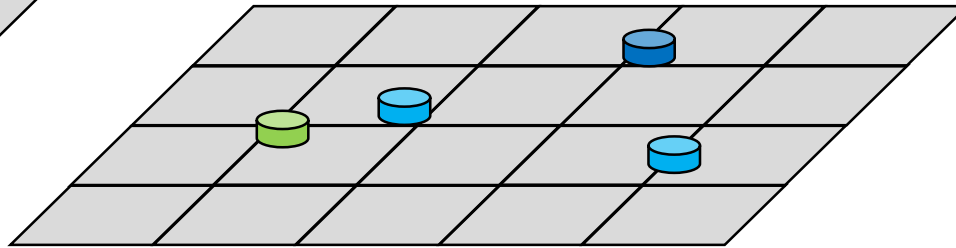


2D

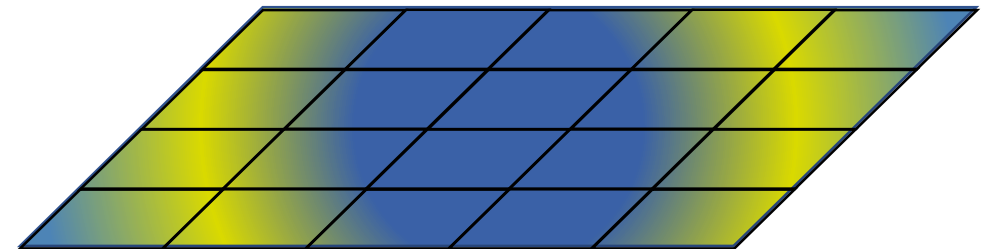
On Lattice  
Agents



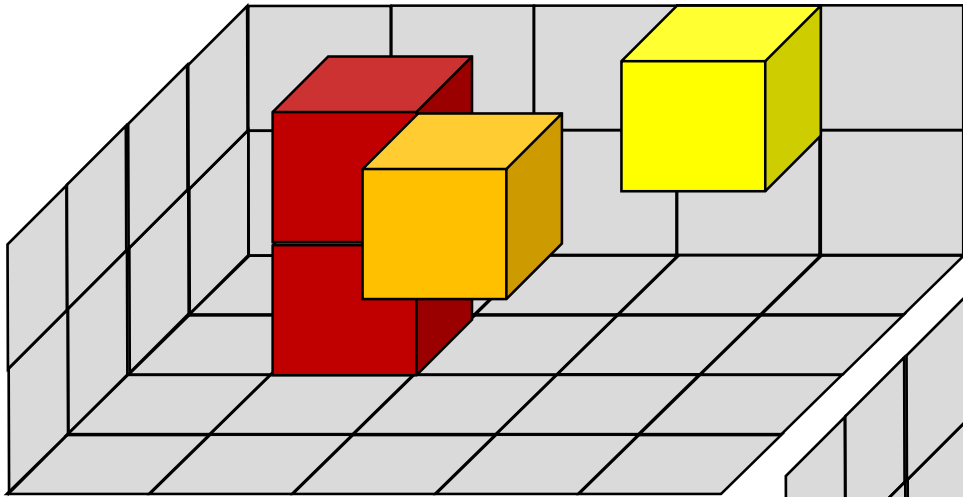
Off Lattice  
Agents



Diffusible  
PDEs

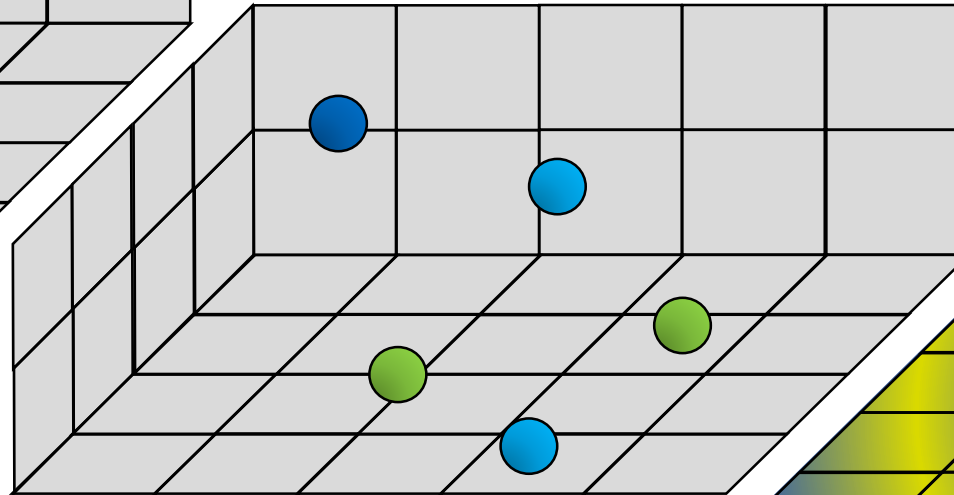


On Lattice  
Agents

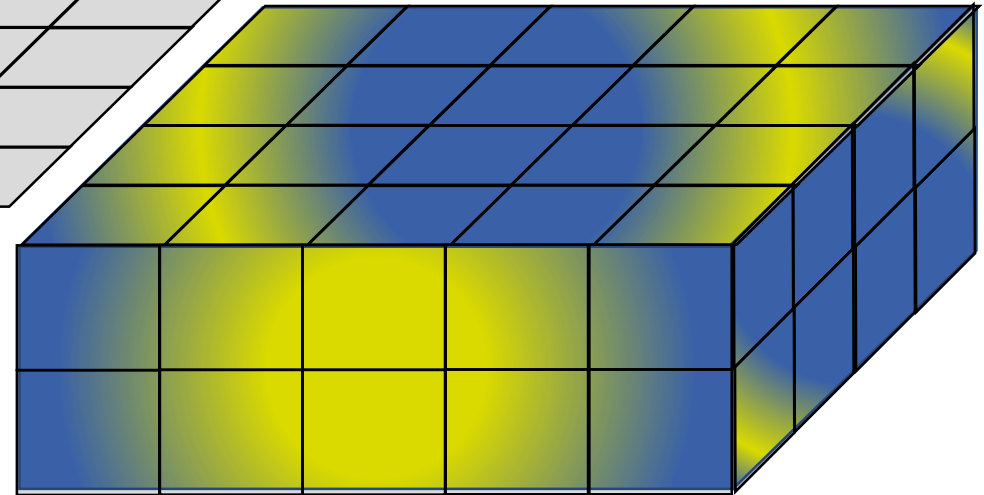


3D

Off Lattice  
Agents

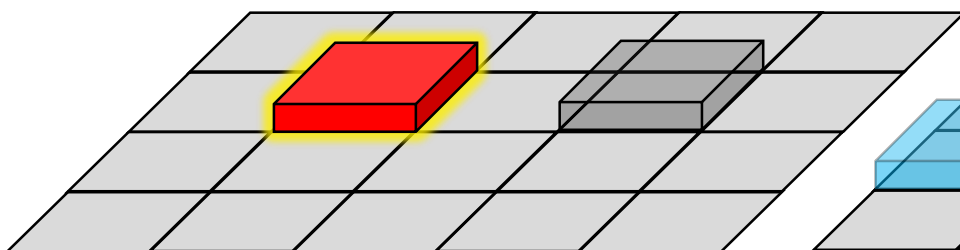


Diffusible  
PDEs

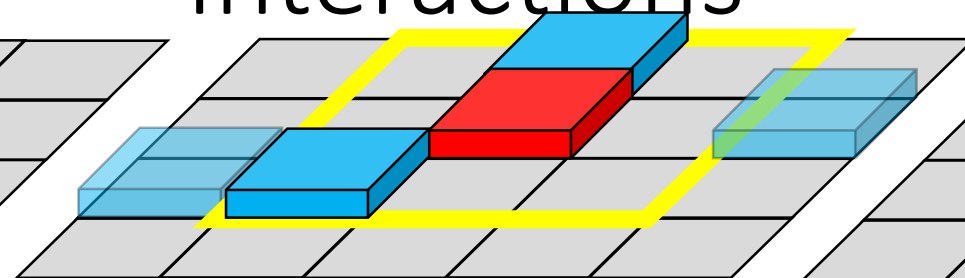


# Base Behaviors

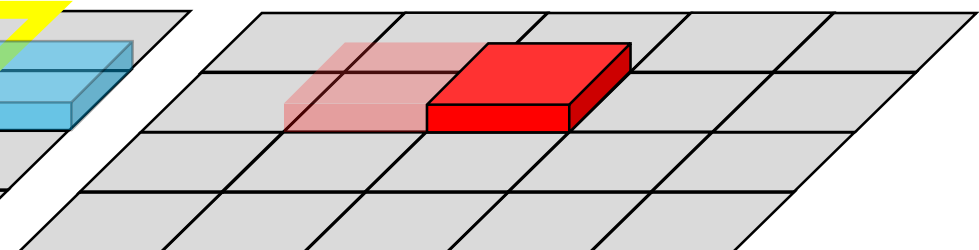
Birth/Death



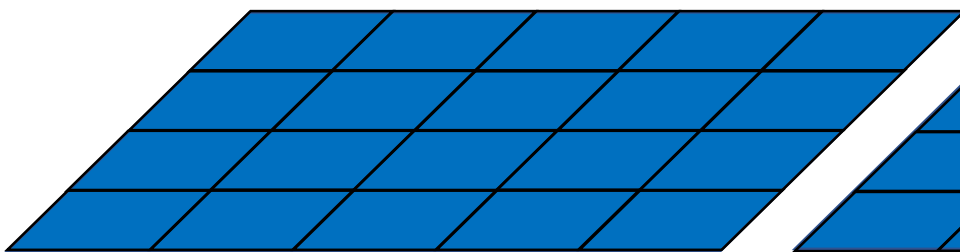
Neighborhood Interactions



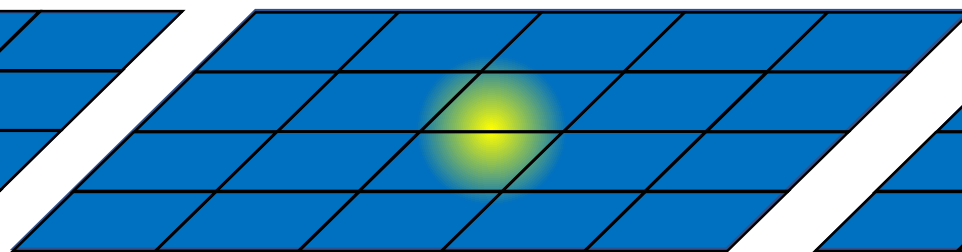
Movement



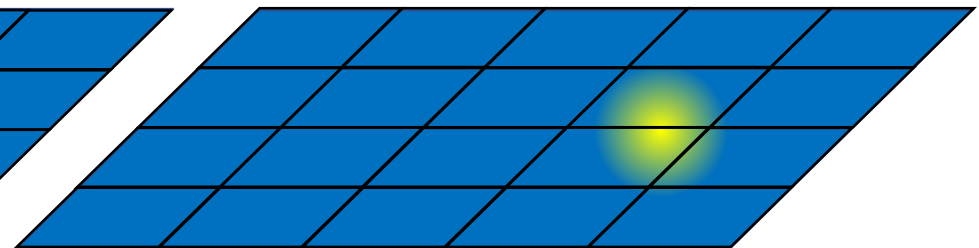
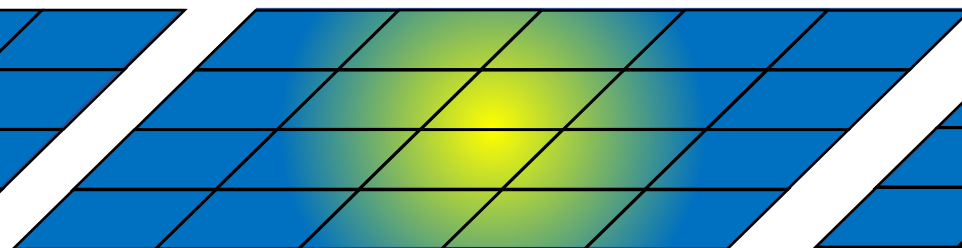
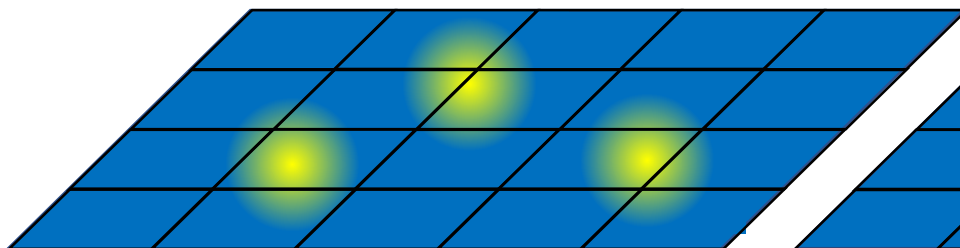
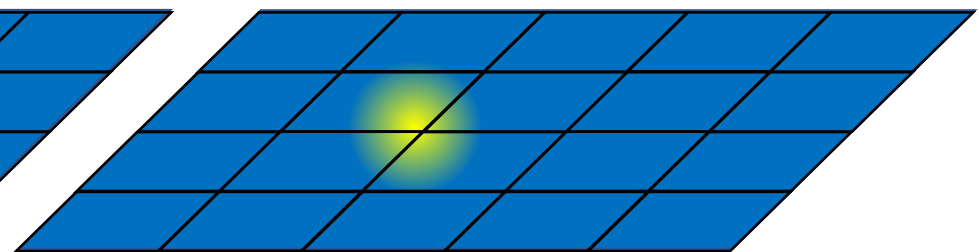
Reaction



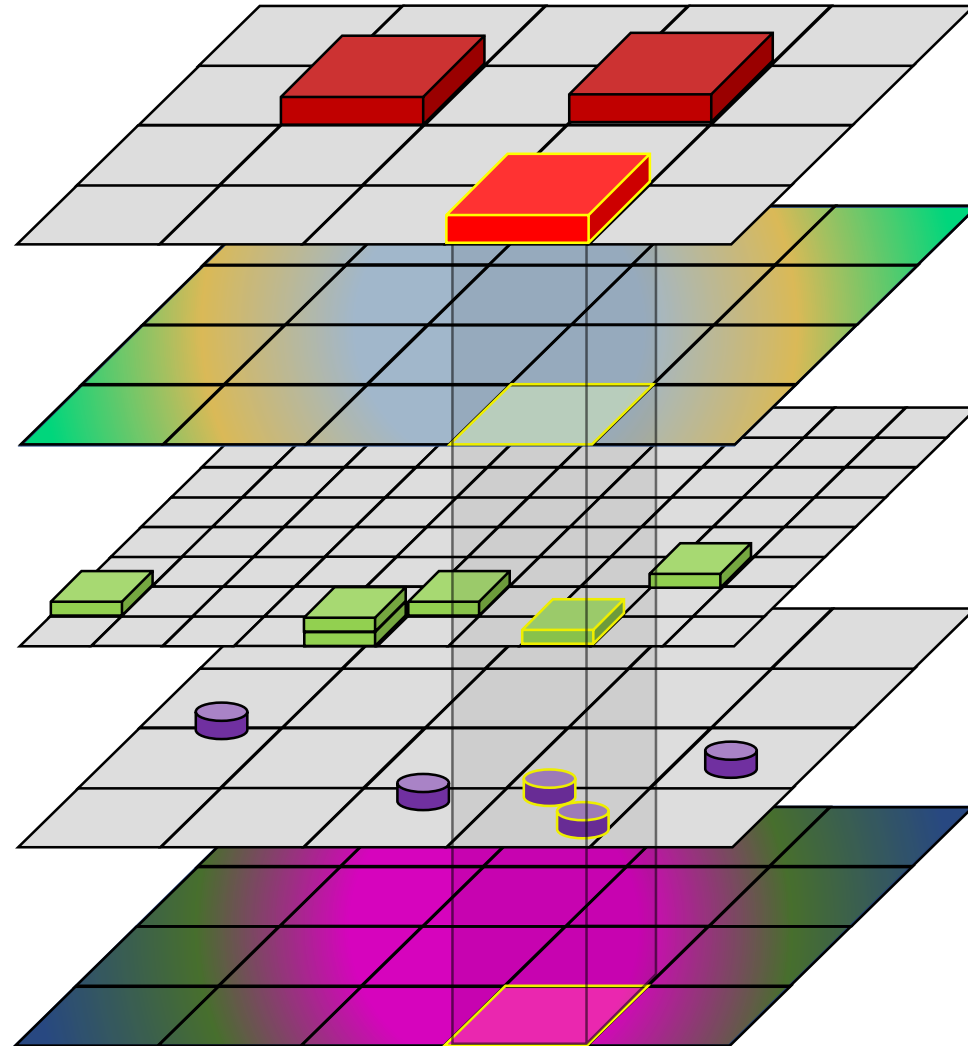
Diffusion



Advection



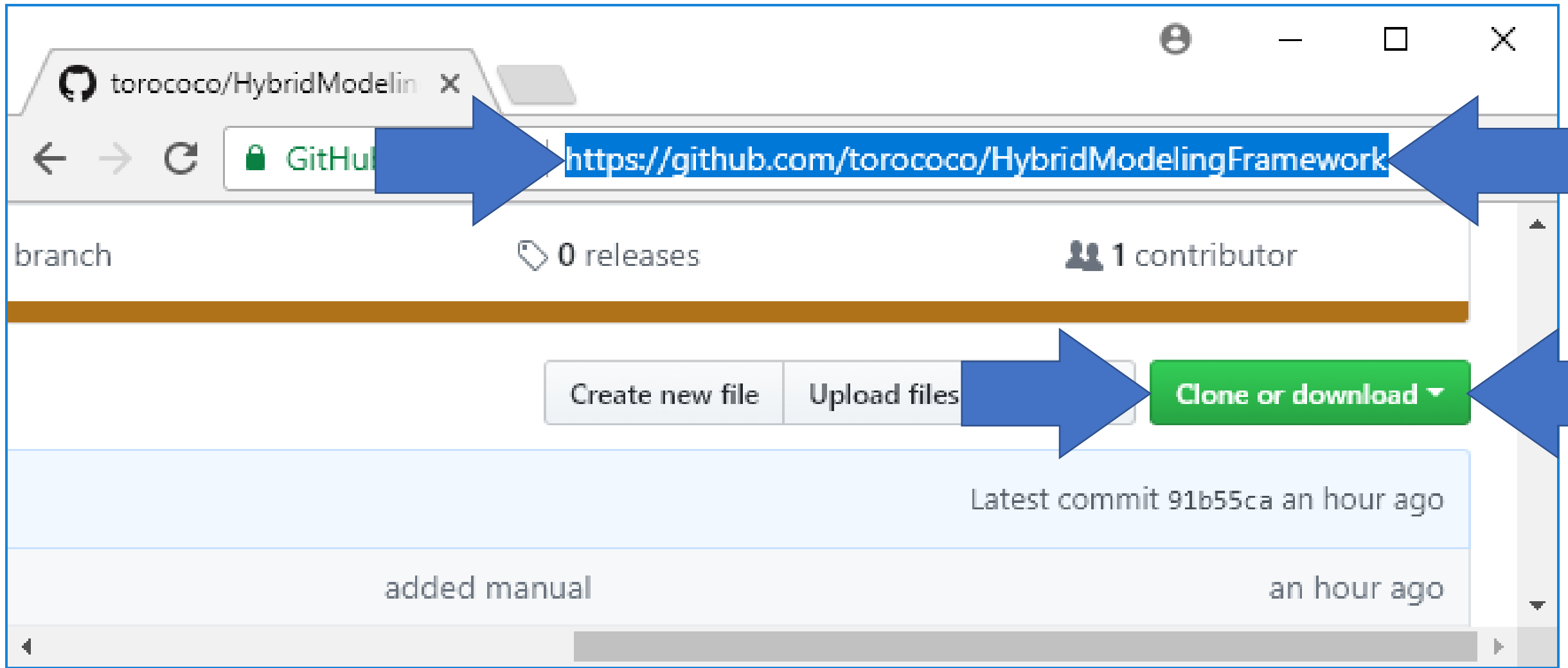
# Facilitate Interactions using Spatial Queries



# Framework Features

- Generic flexible components
- Simple, consistent function interface
- Fast to write and debug (each example is under 200 lines of code)
- Fast Performance
- Can be easily combined with external libraries and tools

# How to get it?



- Comes with a manual to help get setup and programming
- Questions: rafaelfbravo@gmail.com