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Applying Uncertainty Quantification and Sensitivity Analysis to Large -Scale Hippocampal Brain Models

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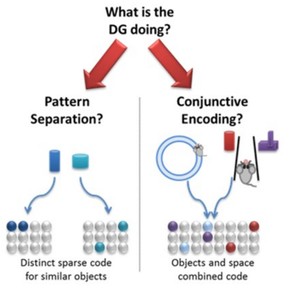
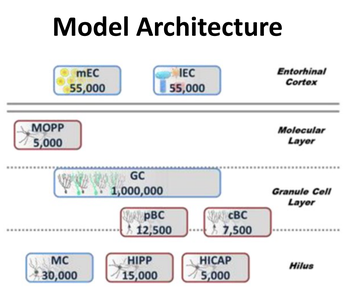
BACKGROUND

Modeling Neurogenesis in the Dentate Gyrus

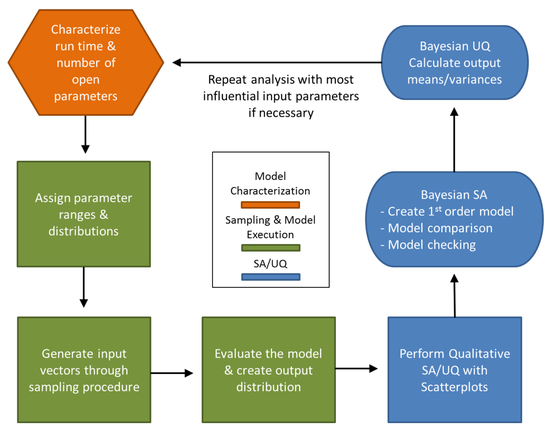
- Neurogenesis: Process of neuron generation
- Occurs most during pre-natal development
- Also occurs in the adult mammalian dentate gyrus
- We have a created a large-scale hippocampal neural model to explain the function of neurogenesis
- We perform model verification & validation using uncertainty quantification and sensitivity analysis





Applying UQ/SA to Neural Models

- Uncertainty Quantification (UQ): The reduction and characterization of uncertainty in model outputs
- Sensitivity Analysis (SA): The assignment of variation in the model outputs to uncertainty in model inputs



UQ & SA METHODOLOGY

Overview

- We utilize Latin-Hypercube sampling to randomly select 9 model parameters from a range/distribution 20 times

Parameter	Range	Dist. Type
EC_Izh_a	0.0380 – 0.0420	Uniform
EC_Izh_b	2.1 – 1.9	Uniform
EC_Izh_c	-68.25 – -61.75	Uniform
EC_Izh_d	95.0 – 105	Uniform
GC_Izh_a	9.5e-4 – 1.05e-3	Uniform
GC_Izh_b	0.95 – 1.05	Uniform
GC_Izh_c	-57.75 – -52.25	Uniform
GC_Izh_d	23.75 – 26.25	Uniform
Neurogen_perc	N/A	Log Normal

- The model was evaluated on an 8-node computer cluster to produce 5 important model output metrics

UQ/SA Quantitative & Qualitative Techniques

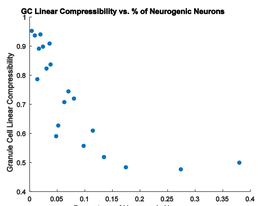
- Calculate mean and variance of each model output
- Generate scatterplots of parameters vs. model outputs
- Perform robust linear regression using probabilistic Bayesian analysis using equations of the form:

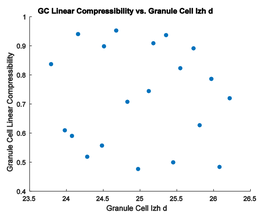
$$y_i = \alpha_i + b_{i1}x_{i1} + b_{i2}x_{i2} + b_{i3}x_{i3} + \cdots + b_{i9}x_{i9}$$

RESULTS: MODEL UQ/SA

Output Parameter	Mean	Variance
EC linear compress.	1.24	4.1e-4
GC linear compress.	0.73	0.03
lEC avg. firing rate	1.2 Hz	1.7e-3
mEC avg. firing rate	1.1 Hz	3.1e-3
GC avg. firing rate	0.73 Hz	1.5e-5

means/variances fall within acceptable ranges



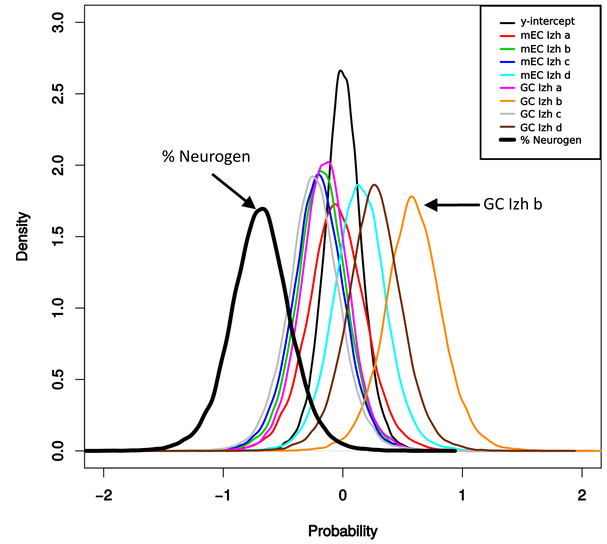


- SA: Which parameters most influence GC linear compressibility?

RESULTS: MODEL SA

Quantitative SA

- Bayesian robust linear regression produces coefficients with probability distributions
- The larger the coefficient, the larger the effect the corresponding parameter has on output variance



SUMMARY

- We confirmed a key model parameter (% Neurogen) had a significant impact on an information metric
- We found output variance of GC linear compressibility depends on unexpected parameters
- We demonstrated the practicality and utility of applying UQ/SA to large-scale neural models
- Future Work: performing full UQ/SA on different model sizes to study the effect of scale on the model

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