Hierarchically Organized Latent Modules for Exploratory Search in Morphogenetic Systems

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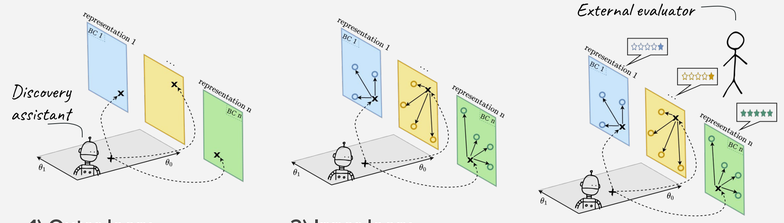
Source code, data and visualisations!
https://mayalenE.github.io/holmes

Motivation: Exploring Morphogenetic Systems

Can we design machine-learning tools to help scientists explore and understand morphogenetic systems ?

Problem Formulation: Meta-Diversity Search



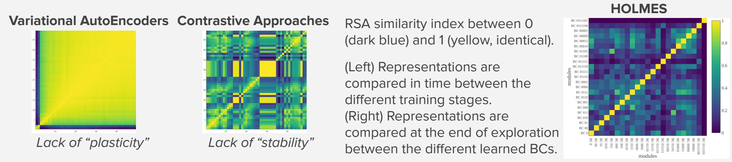
1) Outer loop:
learn a diverse set of representations to characterize behaviors

2) Inner loop:
search for a maximally diverse set of patterns in each learned BC space

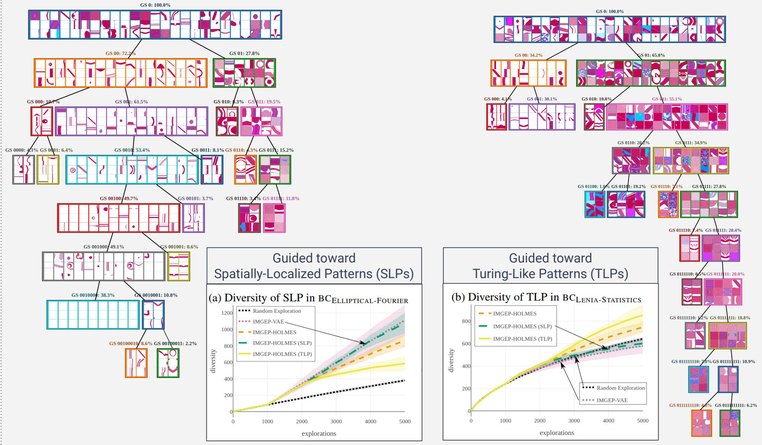
3) Quickly adapt search to user preferences

Results

- **Learning to characterize different niches of patterns**



- **Can we drive the search toward an *interesting* type of diversity?**

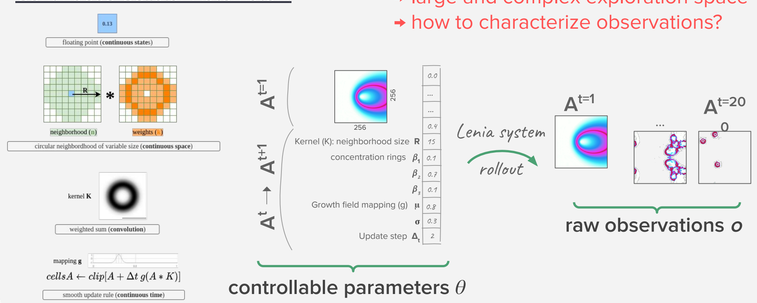


➜ Efficient guidance with very sparse feedback
total of 11 user interventions (one per split) with an average of 6 "clicks" (scores) to provide

Testbed Morphogenetic System: Lenia [1]

Continuous Cellular Automaton:

➜ large and complex exploration space
➜ how to characterize observations?



1) HOLMES: Learning Diverse BC Spaces

Hierarchically Organized Latent Modules for Exploratory Search (HOLMES)
↳ dynamic and modular architecture actively expanded to represent the different niches

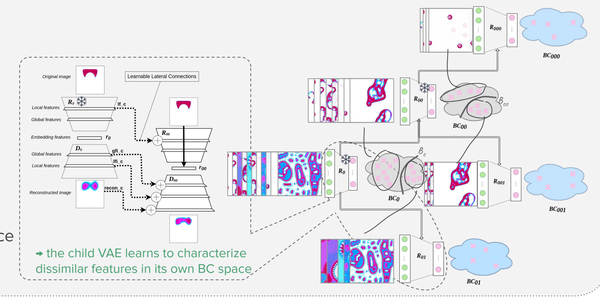
HOLMES architecture:

a) Base **module** embedding neural network ➜ *VAE*

b) Split trigger
➜ *reconstruction loss plateau*

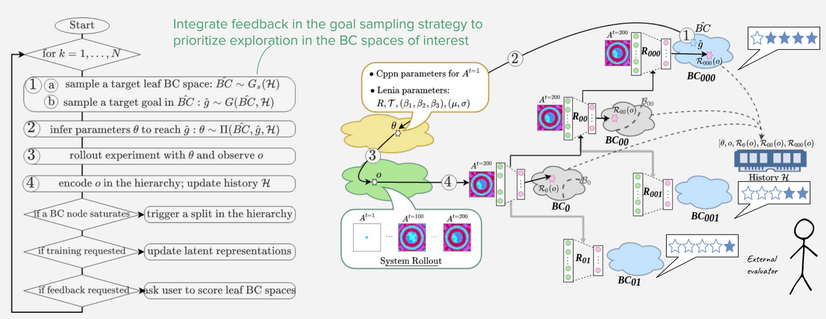
c) Parent-child transfer
➜ *lateral connections [4]*

d) Clustering in the latent space
➜ *K-Means*



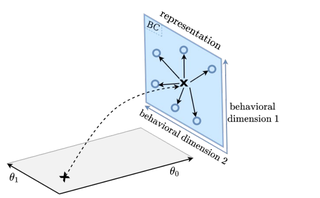
➜ the child VAE learns to characterize dissimilar features in its own BC space

2) IMGEP-HOLMES: Meta-Diversity with Guidance



Formulation of the Exploration Problem?

Standard Diversity-driven Search

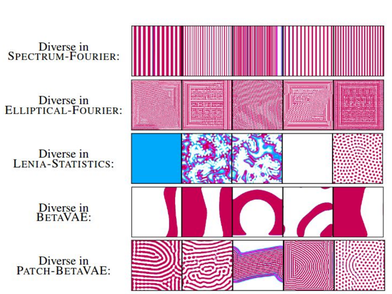


Hypothesis BC: hand-defined [2], unsupervisedly-learned [3]

Solver: intrinsically-motivated goal exploration process (IMGEP)

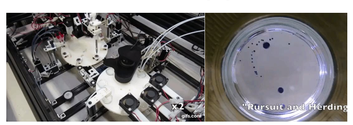
➜ how to characterize our intuitive notion of diversity?

Impact of the choice of the BC



➜ unlikely to be aligned with what a final end-user is considering as "interesting"

Future Work: Application to "wet" systems



Dropfactory Robotic Platform and examples of droplet behaviors.

Poietis NGB-R bioprinting system and examples of bio-printed skin 3D model.

References

[1] Bert Wang-Chak Chan (2019). Lenia-biology of artificial life. Complex Systems, 28(3):251–286.

[2] Jonathan Grizou, Laurie J Points, Abhishek Sharma, and Leroy Cronin (2020). A curious formulation robot enables the discovery of a novel protocell behavior. Science advances, 6(5):eaay4237,

[3] Chris Reinke, Mayalen Etcheverry, and Pierre-Yves Oudeyer (2020). Intrinsically motivated discovery of diverse patterns in self-organizing systems. In International Conference on Learning Representations (ICLR).

[4] Andrei A Rusu et al. (2016). Progressive neural networks. arXiv preprint arXiv:1606.04671.