INVESTIGATING THE EFFECTS OF NOISE ON A CELL-TO-CELL COMMUNICATION MECHANISM FOR STRUCTURE REGENERATION

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INTRODUCTION

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- Note that the shape to which an animal regenerates upon damage can be altered without genetic changes
- For example, it is possible to produce two headed planarian worms
- Genes and proteins involved in regeneration are known, but the exact mechanism of storing and using morphological information for

COMPUTATIONAL MODEL OF MORPHOLOGY DISCOVERY AND REPAIR

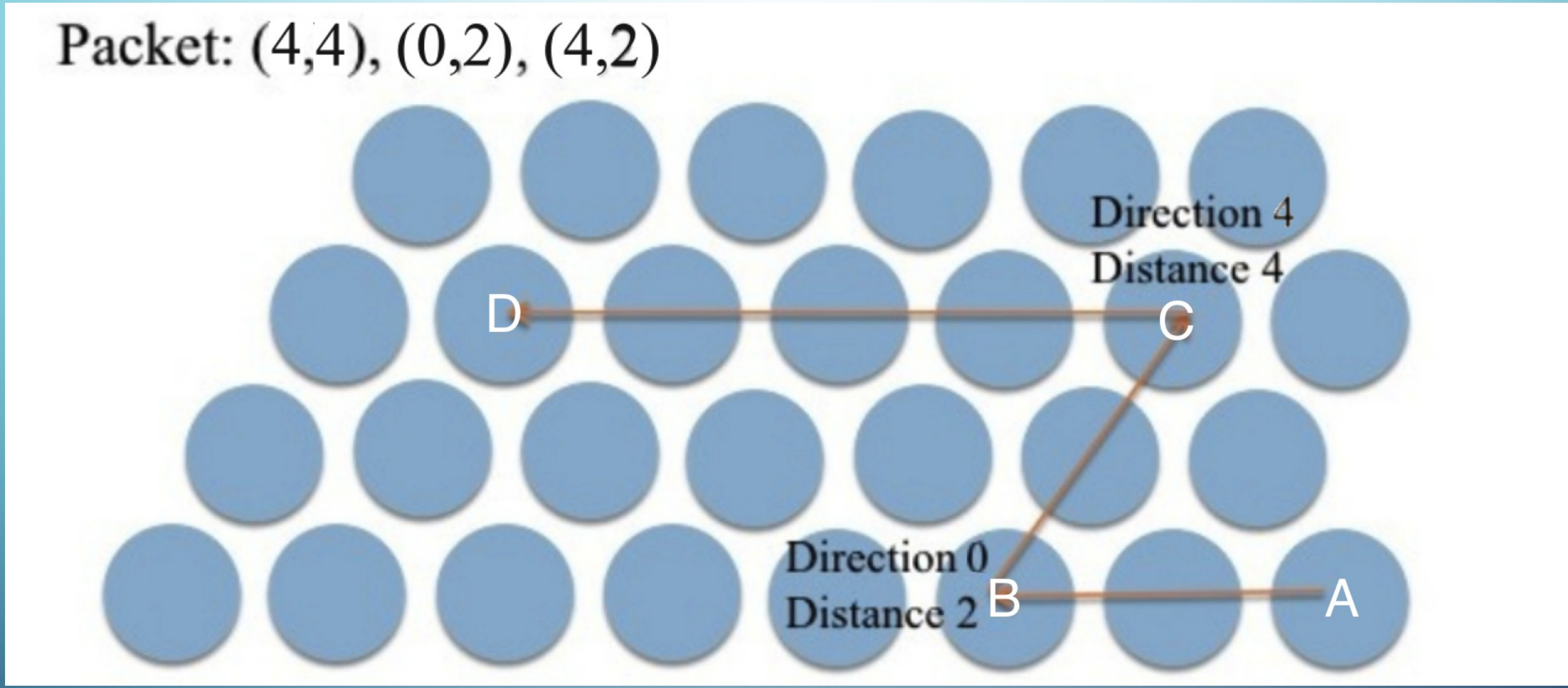
- We previously developed a model that could discover the morphological information of an organism, during a discovery phase
- Later, when the organism was lesioned the dynamic messaging mechanism in the model was able to cause regeneration of the damaged parts
- While the model has not been linked to biological mechanisms yet, it has demonstrated a variety of functional properties of regeneration displayed by planaria

FEATURES OF THE MODEL

- Proposed in Ferreira et al. 2016 [3]
- Morphological information is stored in a dynamic distributed fashion across cells
- The genome is hypothesized to encode the computational machinery necessary for carrying out morphological discovery and repair
- A key feature of the model is that it can dynamically learn and maintain new morphologies using the same computational mechanism

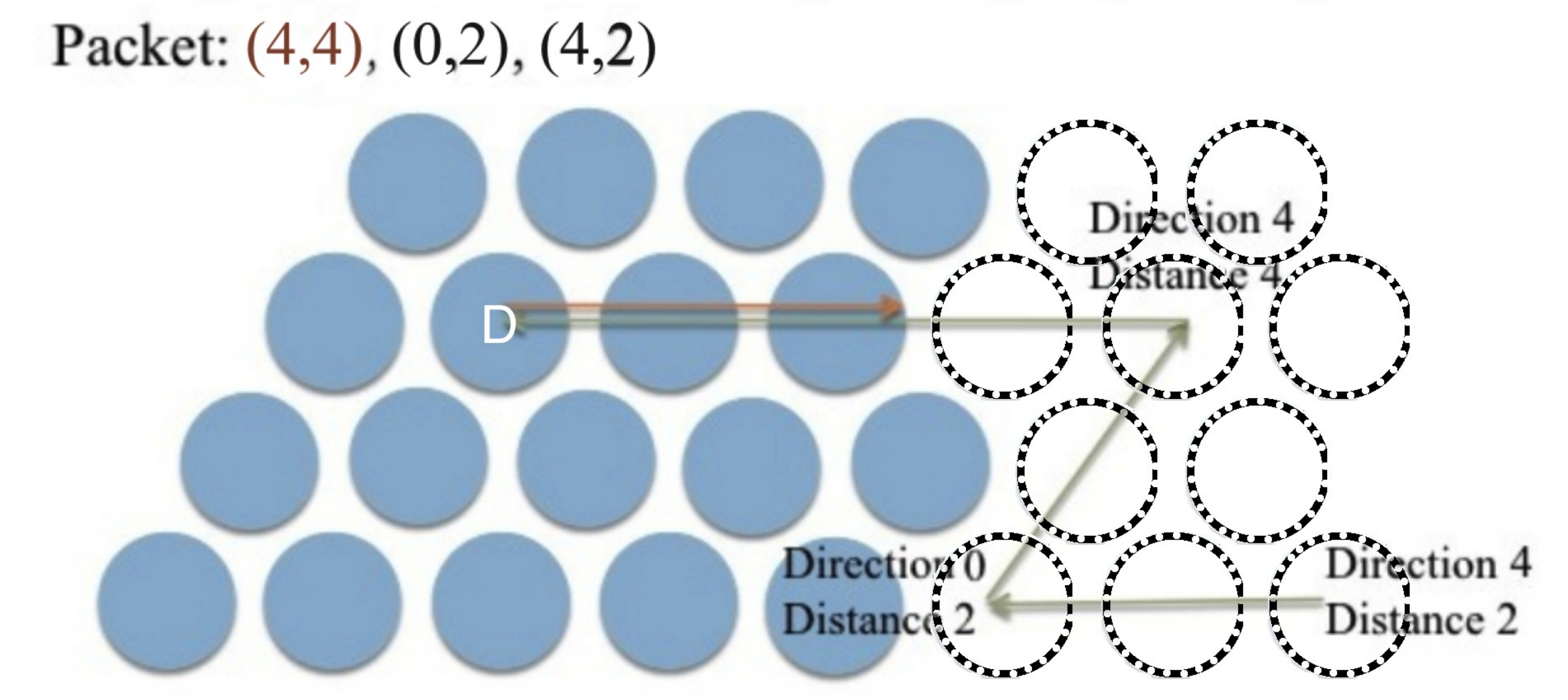
[3] Ferreira, G. B. S., Smiley, M., Scheutz, M., and Levin, M. (2016). Dynamic structure discovery and repair for 3d cell assemblages. In *Proceedings of the Fifteenth International Conference on the Synthesis and Simulation of Living Systems (ALIFEXV)*

DISCOVERY



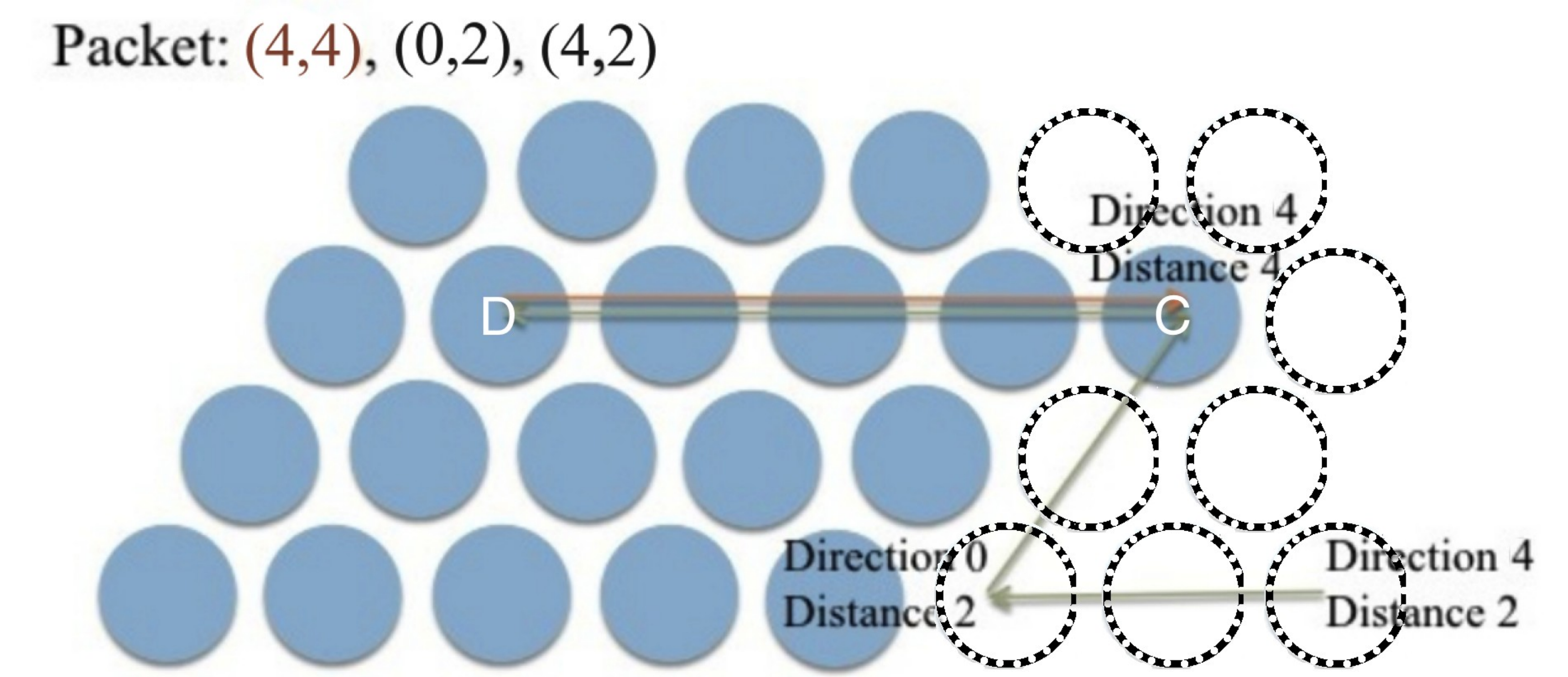
Cells send messages to other cells containing information about the path that those messages traveled.

REGENERATION

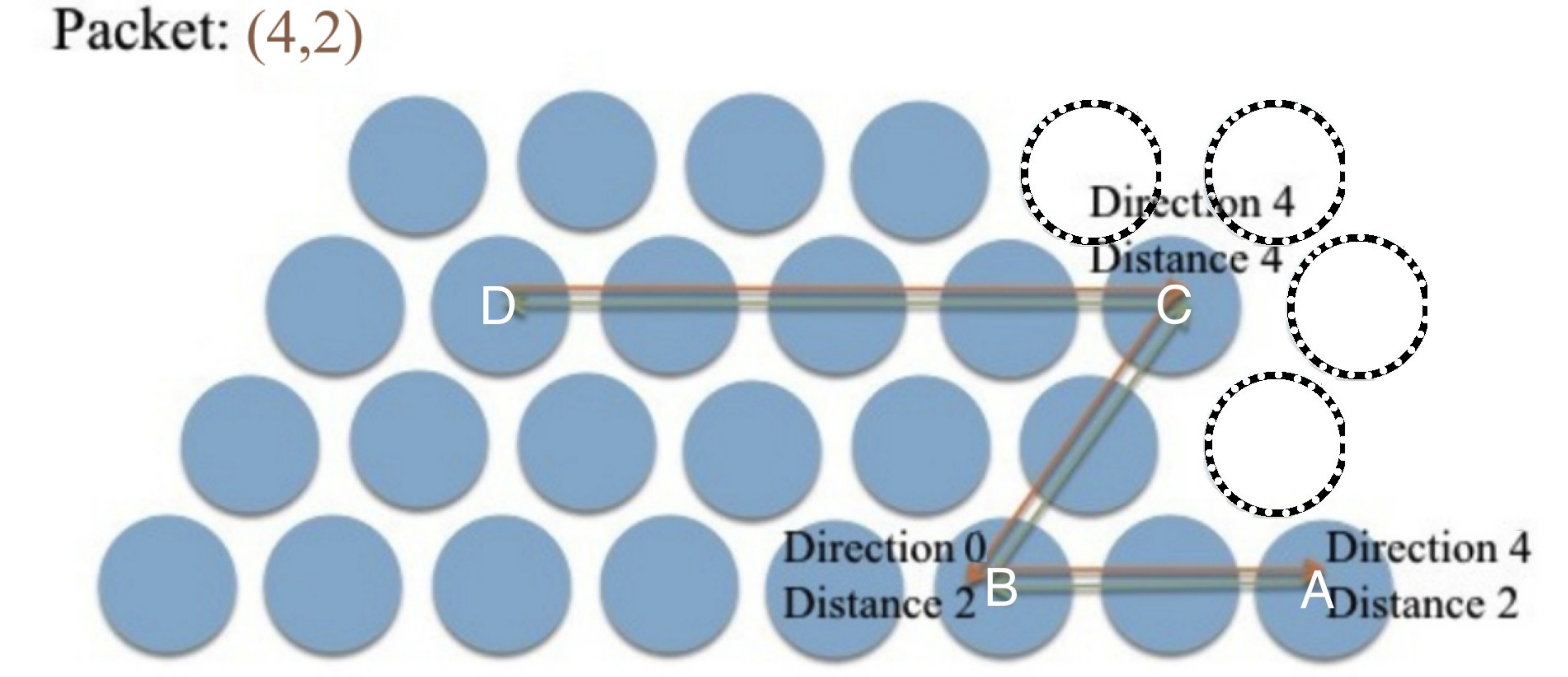


Then those message packets ”backtrack” verifying if there exists a missing cell in the previous path, repairing it.

REGENERATION



REGENERATION

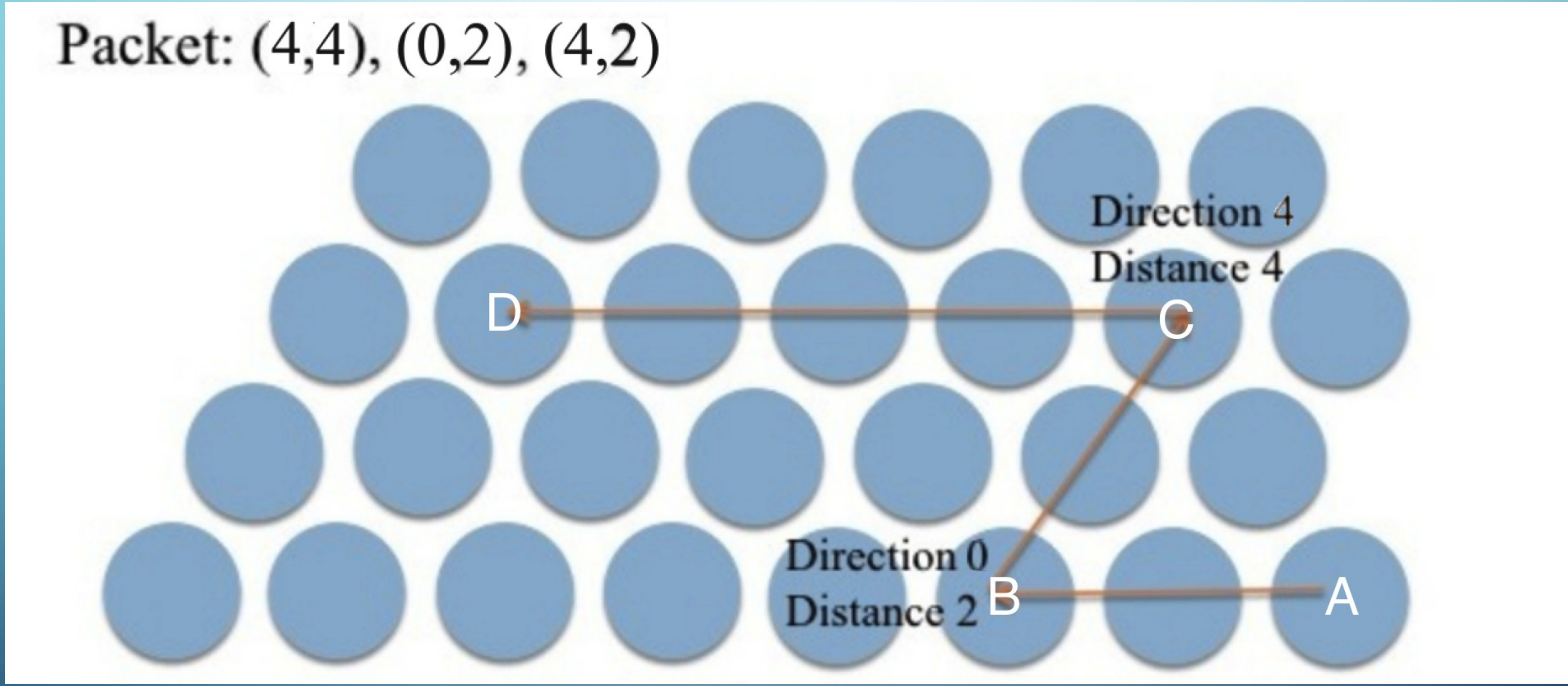


PREVIOUS FINDINGS

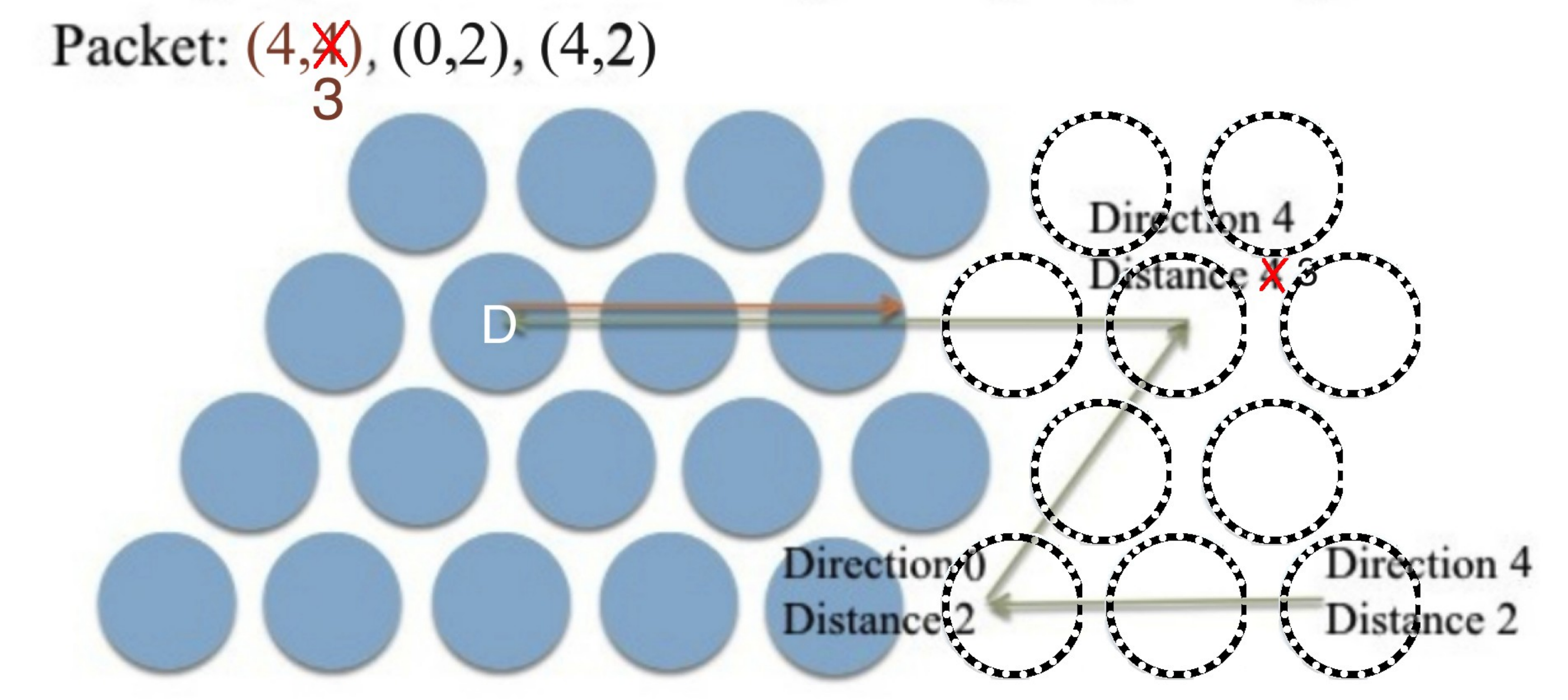
- In Ferreira et al (2016) [3] we showed that this model was capable of maintaining the structure of the worm indefinitely in the light of random damages happening to parts of it
- However, communication was assumed to be perfect and without losses, which is not realistic in any actual organism
- Hence, the goal of this work was to investigate the extent to which the model can handle various types of noise

[3] Ferreira, G. B. S., Smiley, M., Scheutz, M., and Levin, M. (2016). Dynamic structure discovery and repair for 3d cell assemblages. In *Proceedings of the Fifteenth International Conference on the Synthesis and Simulation of Living Systems (ALIFEXV)*

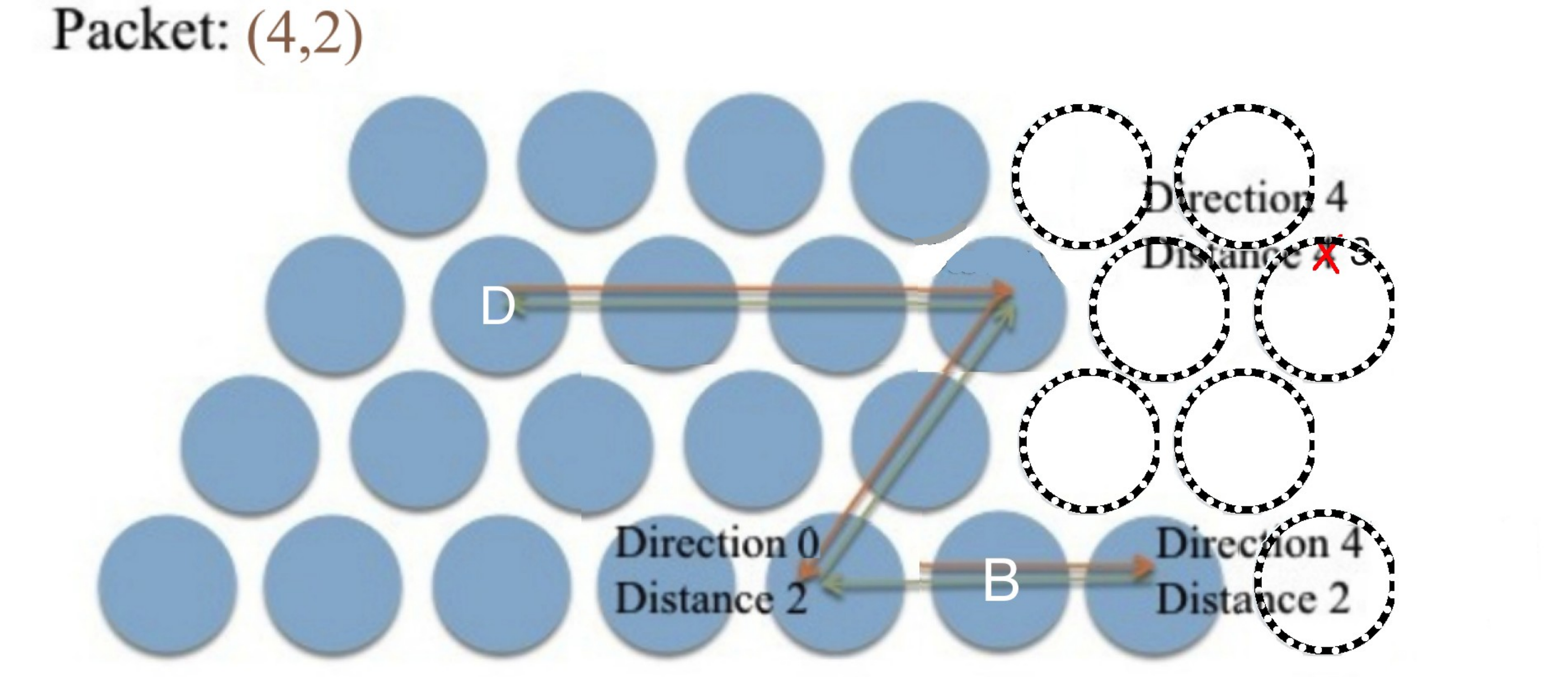
EXPERIMENTS WITH NOISE ON PACKETS



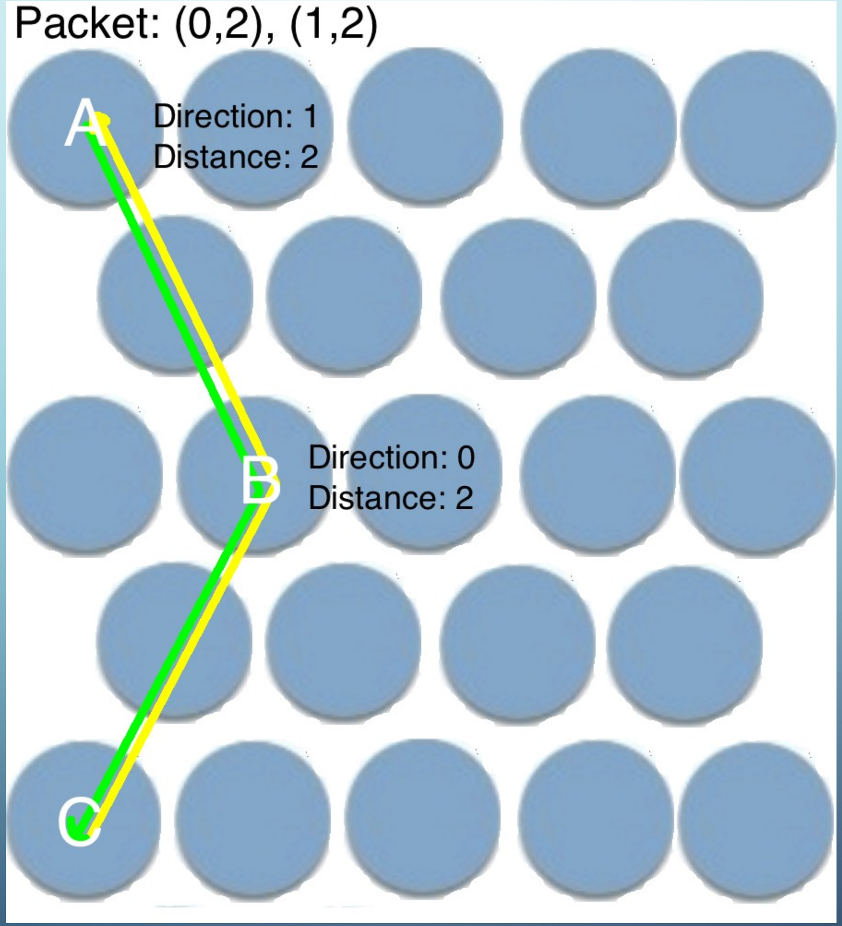
NOISE ON DISTANCE



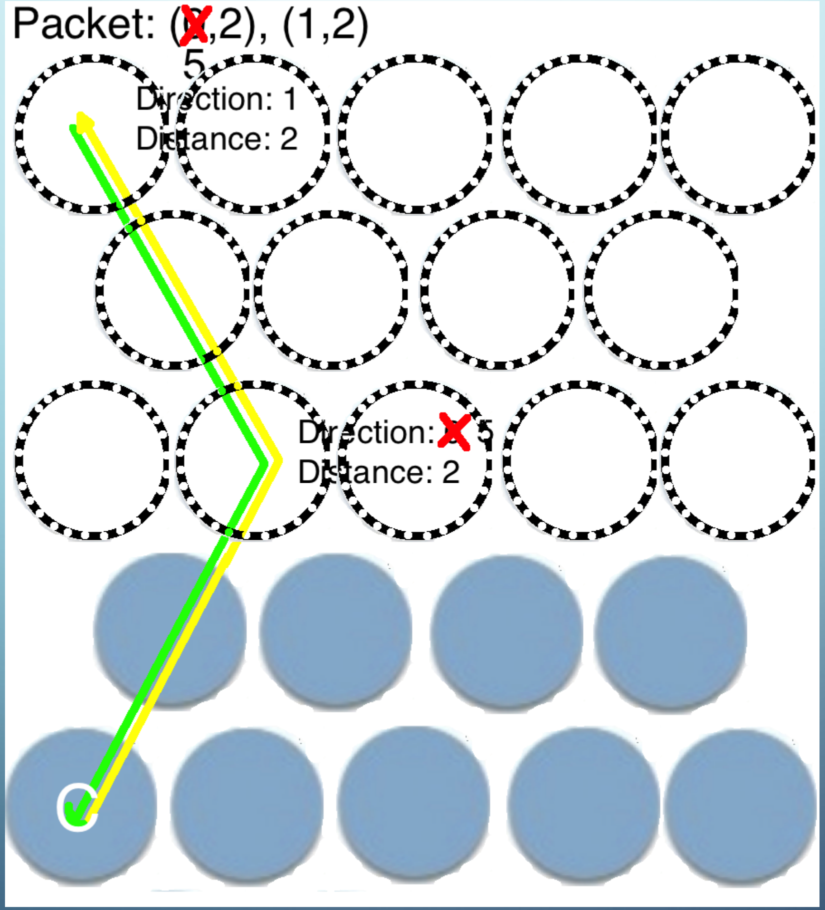
NOISE ON DISTANCE



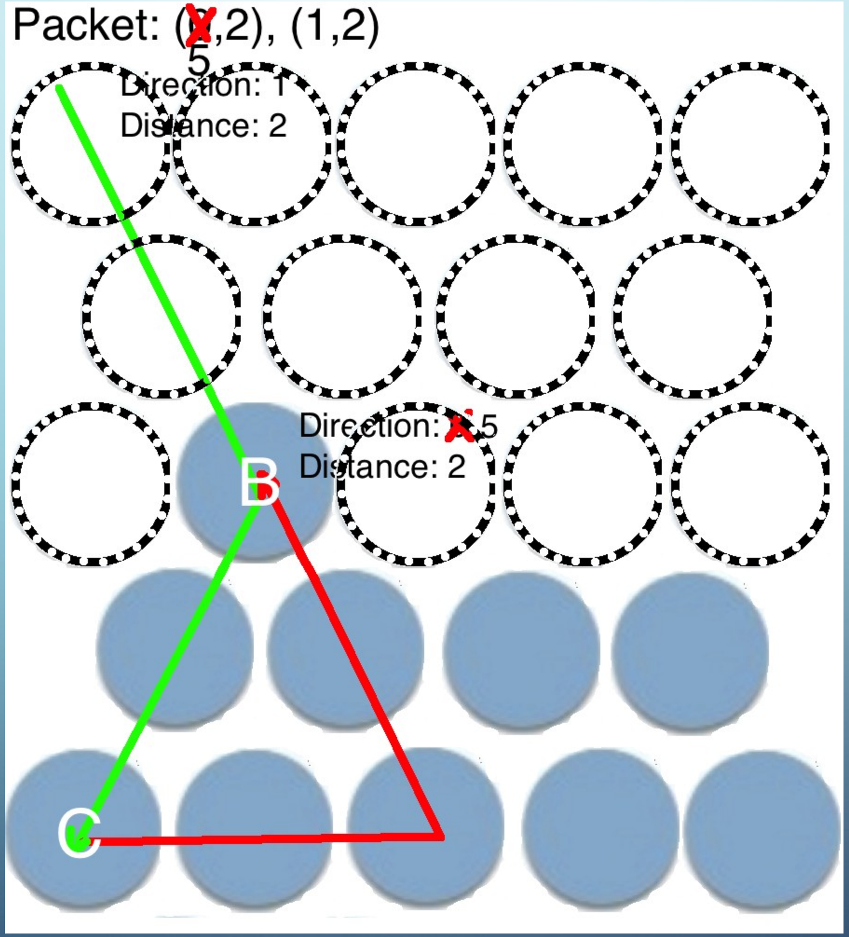
NOISE ON DIRECTION



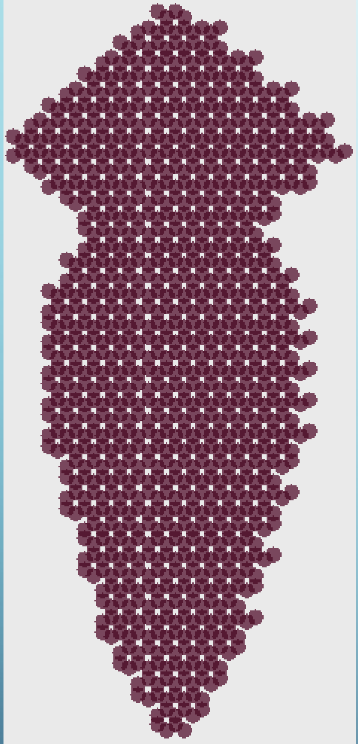
NOISE ON DIRECTION

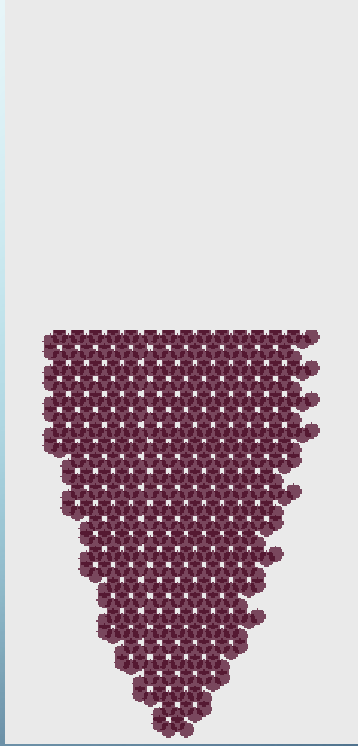


NOISE ON DIRECTION



EXPERIMENTS WITH NOISE ON PACKETS



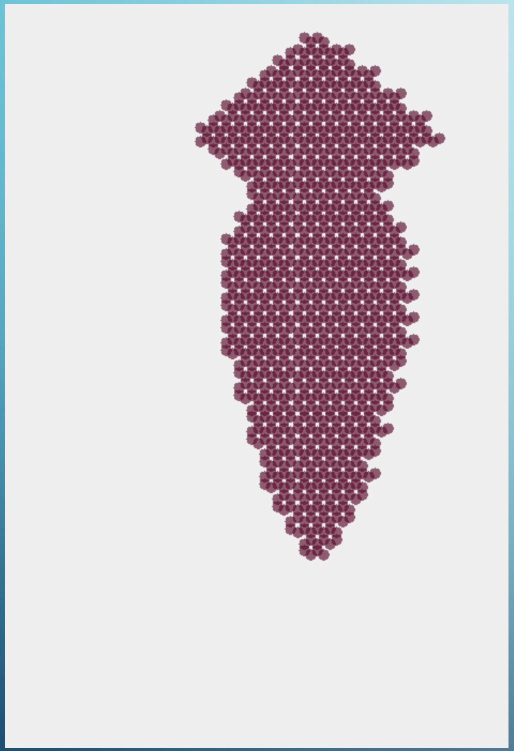


RESULTS OF EXPERIMENTS WITH PACKETS CONTAINING NOISE

- The model completely regenerated the simulated worm in 63% of the parameter space with no noise
- The model completely regenerated the simulated worm in 0% of the parameter space that contained noise

REGENERATED WORMS

$$Sim = \frac{AliveCells - (Overgrowth + MissingCells)}{TotalCells}$$

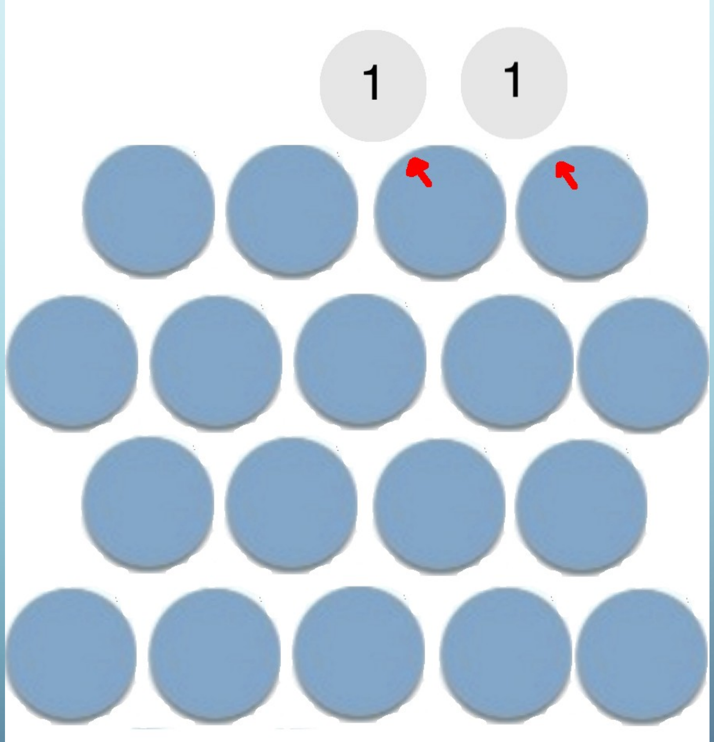


Original worm: Sim = 1

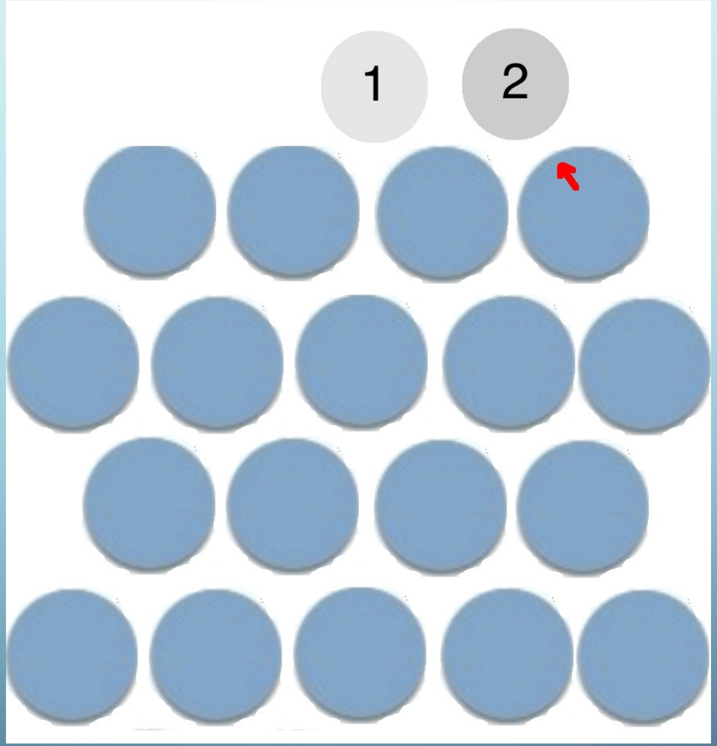
Best worm: Sim = 0.828

Worst worm: Sim = 0.181

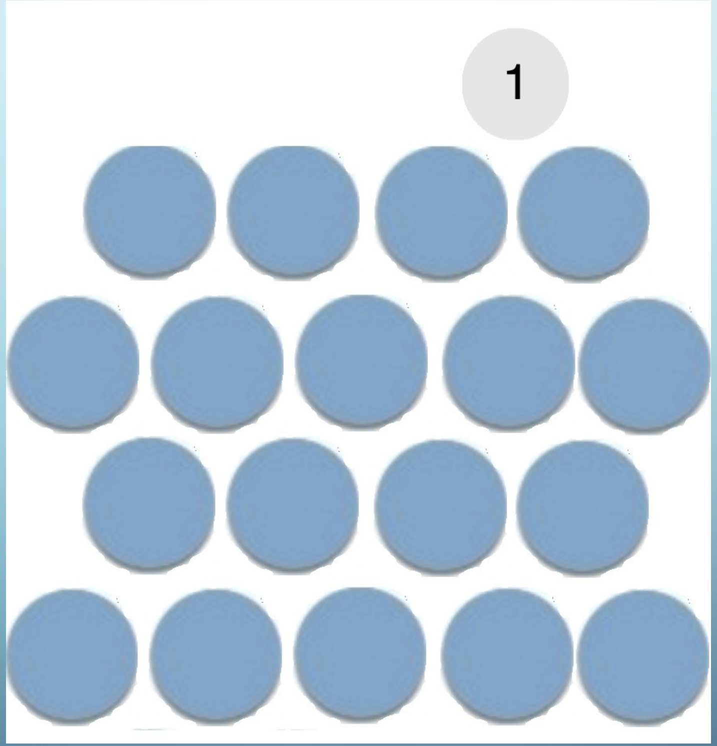
ACTIVATION MECHANISM - NOISE



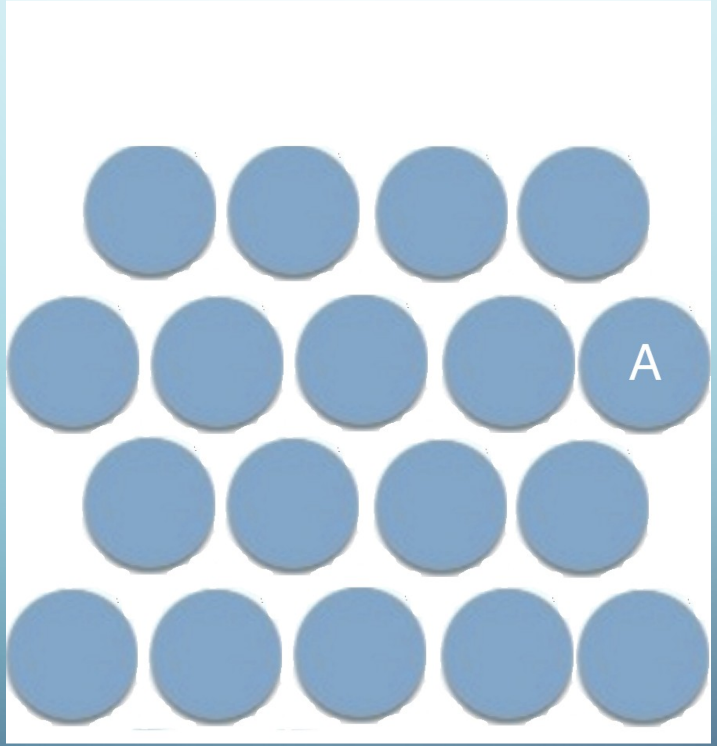
ACTIVATION MECHANISM - NOISE



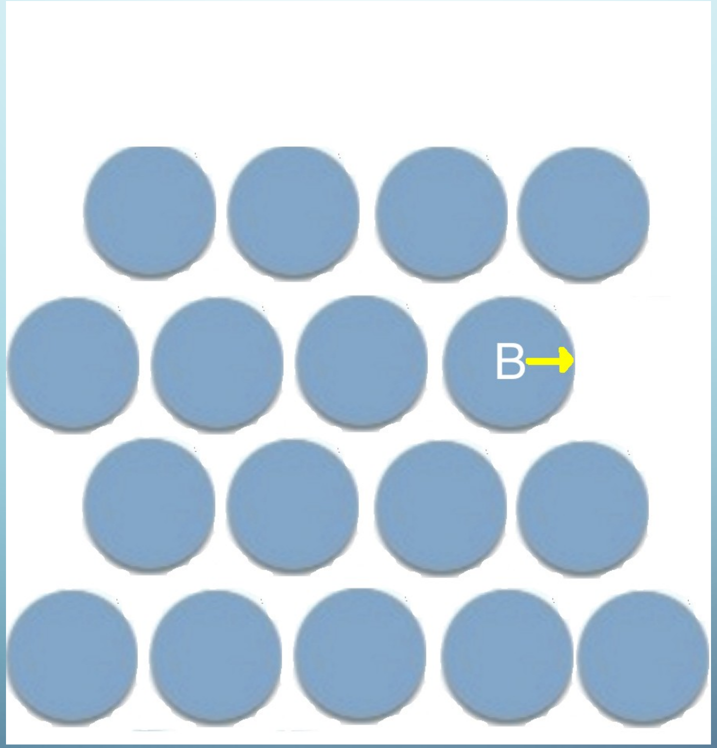
ACTIVATION MECHANISM - NOISE



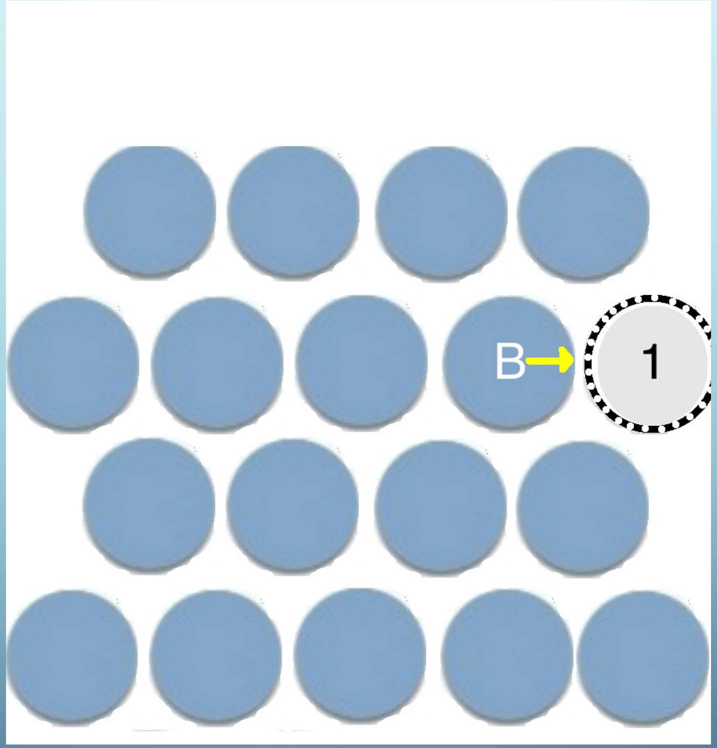
ACTIVATION MECHANISM



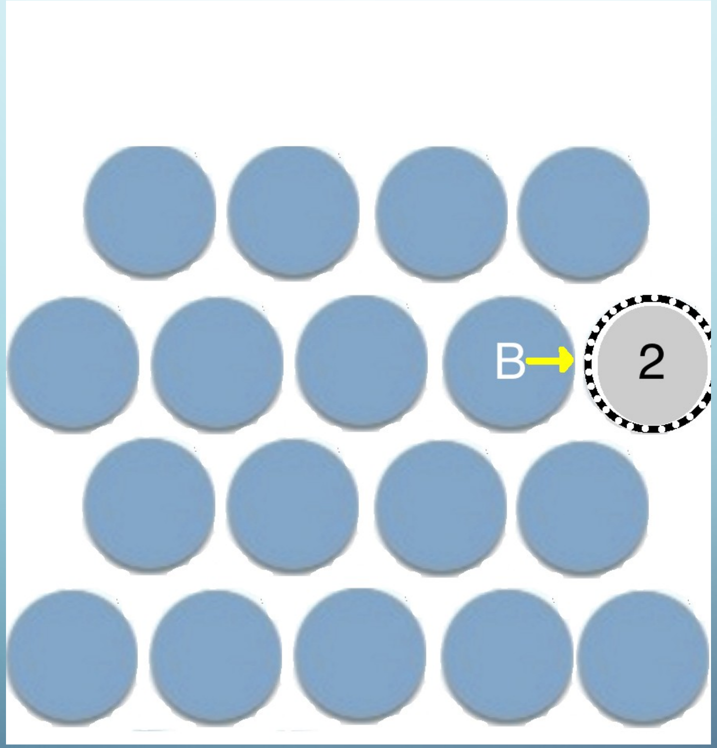
ACTIVATION MECHANISM



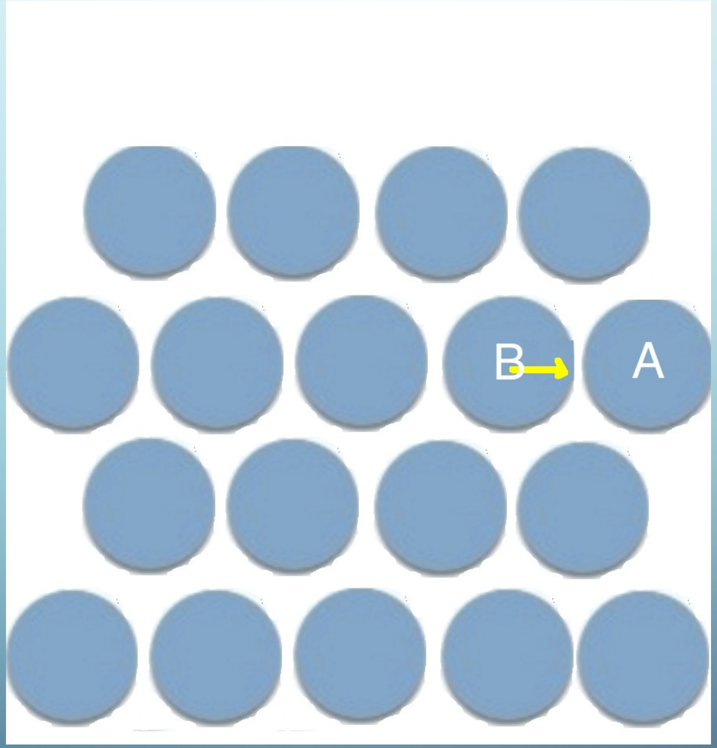
ACTIVATION MECHANISM



ACTIVATION MECHANISM



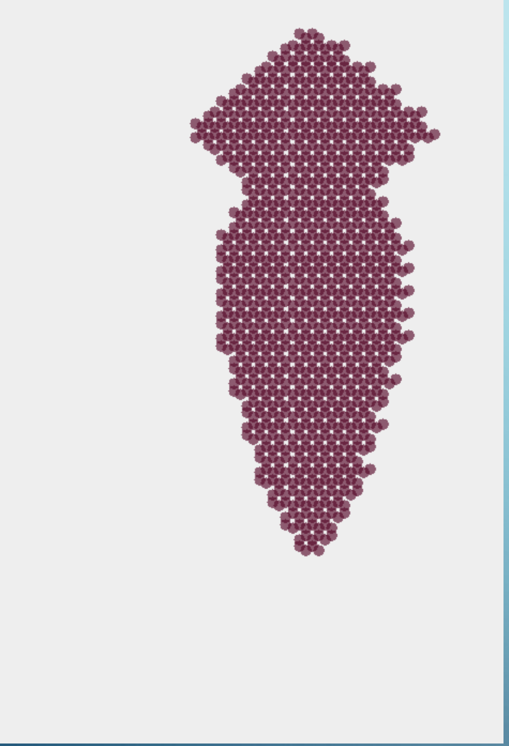
ACTIVATION MECHANISM



RESULTS OF EXPERIMENTS WITH THE ACTIVATION MECHANISM

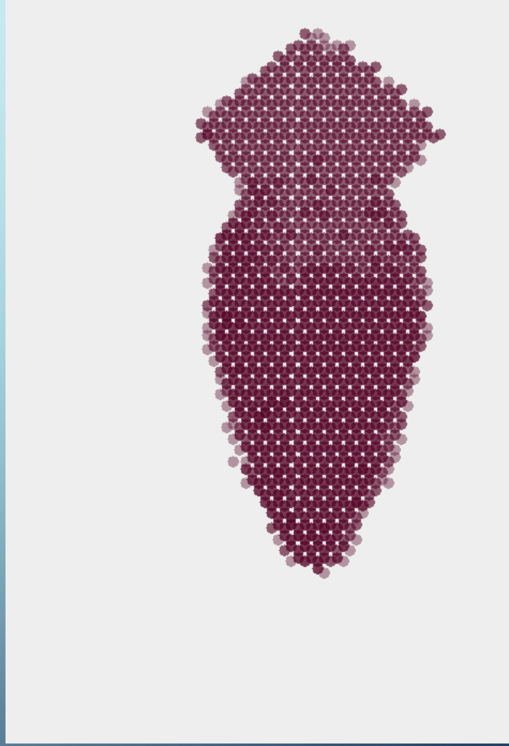
- The model completely regenerated the simulated worm in 39% of the parameter space with no noise (63% without the activation mechanism)
- The model completely regenerated the simulated worm (with 100% similarity) in 5.7% of the parameter space that contained noise, compared to 0% of the parameter space without the activation mechanism

REGENERATED WORMS



Original worm: Sim = 1

Best worm without the activation mechanism: Sim = 0.828



Worst worm with activation mechanism: Sim = 0.664

CONCLUSION

- We investigated our model of dynamic messaging morphology discovery and repair under various conditions of noise and proposed simple extensions to overcome the detrimental effects of noise
- Large parameter sweeps of the model determined that in about 6% of the parameter space the model was able to fully regenerate the original morphology with noise on the direction of packets
- We are currently investigating why the proposed extensions do not suffice for noise on packet distances