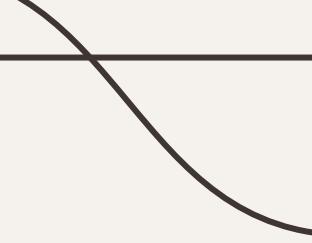


Neural Cellular Automata (NCA)

What are NCA?



CA

Discrete state

Rule-table

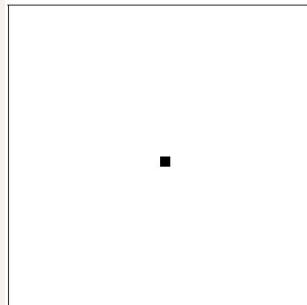
NCA

Continuous state

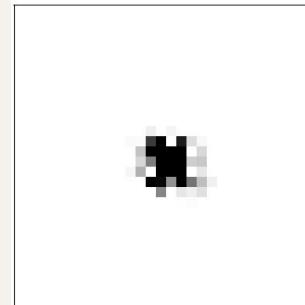
Small Neural Network

What are NCA?

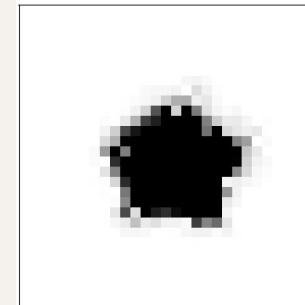
Step 1



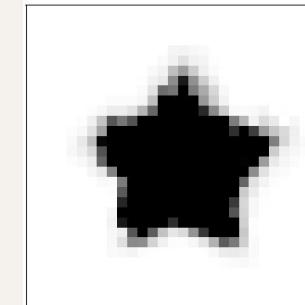
Step 5



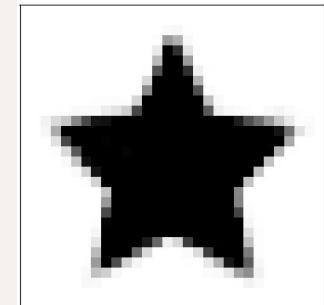
Step 15



Step 25

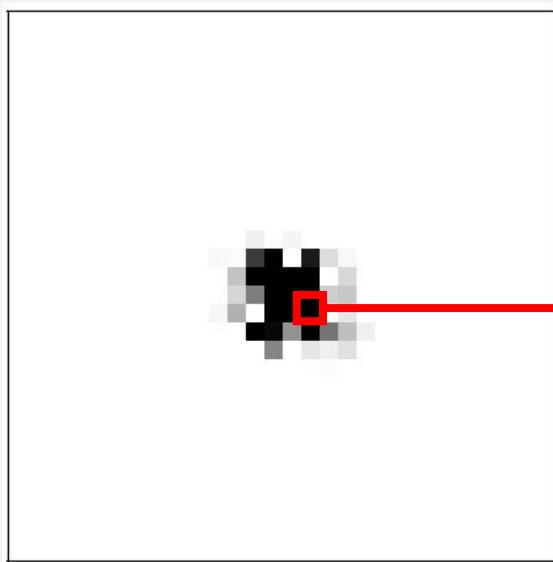


Step 60

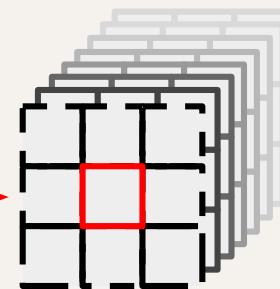


Emergence

How does the grid update (1/2)



8 Channels



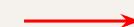
Sobel-X

-1	0	1
-2	0	2
-1	0	1



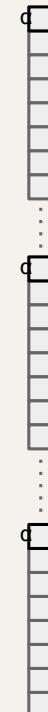
Sobel-Y

-1	-2	-1
0	0	0
1	2	1

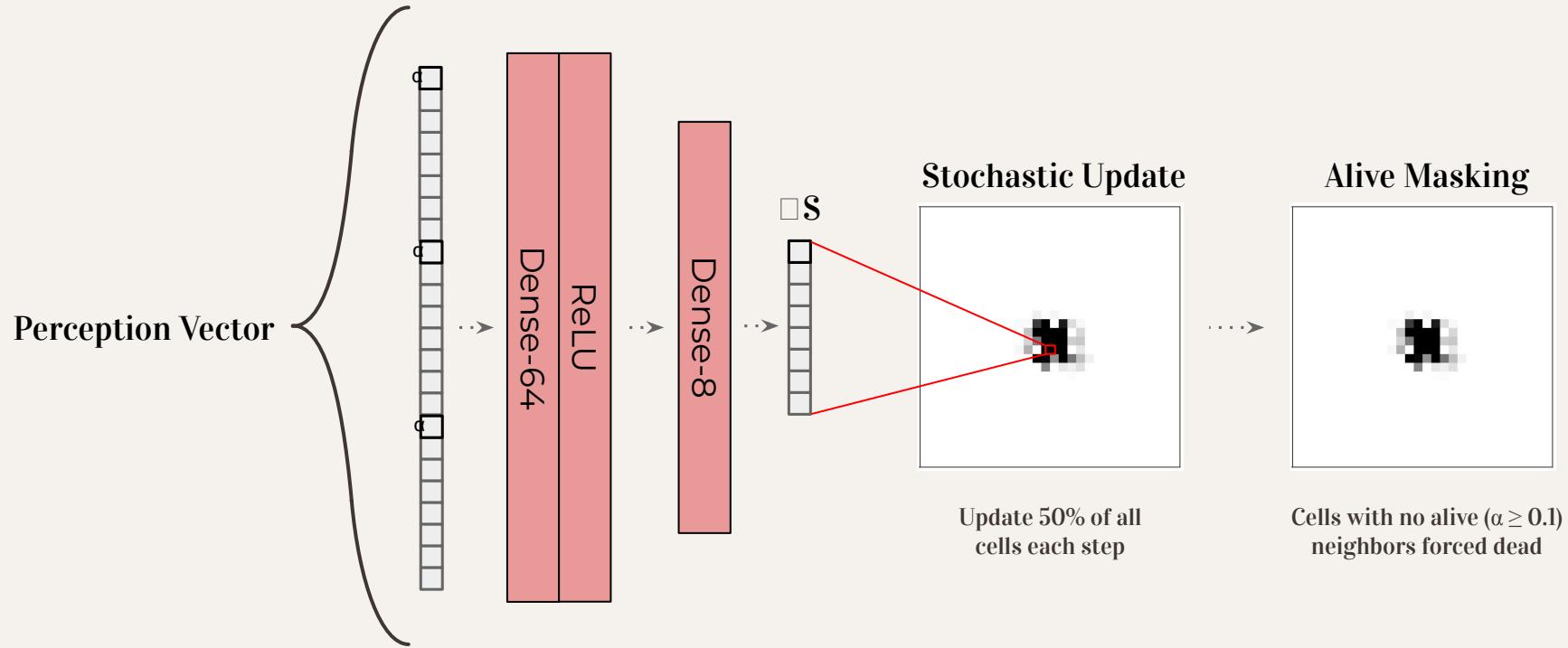


Identity

0	0	0
0	1	0
0	0	0



How does the grid update (2/2)



Research Questions (1/2)

RQ1.

"Is there a specific pattern in the state vector of each cell revealing its specialisation with regard to the pattern it was optimized for?"

H1.

"Yes. Since the rule table (NN) is shared across all cells, hence specific behaviors have to be encoded locally in the state. However, they might be difficult to interpret as a 'pattern' by humans."

Research Questions (2/2)

RQ2.

"Is there a critical damage threshold for regeneration, and does the type of damaging matter for regeneration?"

H2.

"Yes. We expect there to be some non-trivial threshold after which regeneration is not always possible. Furthermore regeneration from "chunk" damage will be harder to overcome than random damage."

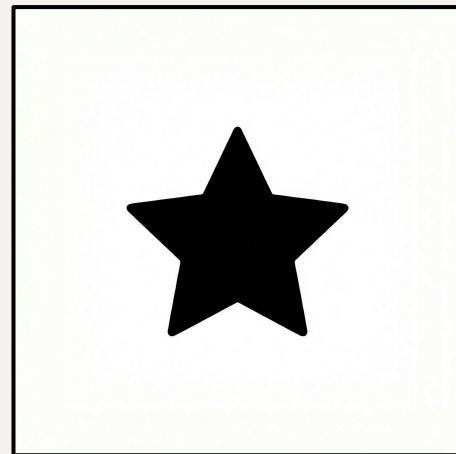
EA optimization

- Structure through Evolution
- Fitness function
- CMA-ES, DE
- Search Space

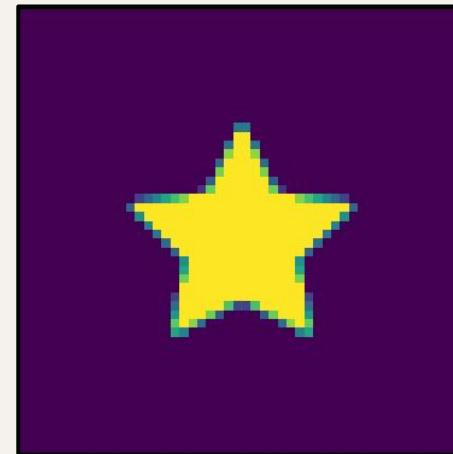


Alternative: Backpropagation

Target Image

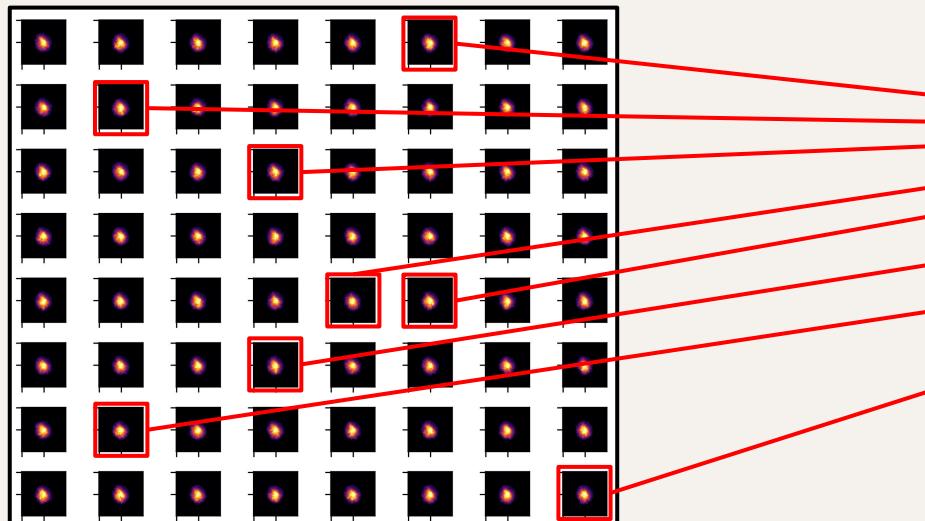


Target Pattern

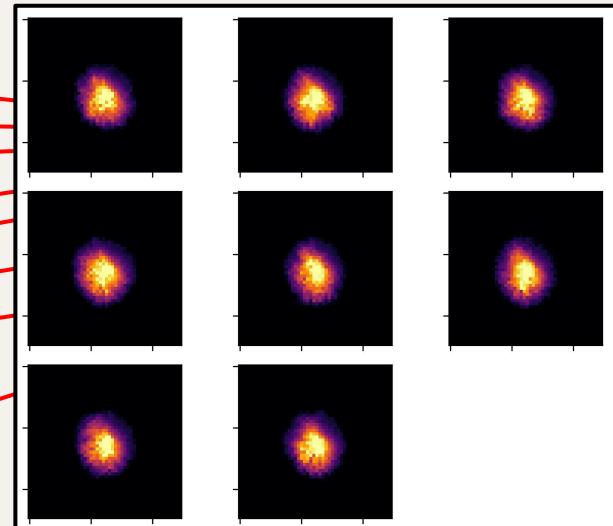


Alternative: Backpropagation

Store Pool of States



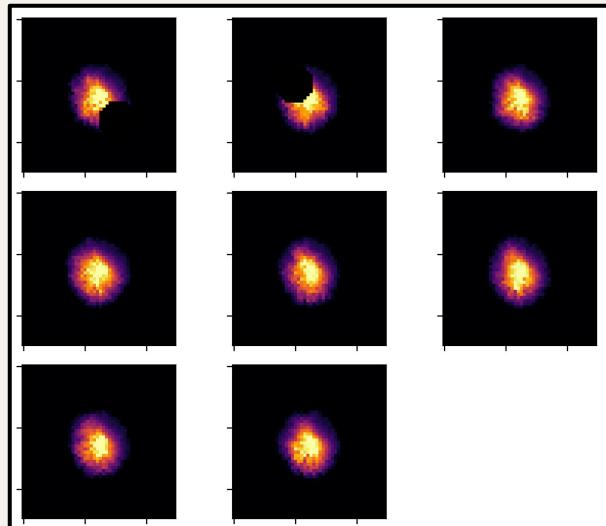
Get Random Batch



(Sorted on how well they fit
the target pattern)

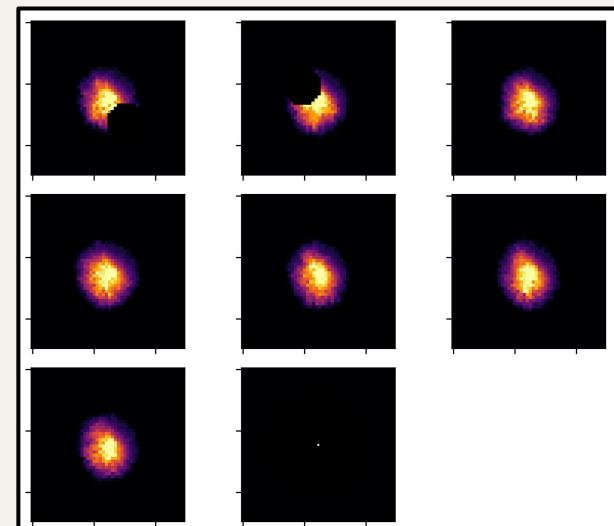
Alternative: Backpropagation

Damage Best 2



Learn to regenerate

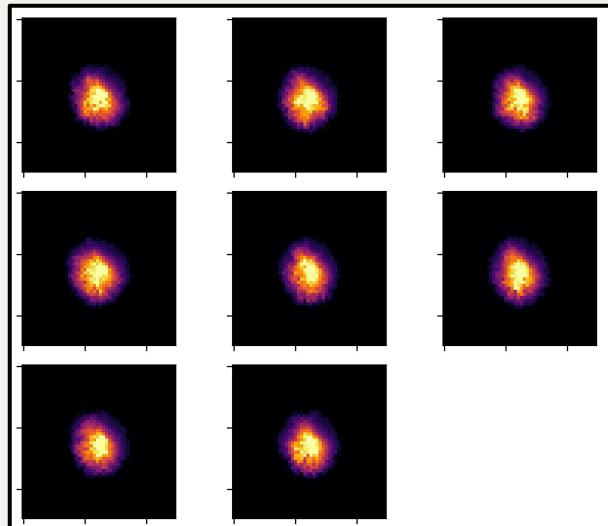
Re-seed Worst



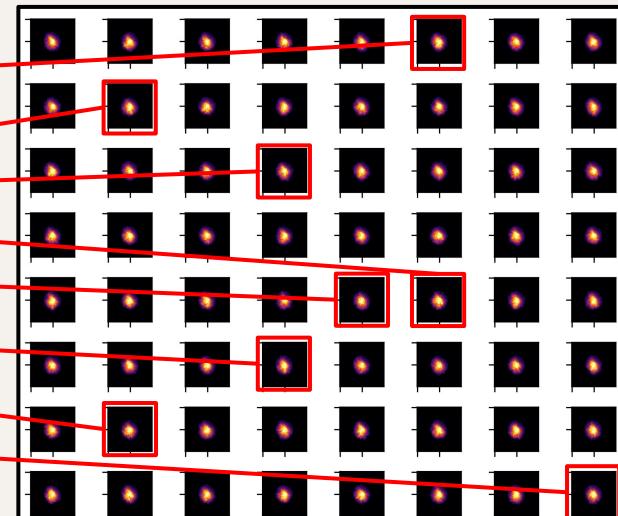
Don't forget how to grow from seed

Alternative: Backpropagation

Run for 50-90 Steps

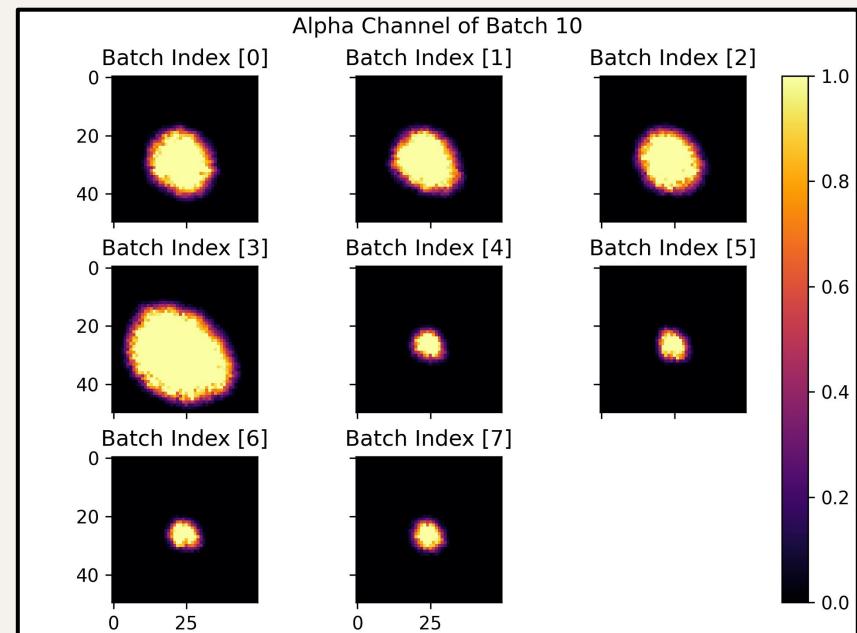
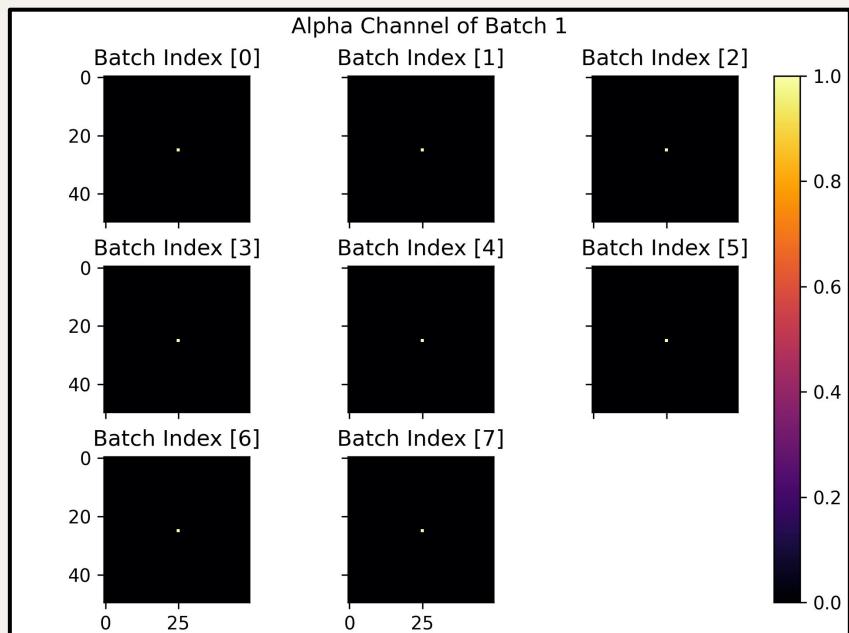


Backpropagate & Return to Pool



Learn to be resilient for different step sizes

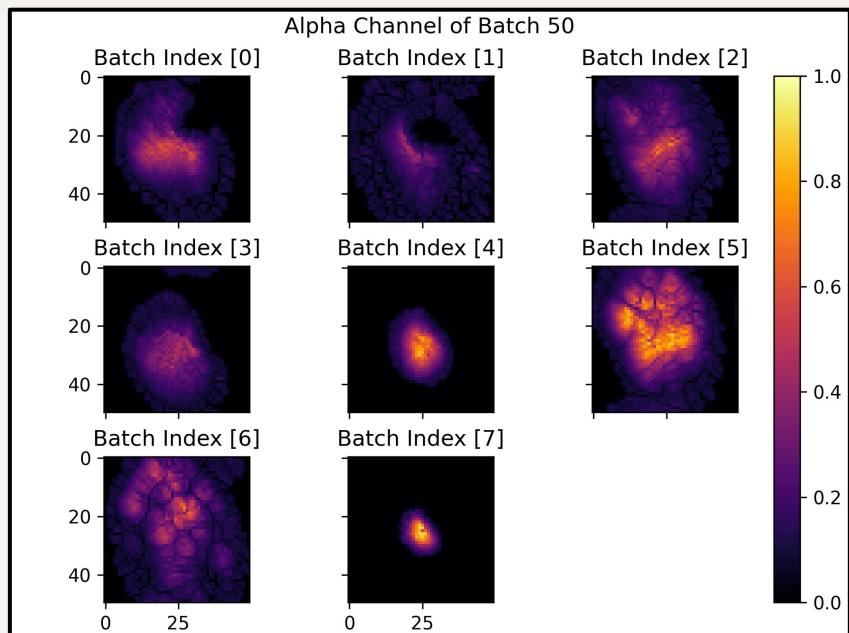
Training example



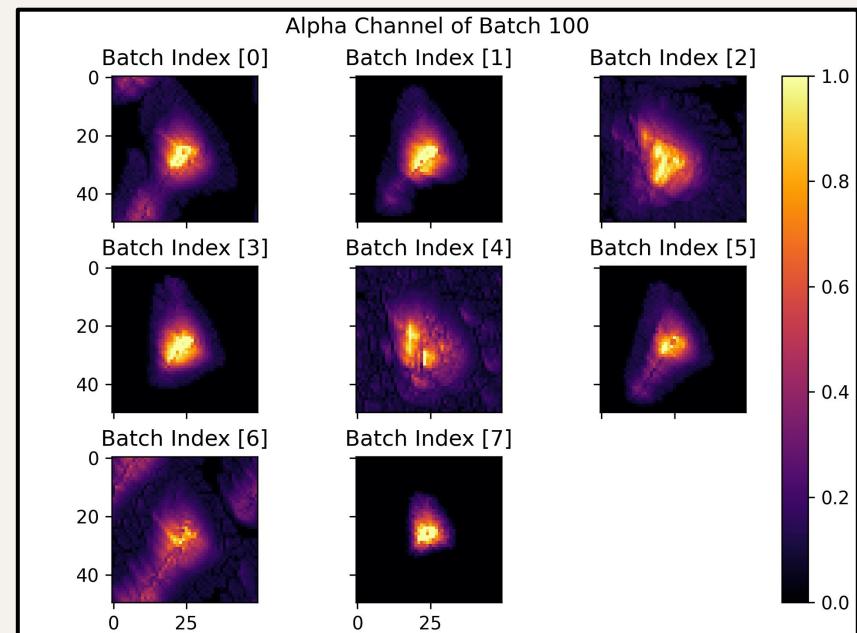
Step 1

Step 10

Training example

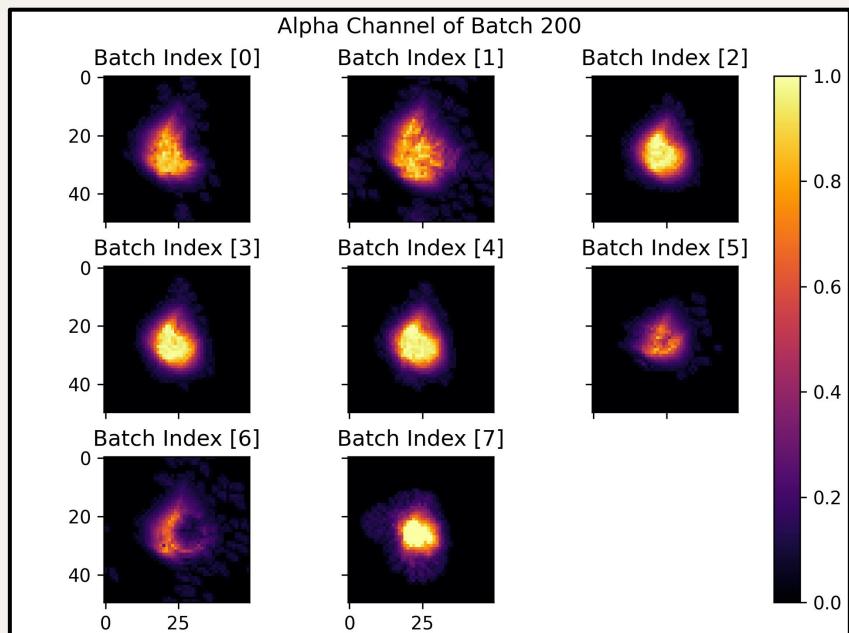


Step 50

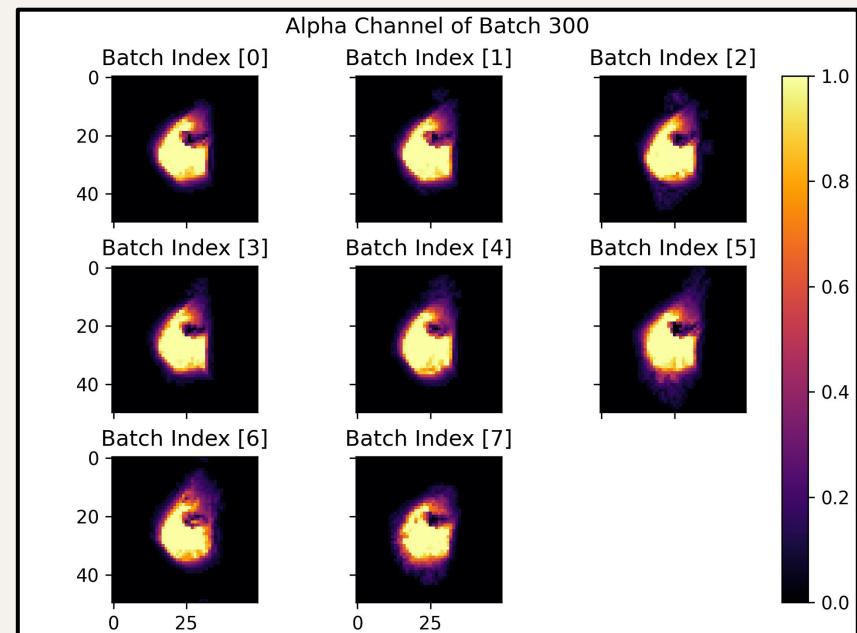


Step 100

Training example

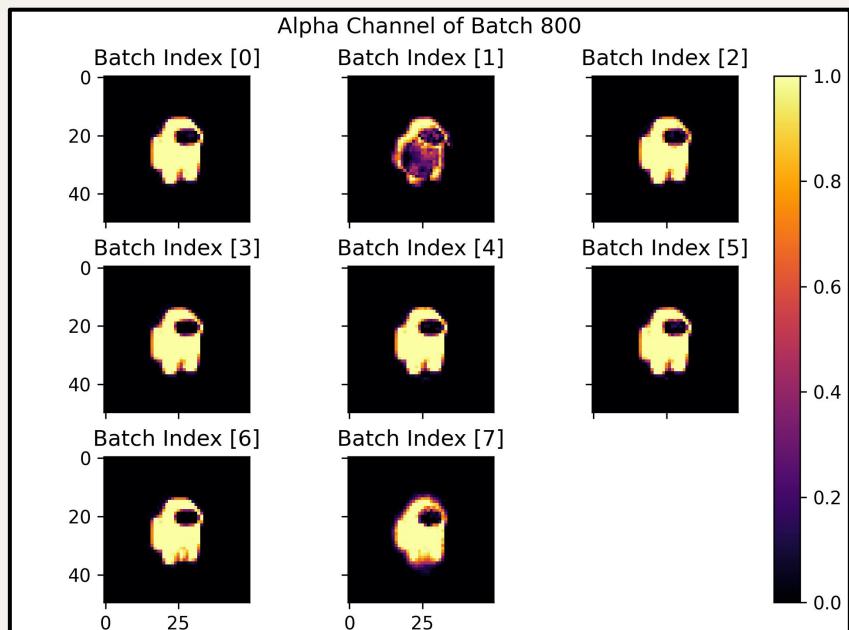


Step 200

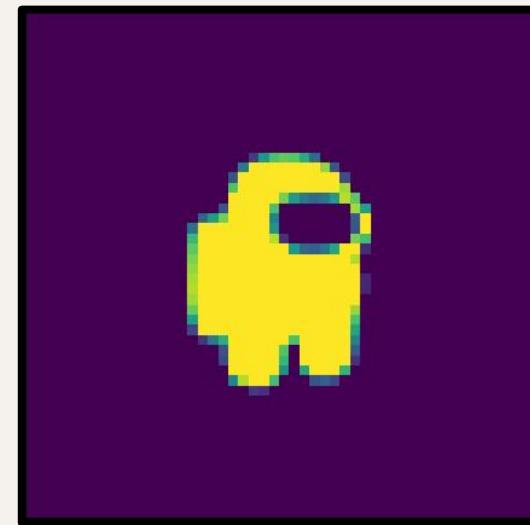


Step 300

Training example

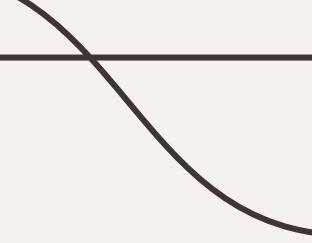


Step 800



Target

Back to research questions

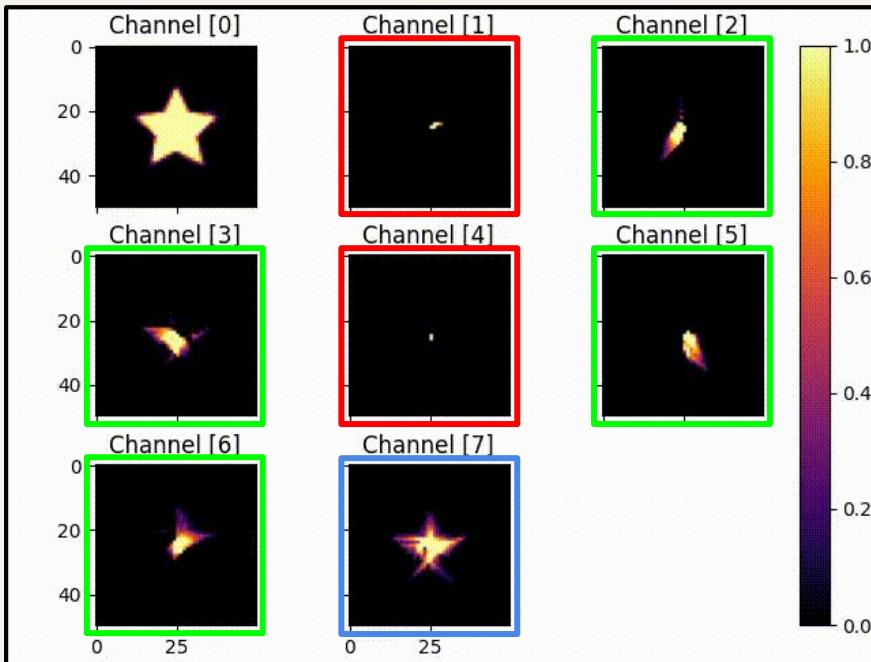


RQ1.

"Is there a specific pattern in the state vector of each cell revealing its specialisation with regard to the pattern it was optimized for?"

Back to research questions

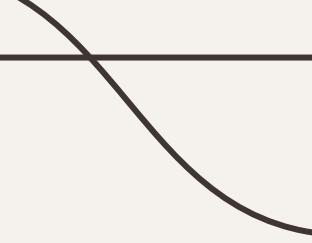
Yes



Likely Interpretation

- Core: handles centering
- Responsible for Arms
- Size of star?

Back to research questions

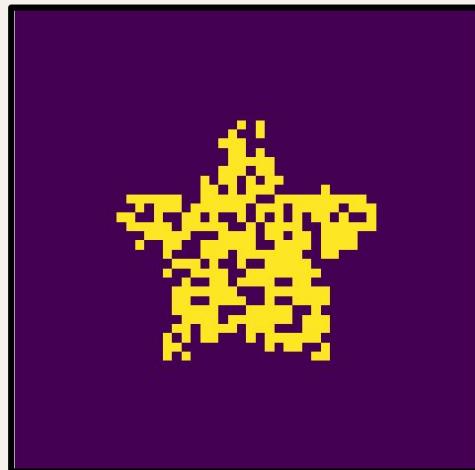


RQ2.

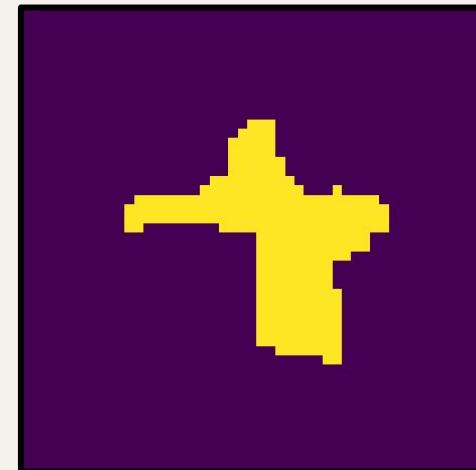
"Is there a critical damage threshold for regeneration, and does the type of damaging matter for regeneration?"

Back to research questions

Random Damage



Blob Damage



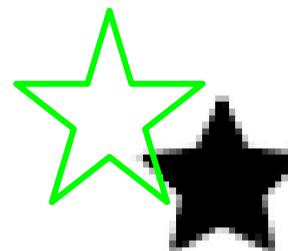
Measurement methods

MSE

good



bad



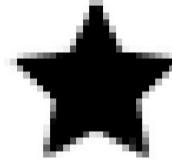
bad



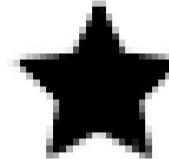
Measurement methods

Mean cell count

good



good



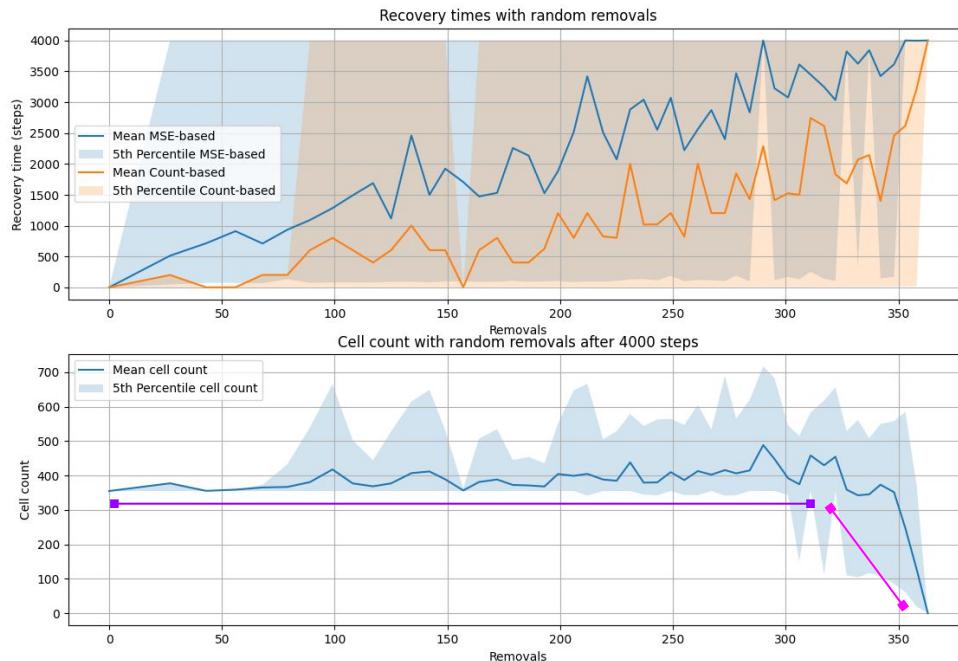
False good*



*if total cell count is the same

Back to research questions

Random Damage



Linear Increase

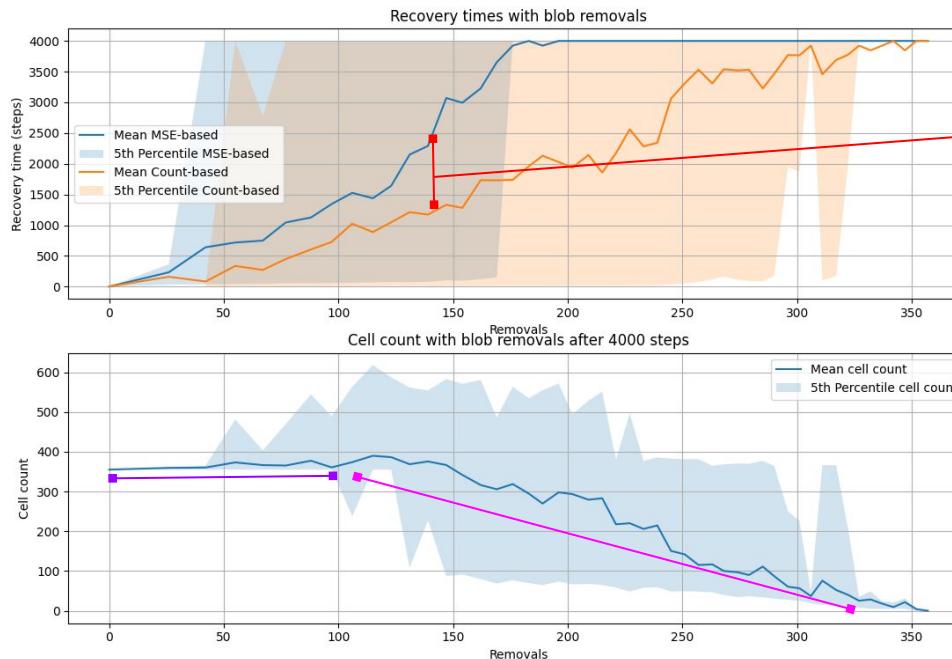
Similar Scaling

■ Almost perfect regeneration

■ Sharp Drop-Off

Back to research questions

Blob Damage



Seems to spread out

- Regrowing but off-center
- Maybe mutation?

➡ Almost perfect regeneration

➡ Linear Decline

Conclusion

RQ1.

- Pattern for simple figures easily detectable
- Unsure if it scales with more difficult targets

More robust against random damage

More difficulties with blob damage

Blob damage can cause off-center regeneration

RQ2.

Live Demo