Convolutional LSTMs for next-frame prediction of a growing bacterial colony

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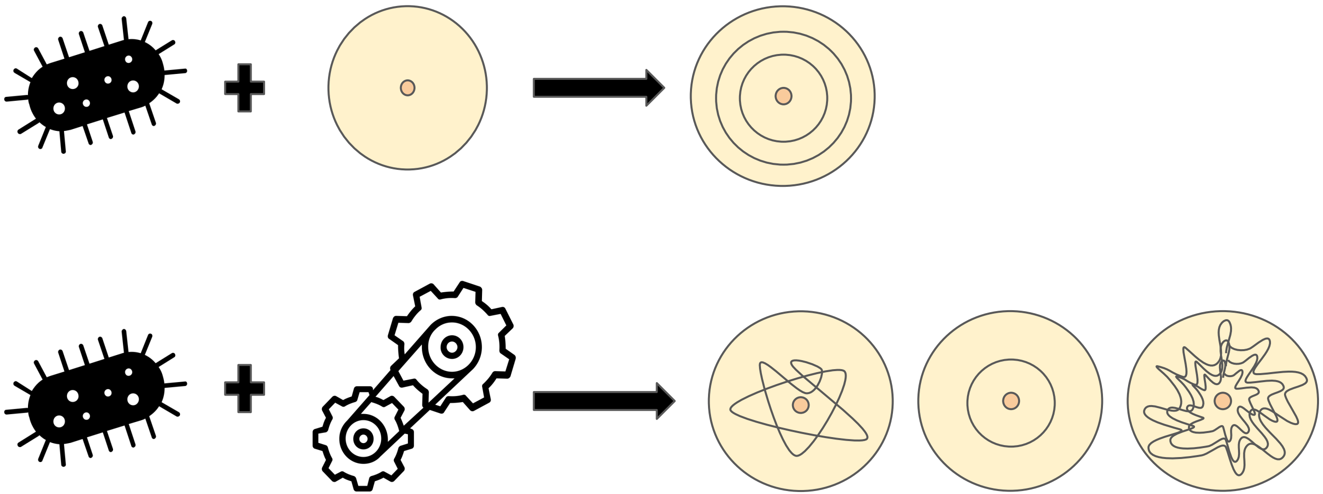
BMENE4470: Deep Learning for Biosignal Processing

Introduction

- *P. mirabilis* cells form a symmetrical bullseye pattern
- Using various genetic circuits that regulate the expression of swarming-implicated genes, the bacterium has been engineered to form more complex macroscopic patterns in response to the environment.



Introduction

Documenting the spatiotemporal dynamics of the growing bacterial pattern is challenging.

Current Method:

2-3 days long timelapses

Our Proposed Method:

Deep Learning based next-frame video prediction

Project Goal

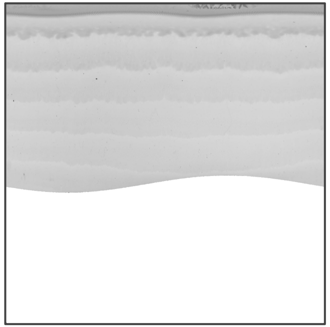
Implement a convolutional long short-term memory (LSTM) network and an ODE2VAE model to predict future frames in a timelapse showing a growing bacterial colony.

Methodology

1. Patterning assays and data acquisition

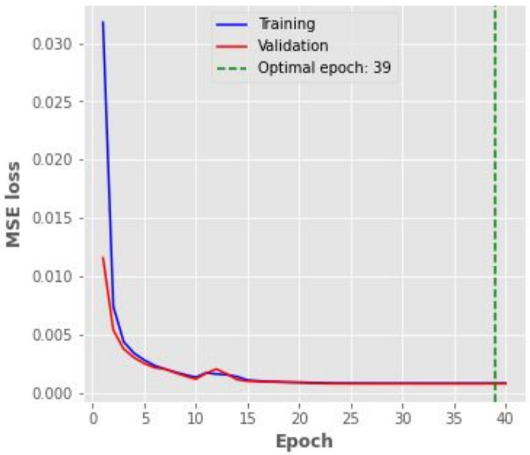
42 timelapse images of 1500x1500 pixels each that document the growth of 5 different engineered *P. mirabilis* strains at various IPTG concentrations

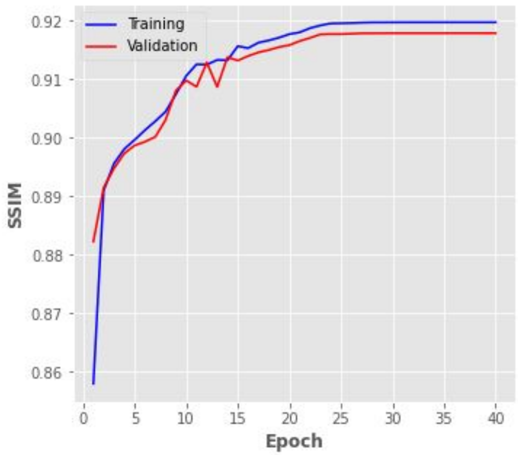
2. Preprocessing of timelapse images



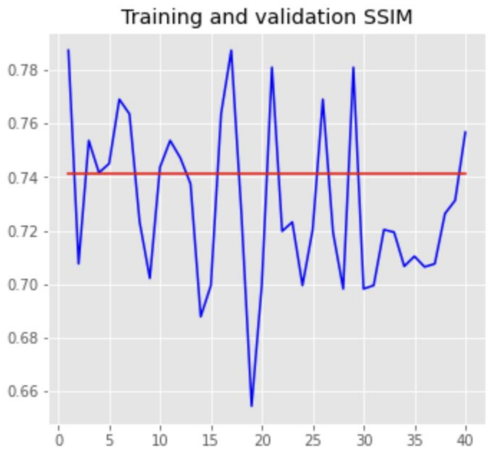
Methodology

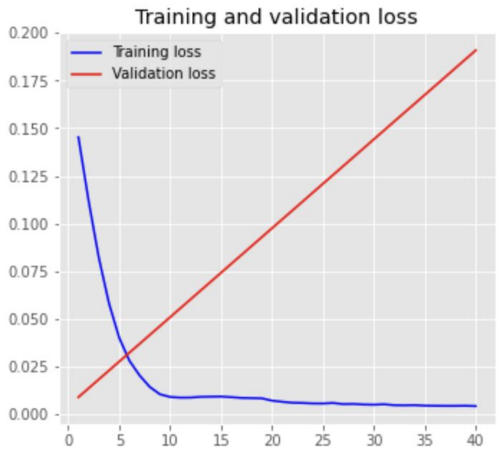
3. Timelapse prediction with Convolutional LSTMs





4. Timelapse prediction with ODE2VAE





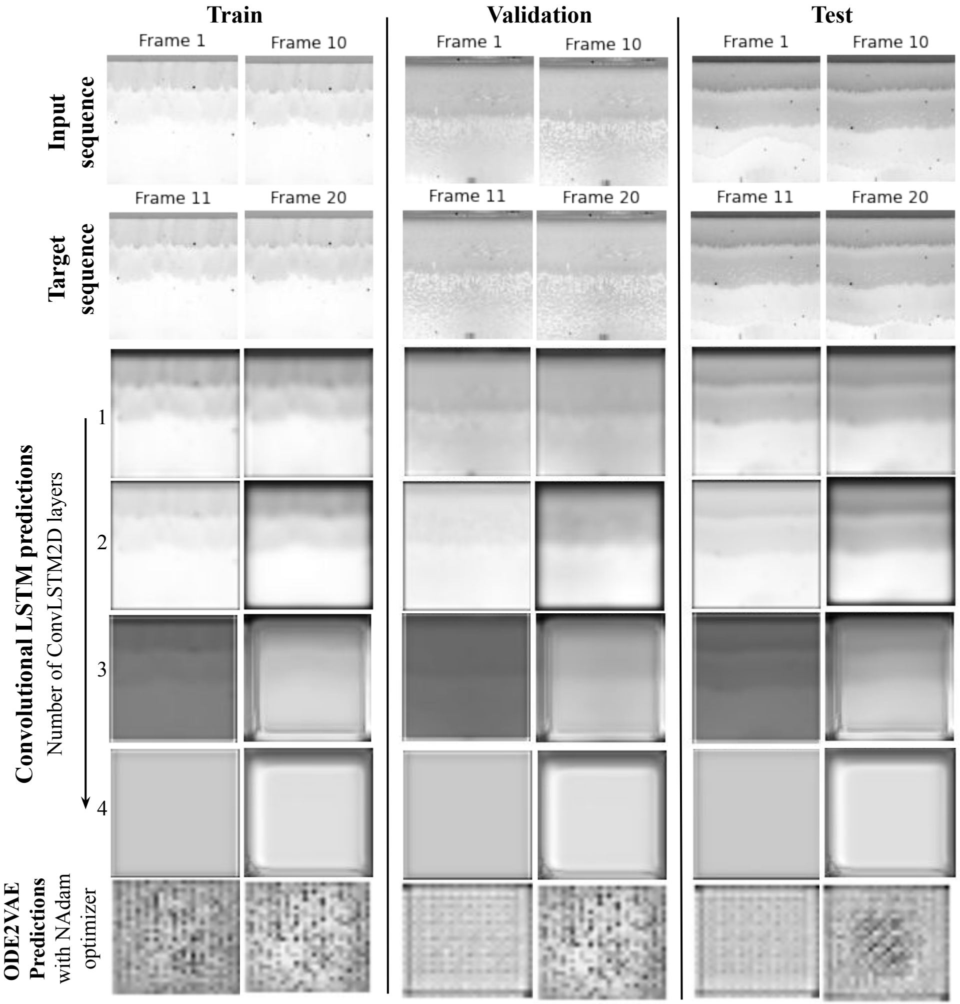
Findings

On 20 frames sub-timelapses **the baseline Convolutional LSTM model** produced the most accurate frames.

Convolutional LSTM approach: **number of ConvLSTM2D layers**	**Optimal epoch**	**MSE loss**	**SSIM index**
1	39	7.538e-4	0.9924
2	5	2.780e-2	0.8633
3	23	1.770e-2	0.8615
4	17	5.602e-3	0.8651
ODE2VAE approach: **optimizers**			
Adam	40	4.153e-3	0.6543
AdaDelta	29	4.131e-2	0.7470
NAdam	40	4.201e-3	0.7482

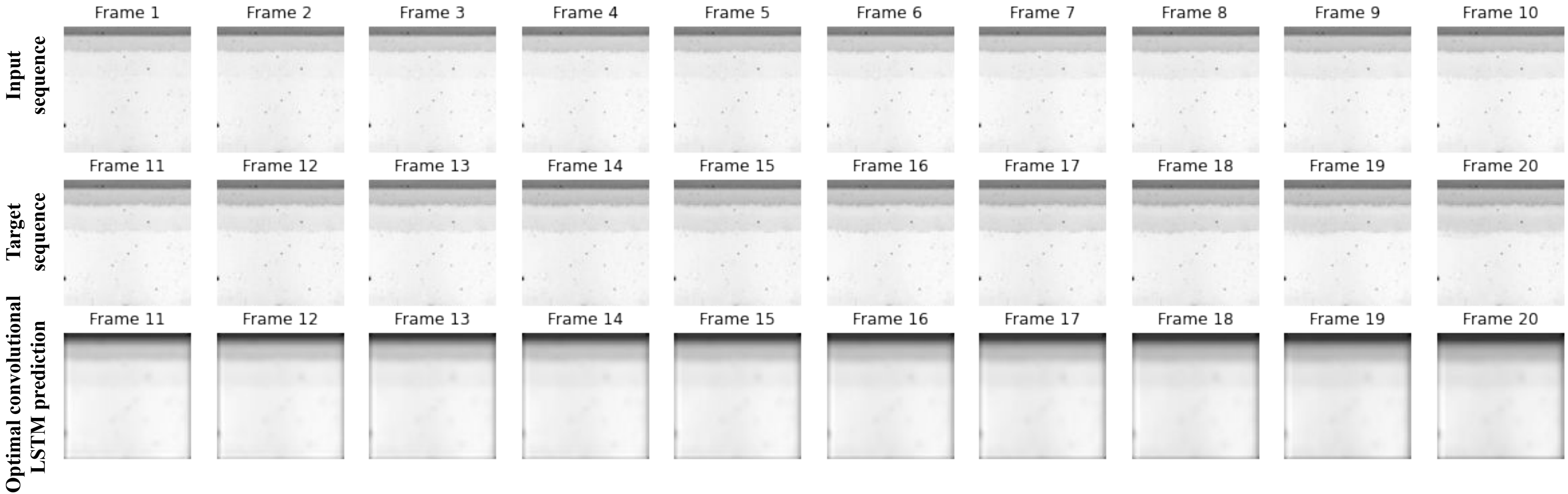
Findings

- Predicted frame quality was compromised for frames further away from the input.
- Visual quality of predicted frames did not significantly vary between training, validation, and testing timelapses.



Findings

On a new dataset compiled from 42 timelapses the baseline model achieved an MSE loss of **9.498e-4** and an SSIM index of **0.9528**.



Conclusions

- For prediction of future frames in a timelapse showing the growing bacterial colony, two models were implemented:
    - A convolutional long short-term memory (LSTM) network
    - An ODE2VAE model

- Training, validation, and testing with a dataset containing a small set of frames proved that the convolutional LSTM with one 2D layer was the most suited for our data.
    - MSE loss = 7.538e-4
    - SSIM index = 0.9924

Acknowledgements

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