

Evaluating the Applicability of Transfer Learning for Deep Learning Based Segmentation of Microscope Images

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University of Konstanz

What was the Title Again?

Evaluating the Applicability of Transfer Learning for Deep Learning Based Segmentation of Microscope Images

Evaluating the Applicability of Transfer Learning for Deep Learning Based Segmentation of **Microscope Images**

Microscopy

“Microscopy [...] has served as a fundamental scientific technique for centuries. [...]. It **remains an invaluable tool in biology and healthcare** and has been integrated increasingly into modern chemical instrumentation. [emphasis added]”¹

¹Bell and Morris, *An Introduction to Microscopy*.

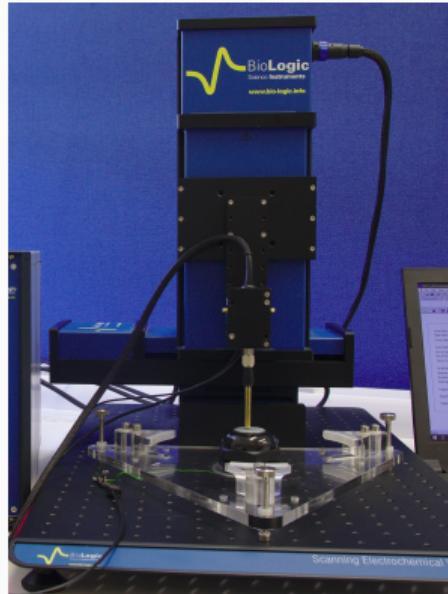
Microscope Images



(a) Light microscope
Image by Masur [CC BY-SA 3.0
(<https://creativecommons.org/licenses/by-sa/3.0/>)]



(b) Electron microscope
Image by Akademie věd České republiky / Czech Academy of Science [CC BY-SA 3.0 cz
(<https://creativecommons.org/licenses/by-sa/3.0/cz/deed.en>)]



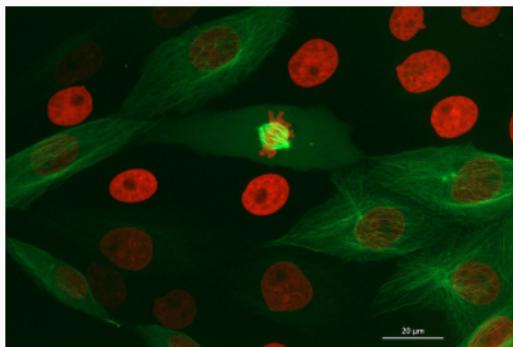
(c) Scanning-probe microscope
Image by Sraisac [CC BY-SA 4.0
(<https://creativecommons.org/licenses/by-sa/4.0/>)] (cropped)

Microscope Images



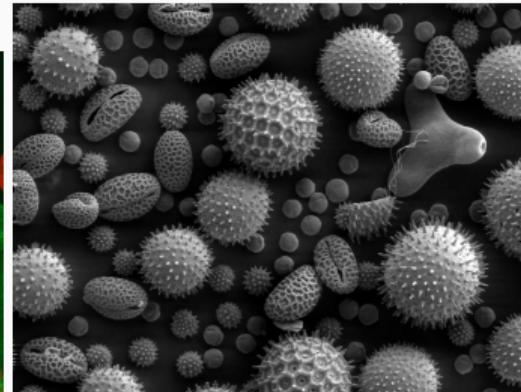
(a) Bright field microscopy image

Image by Medmyco at English Wikipedia [CC0]



(b) Fluorescence microscopy image

Image by ZEISS Microscopy from Germany [CC BY 2.0]
(<https://creativecommons.org/licenses/by/2.0/>)



(c) Electron microscopy image

Image by Dartmouth College Electron Microscope Facility
[Public domain]

Evaluating the Applicability of Transfer Learning for Deep Learning Based **Segmentation** of Microscope Images

Segmentation



Figure 3: Semantic segmentation and instance segmentation of kittens.

Image by "axelle b" [CC0]

Evaluating the Applicability of Transfer Learning for Deep Learning Based Segmentation of Microscope Images

Evaluating the Applicability of Transfer Learning for Deep Learning Based Segmentation of Microscope Images

U-Net

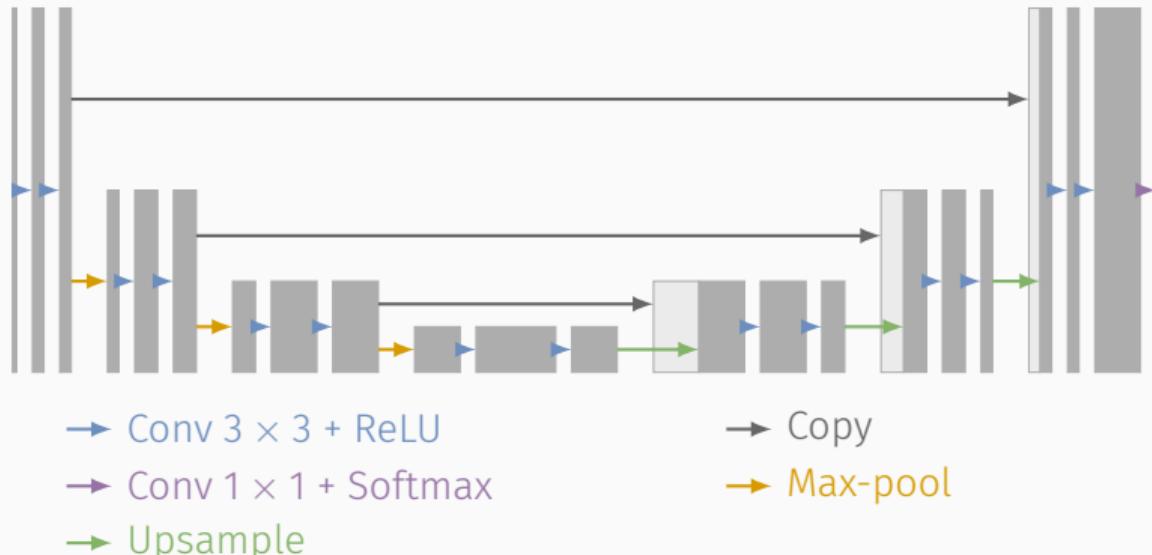


Figure 4: U-Net² architecture.

²Ronneberger, Fischer, and Brox, “U-Net: Convolutional Networks for Biomedical Image Segmentation”.

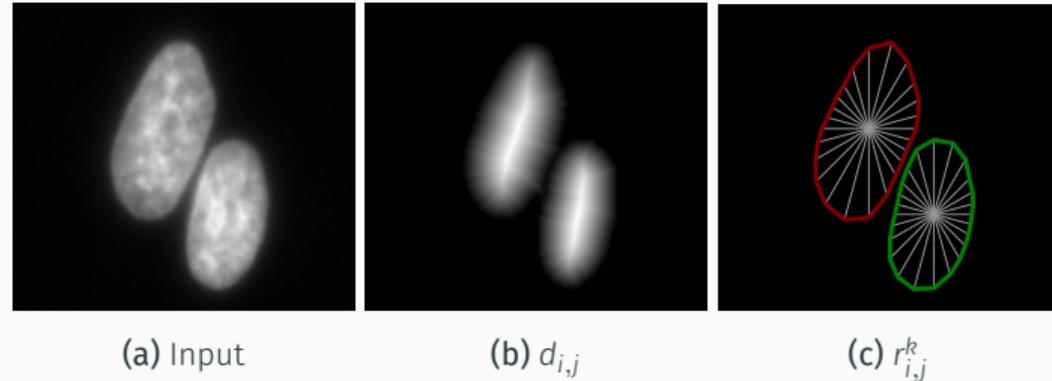


Figure 5: Input and outputs of a StarDist³ model.

³Schmidt et al., “Cell Detection with Star-Convex Polygons”.

Advantages:

- No merging of touching objects
- No suppression of crowded object
- Relatively few parameters

Res-U-Net

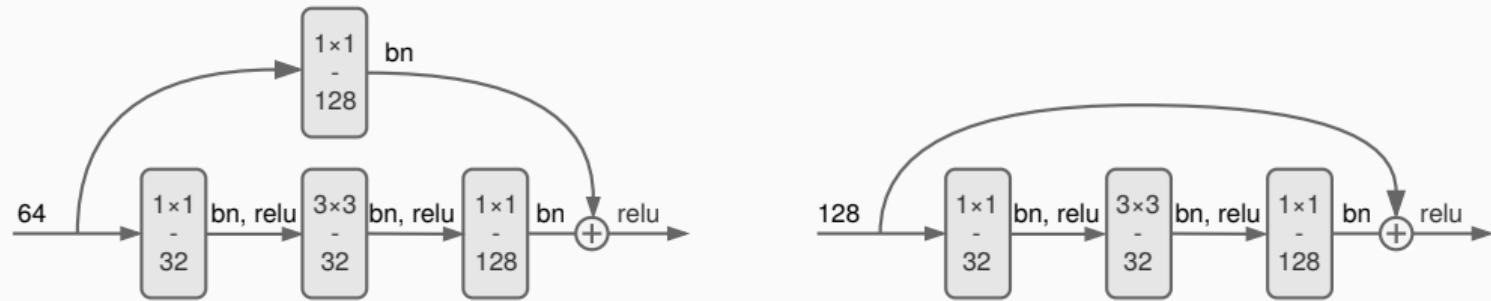


Figure 6: Residual building blocks⁴ of the Res-U-Net.

⁴He et al., “Deep Residual Learning for Image Recognition”.

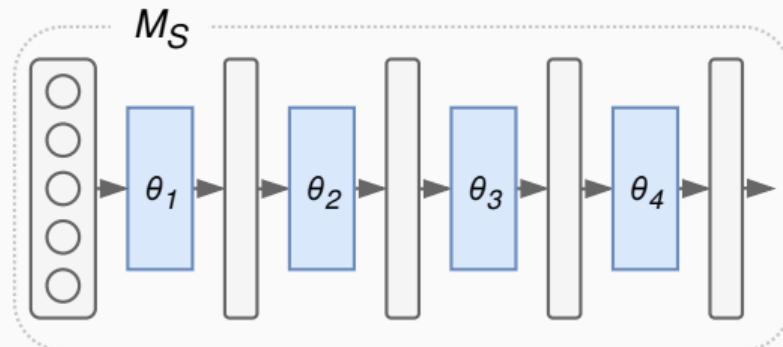
Evaluating the Applicability of **Transfer Learning** for Deep Learning Based Segmentation of Microscope Images

Transfer Learning

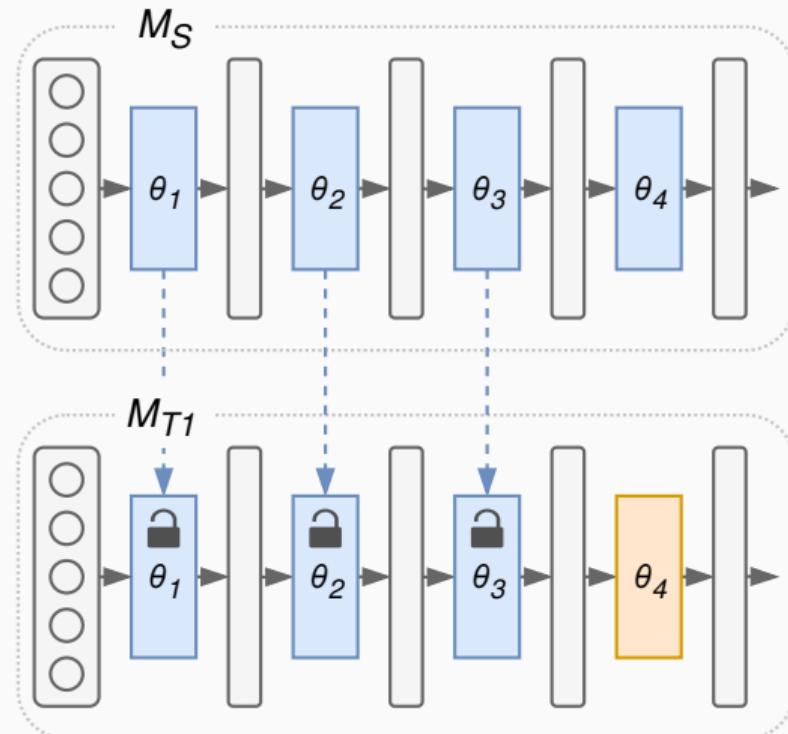
Transfer learning means adapting knowledge from one task to another task



Deep Transfer Learning

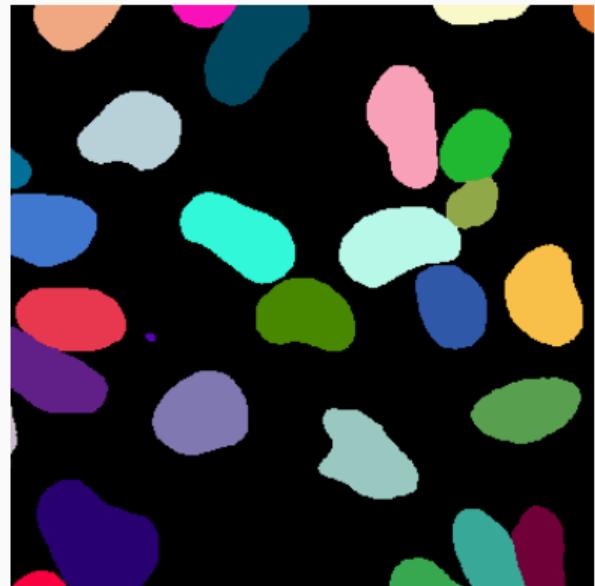
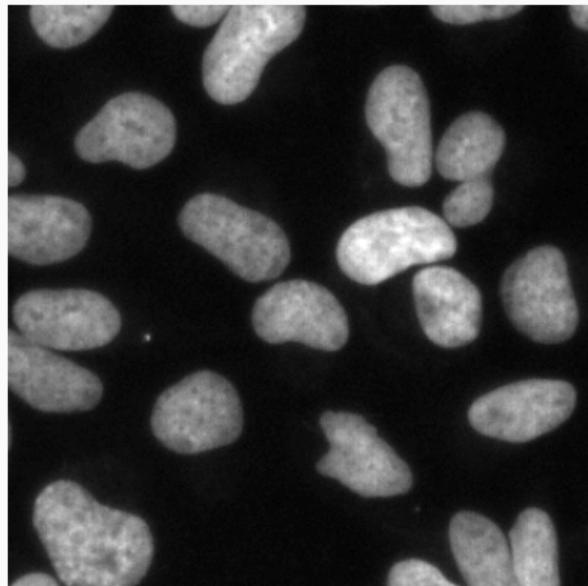


Deep Transfer Learning

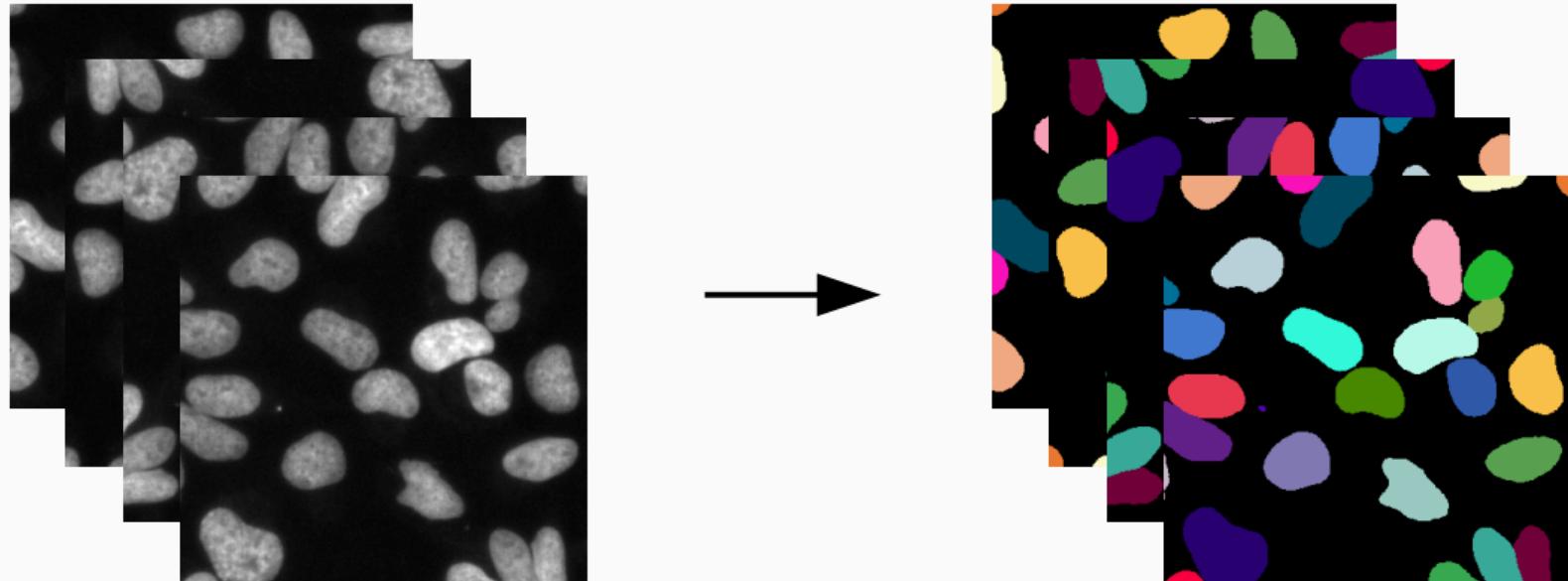


Motivation

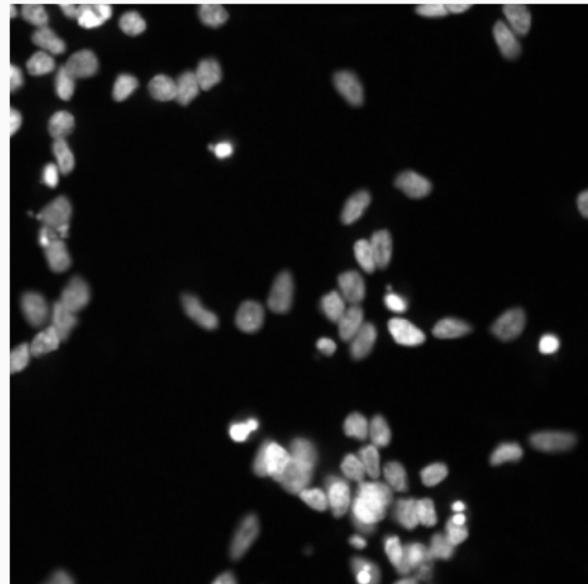
Motivation



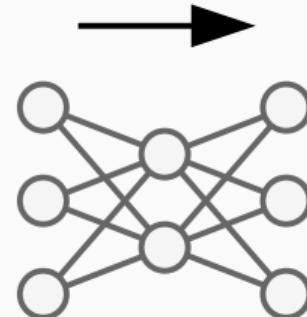
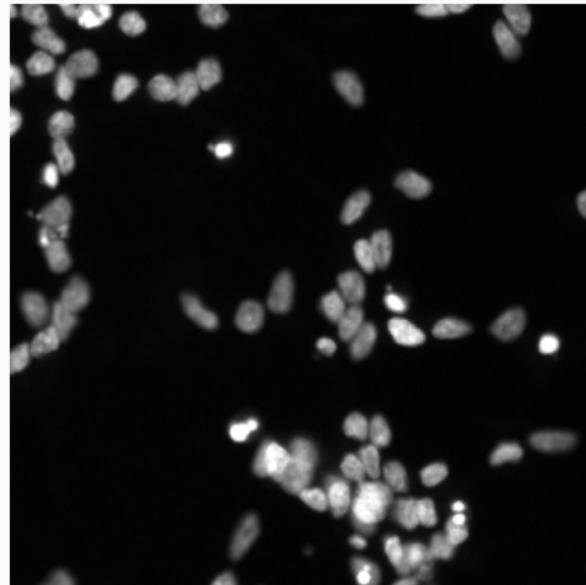
Motivation



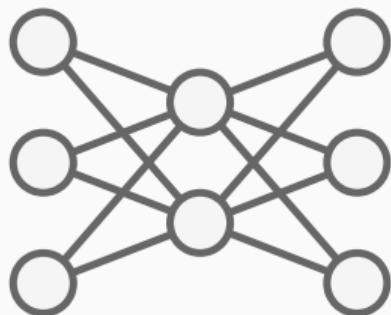
Motivation



Motivation



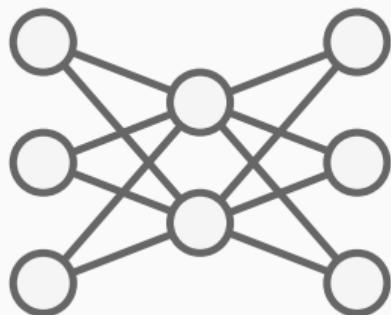
Motivation



Drawbacks

- Require many labeled training images
- Require an expert to train and apply

Motivation



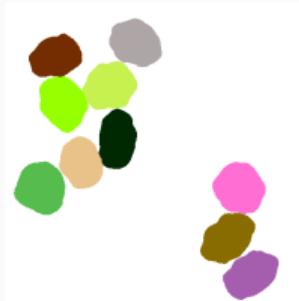
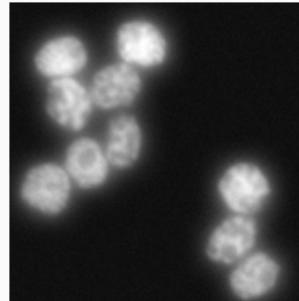
Drawbacks

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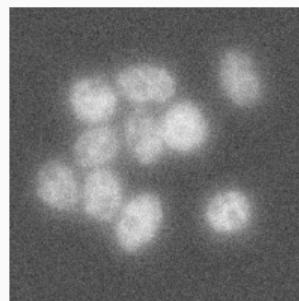
Evaluate Transfer Learning

Experiment: Different Noise Levels

- Imaging conditions change
- Same content but different images
- Transfer knowledge of previous model to reduce training images and training time

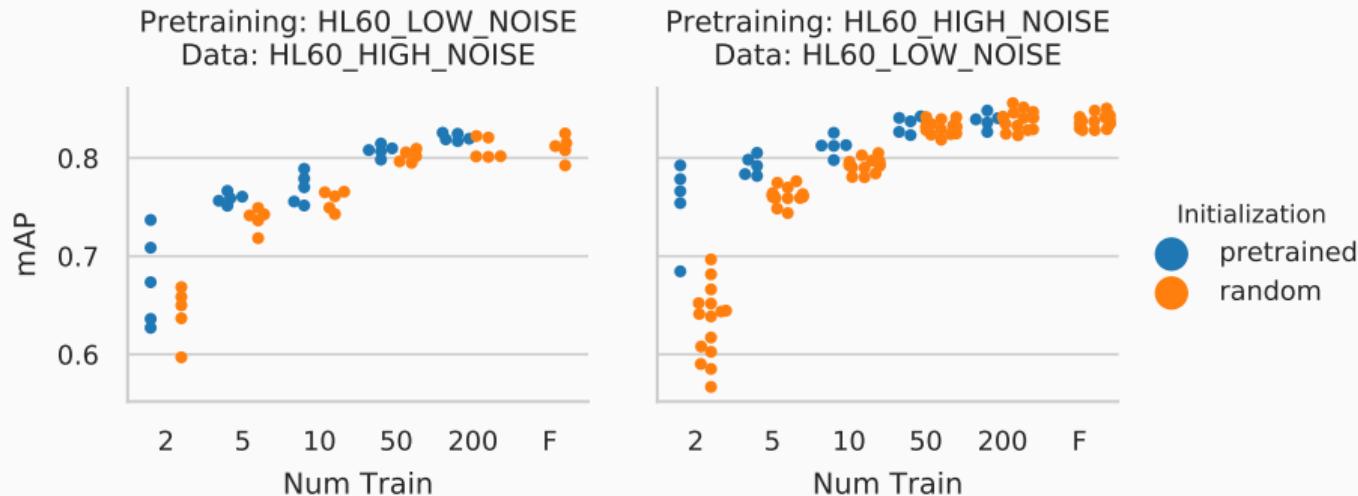


(a) HL60_LOW_NOISE

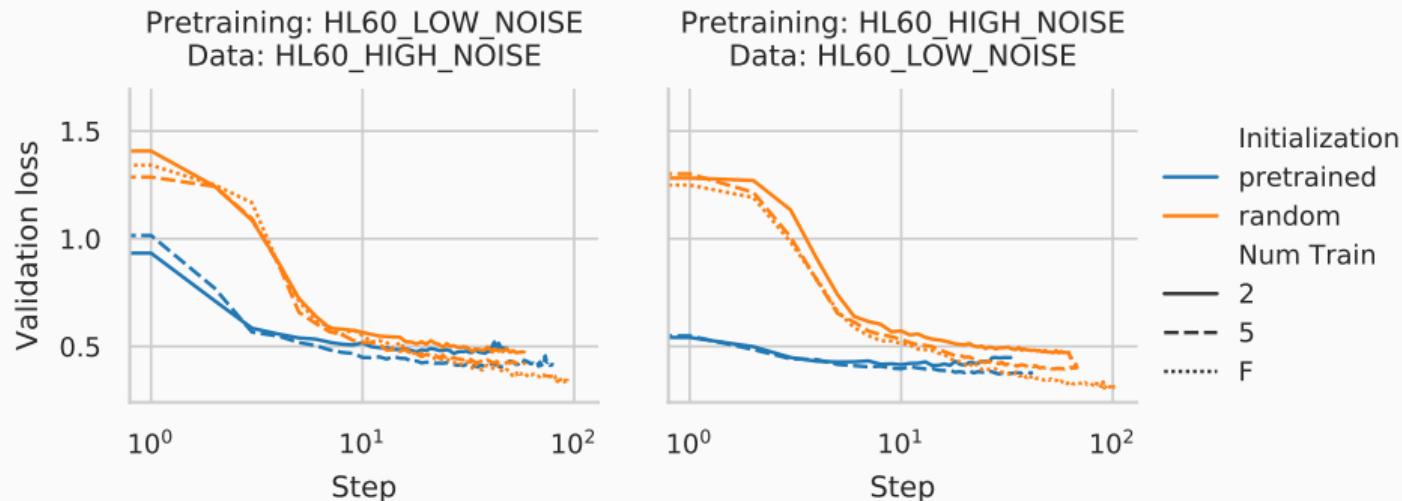


(b) HL60_HIGH_NOISE

Experiment: Different Noise Levels

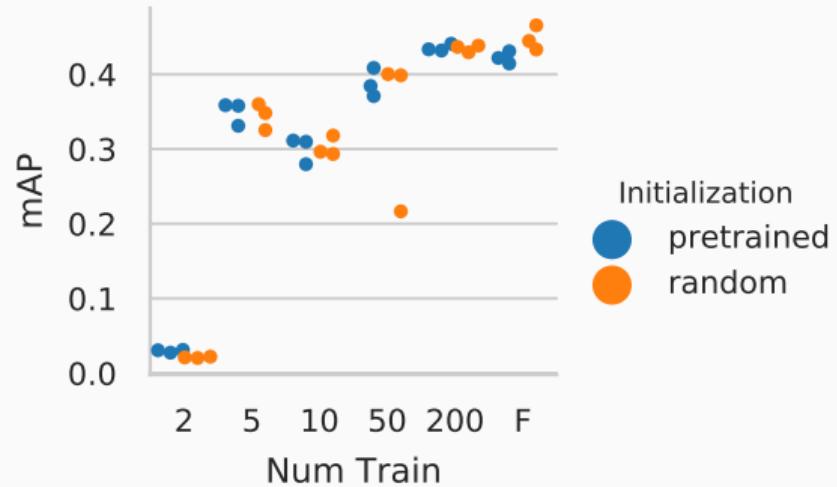
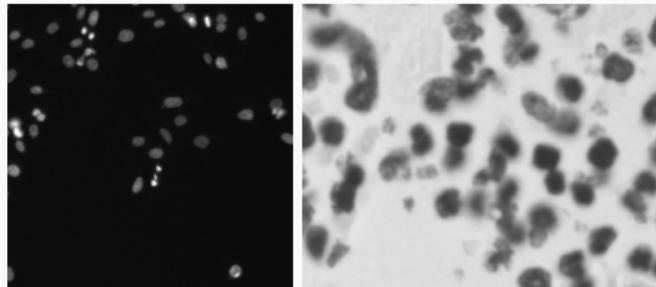


Experiment: Different Noise Levels



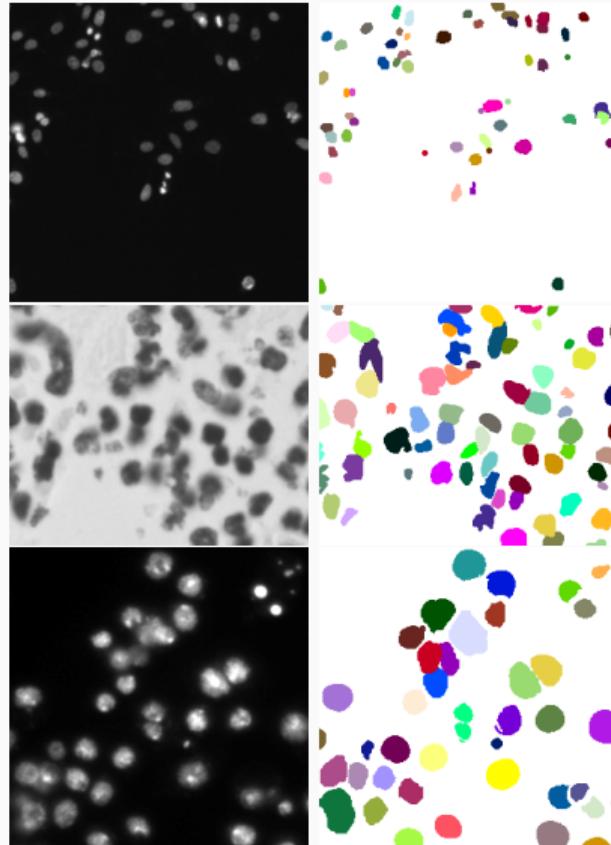
Experiment: Natural Images

- ResNet encoder pretrained on ImageNet
- Used for many models
- Train on DSB2018

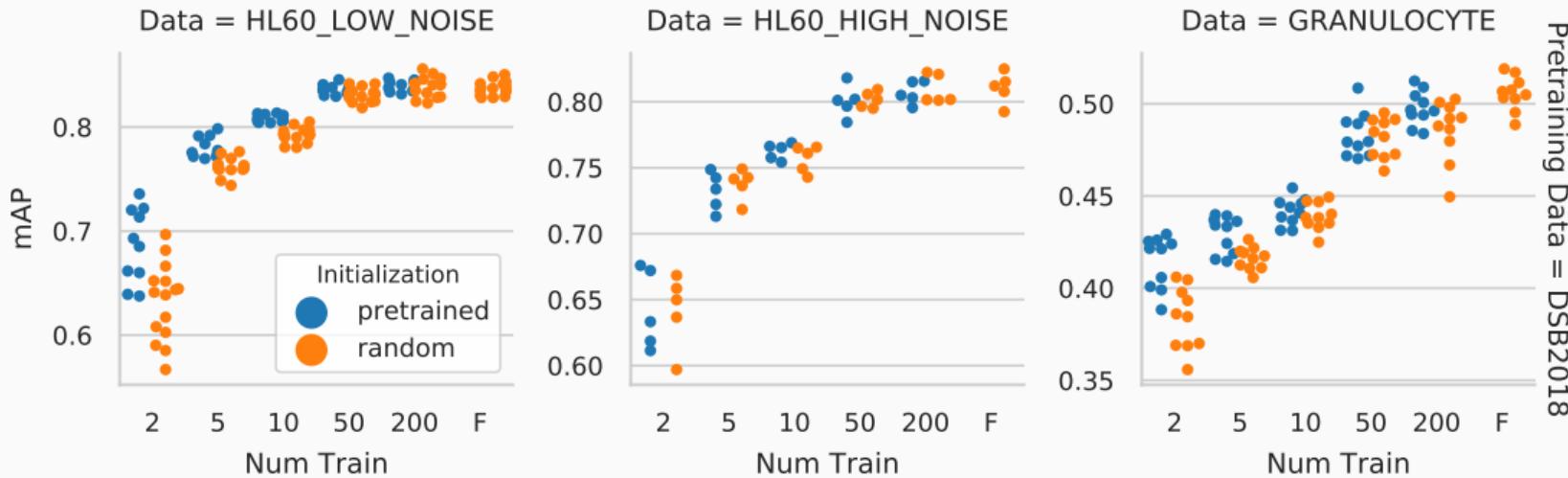


Experiment: Pretraining on DSB2018

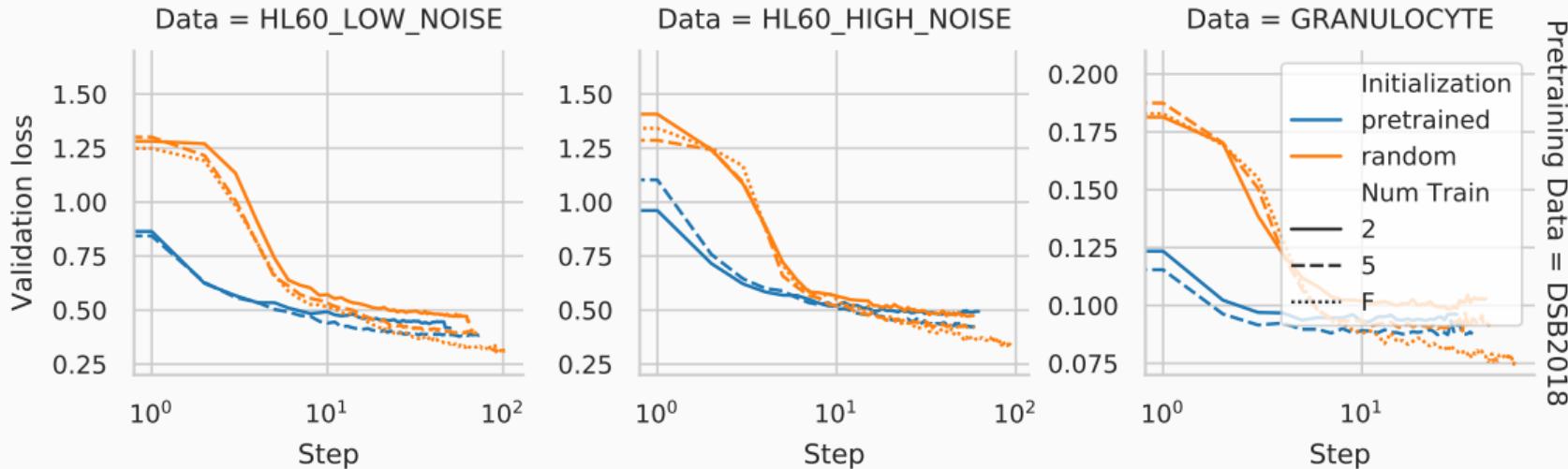
- Finding a good pretraining dataset:
DSB2018
- Fluorescence and bright-field
microscopy
- Different conditions
- Diverse and relatively big
→ Good for pretraining



Experiment: Pretraining on DSB2018

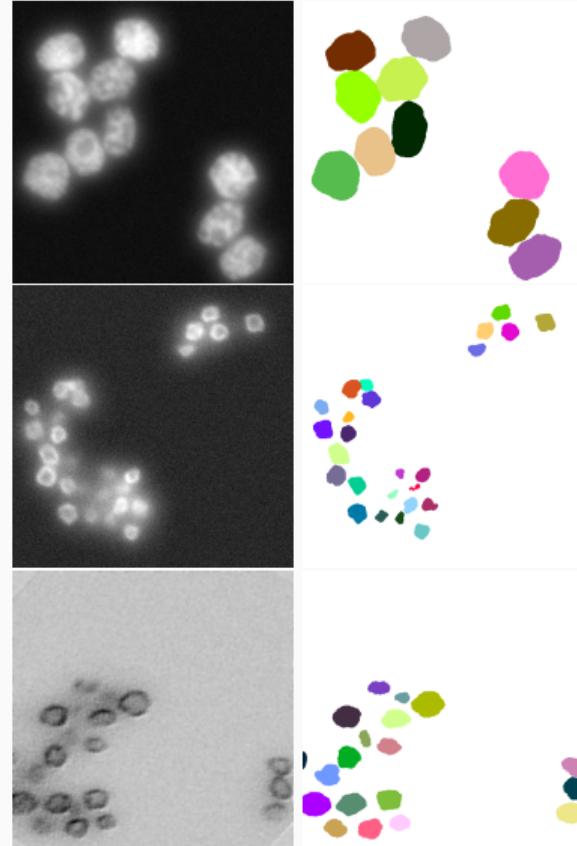


Experiment: Pretraining on DSB2018

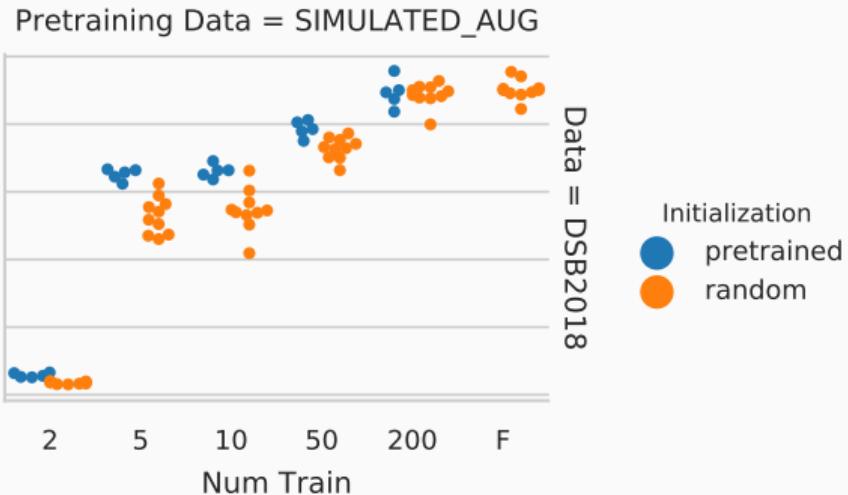
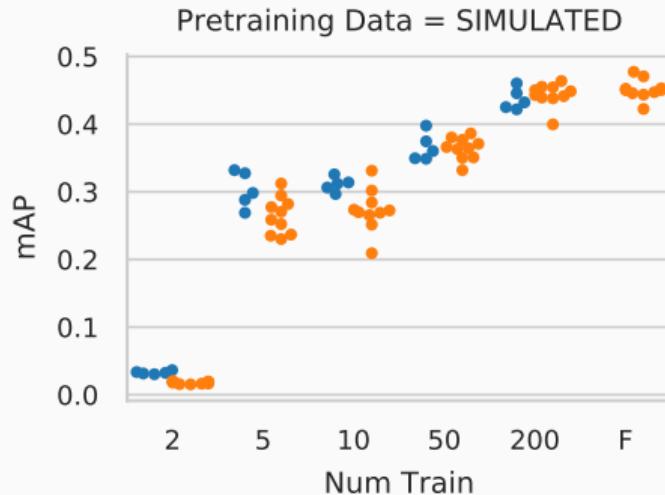


Experiment: Combining Simulated Datasets for Pretraining

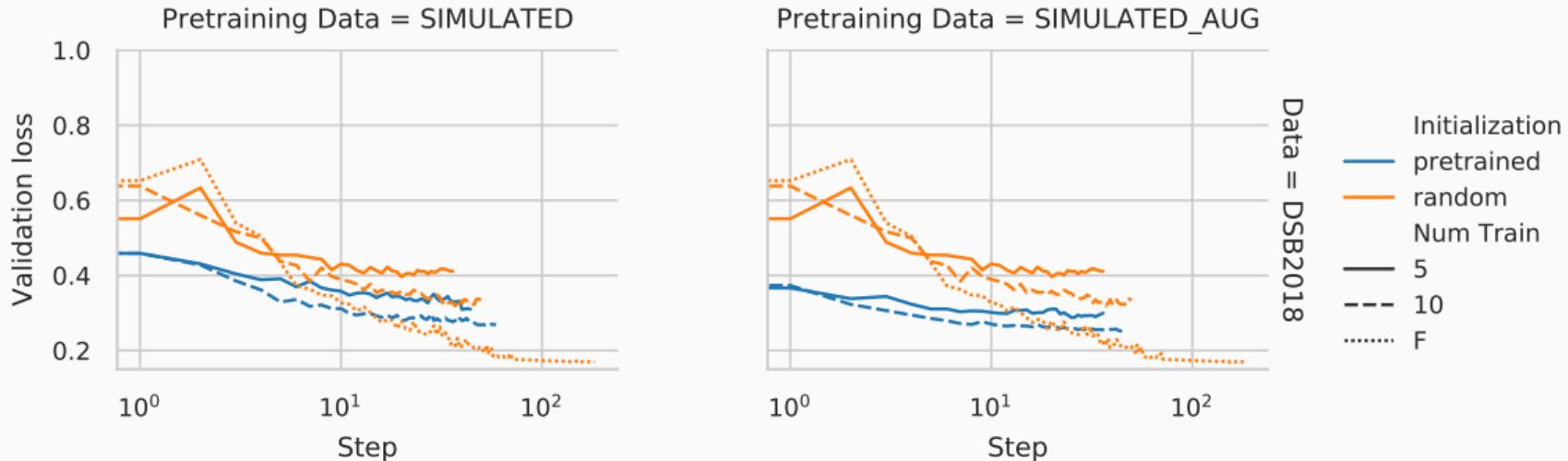
- Use simulated data
- Can generate tons of images
- Different simulators to increase diversity
- Data augmentation to increase diversity



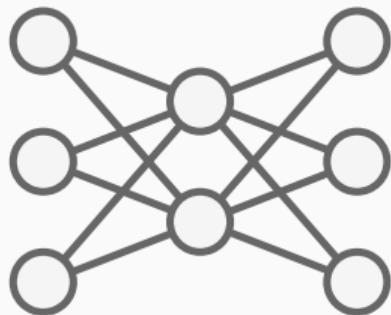
Experiment: Combining Simulated Datasets for Pretraining



Experiment: Combining Simulated Datasets for Pretraining



Motivation



Drawbacks

- Require many labeled training images
- Require an expert to train and apply

KNIME Implementation for Simplified Usage

KNIME Analytics Platform

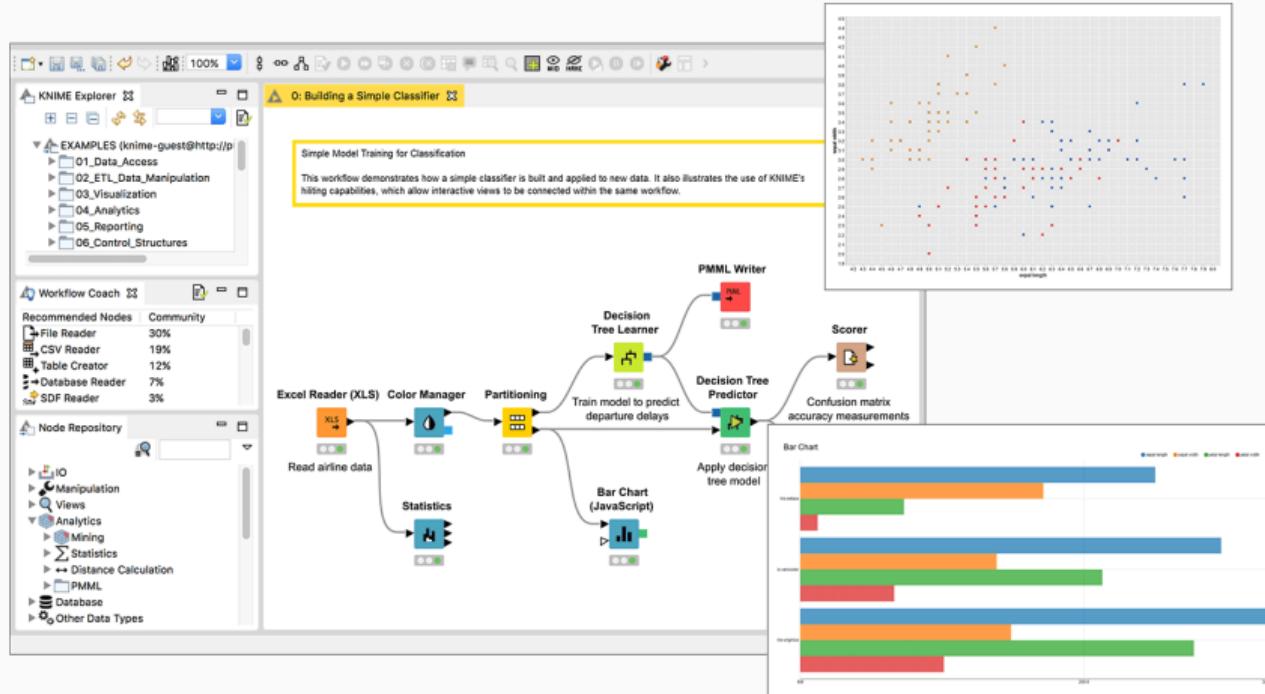
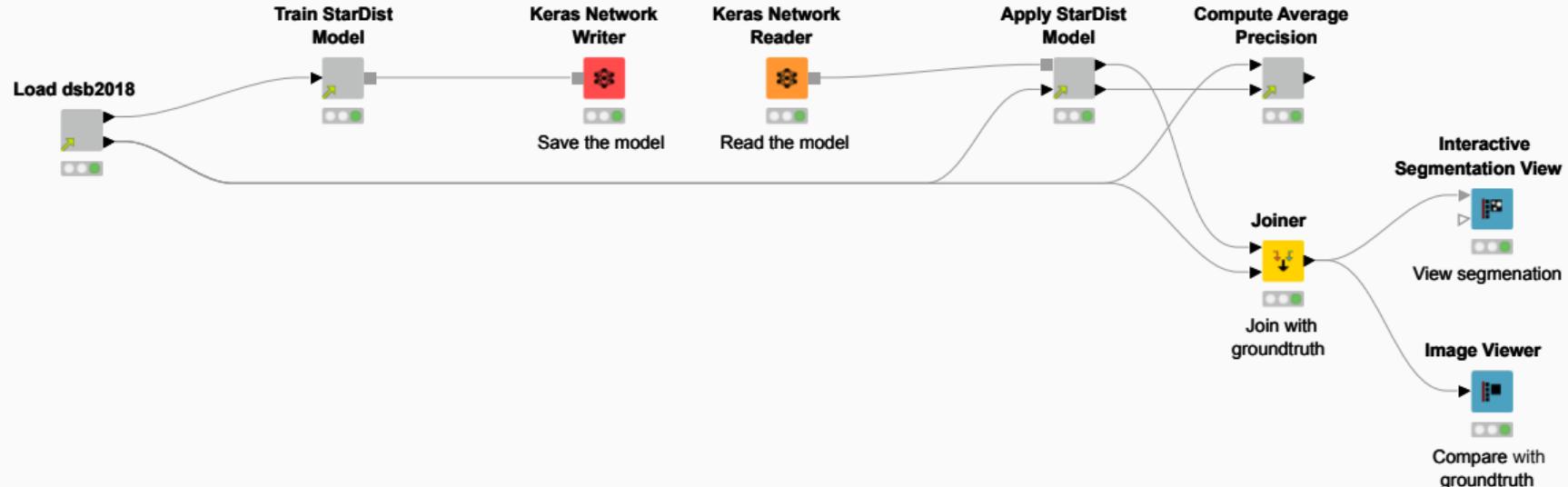


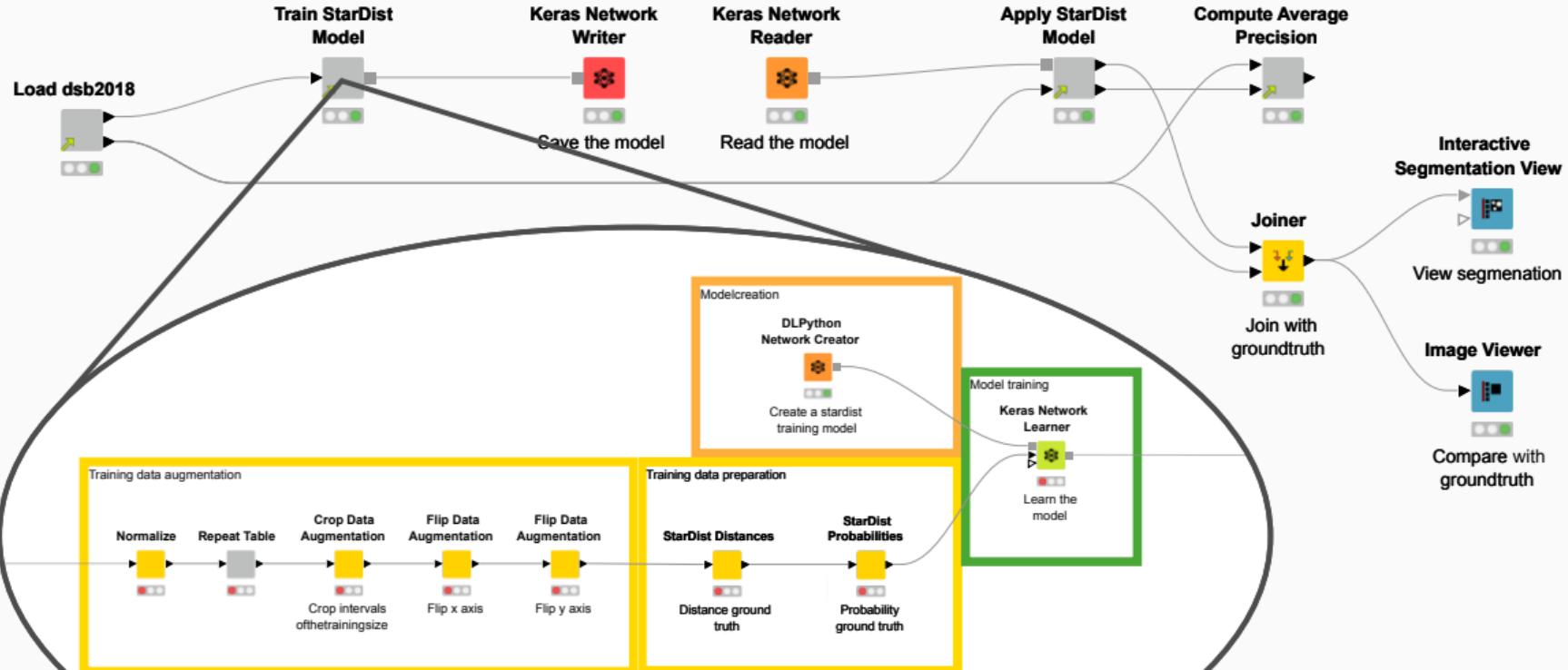
Figure 10: KNIME Analytics Platform

Image from <https://www.knime.com/knime-analytics-platform>

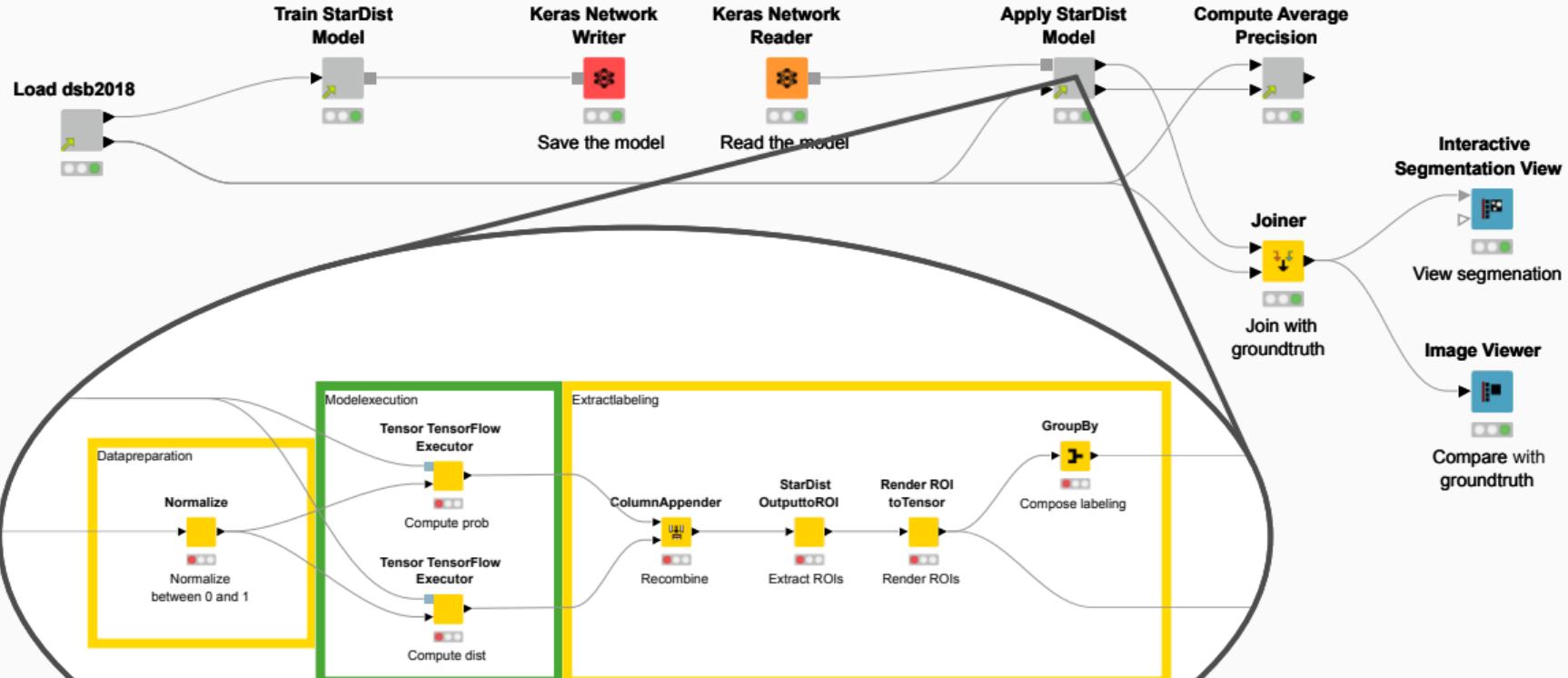
StarDist Workflow KNIME Workflow



StarDist Workflow KNIME Workflow



StarDist Workflow KNIME Workflow

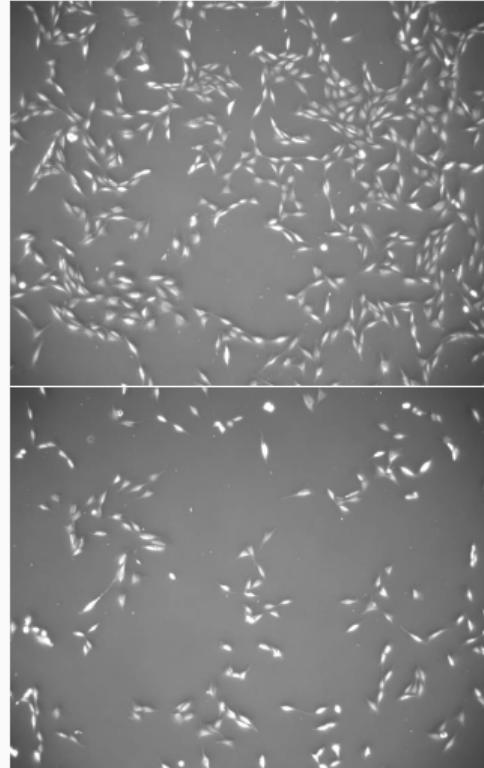


KNIME Components

Loading data		Training models			
Generate Toy Example	Load dsb2018	Train StarDist Model	Retrain StarDist Model	Train U-Net 2-class Model	Train U-Net 3-class Model
					
Evaluation		Applying models			
Read Pancreatic Cells Dataset	Compute Average Precision	Apply StarDist Model	Apply StarDist Model (DL Executor)	Apply U-Net 2-class Model	Apply U-Net 3-class Model
					

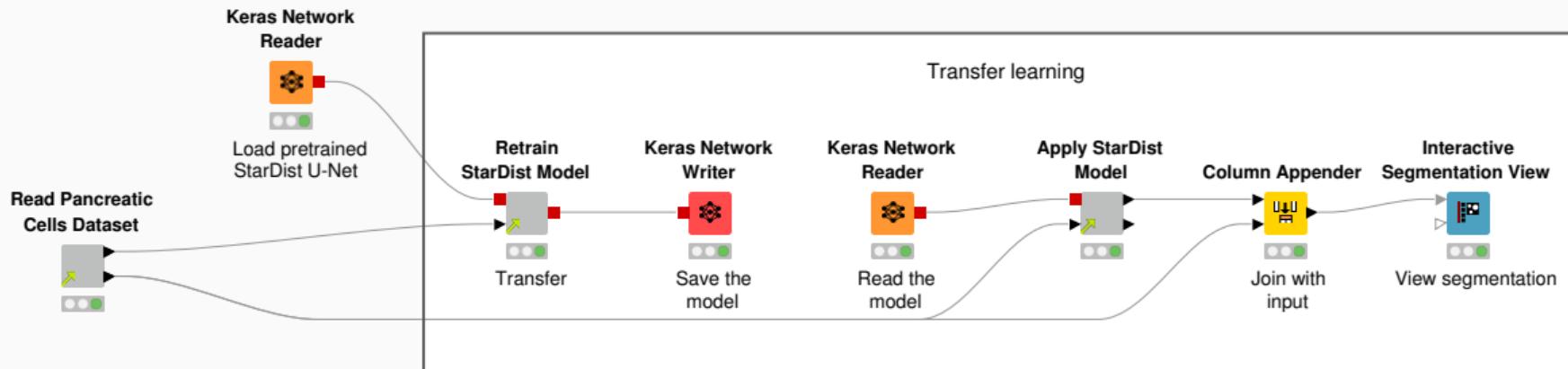
Retrain StarDist Application

- Dataset from the *celltrackingchallenge*⁵
- Phase contrast microscopy
- Only 4 segmented images
- Retrain StarDist model trained on
DSB2018

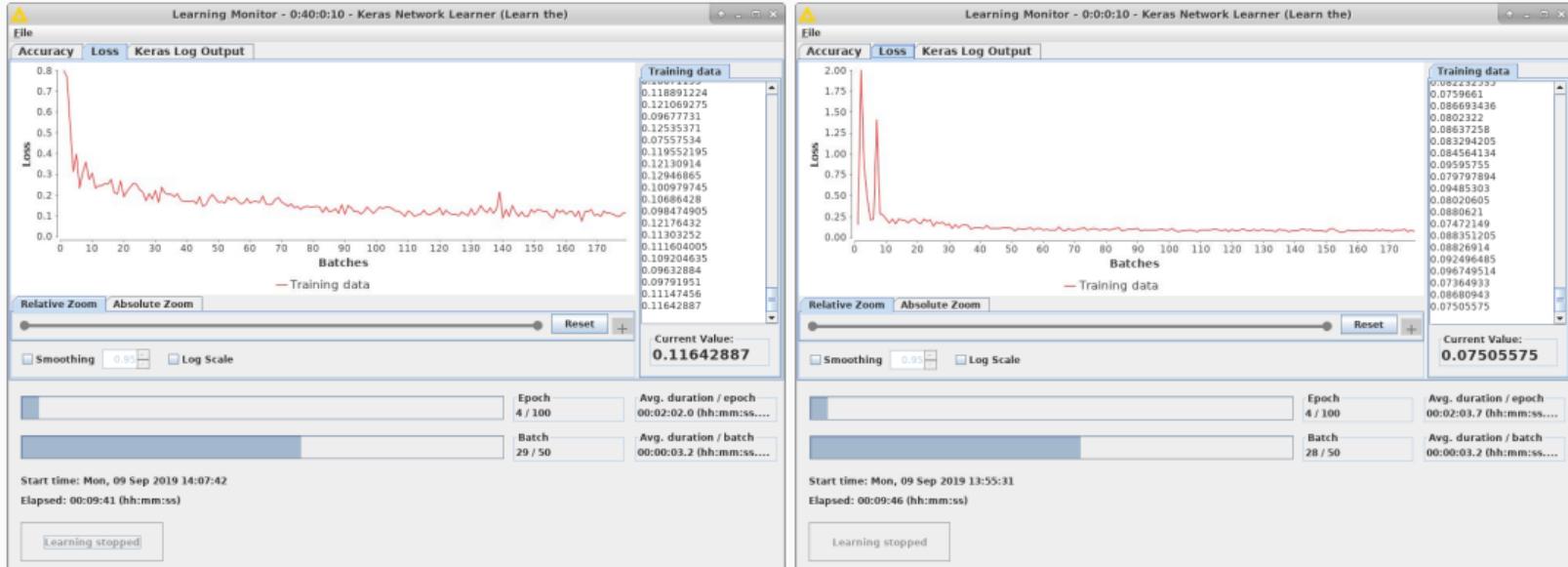


⁵<http://celltrackingchallenge.net/2d-datasets/>

Retrain StarDist Application



Retrain StarDist Application



Retrain StarDist Application

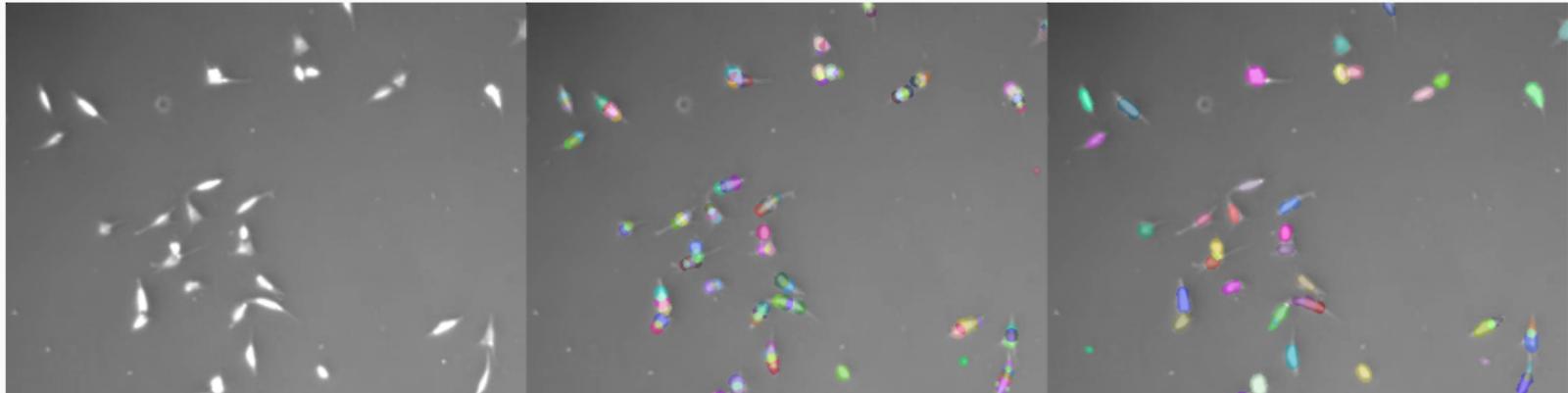


Figure 11: Results of a model with random initialization vs a pretrained model.

Conclusion

Conclusion

Transfer learning evaluation

- Can improve the model performance on small datasets
- Training time can be reduced
- Choice of the pretraining dataset is essential

Developed Framework

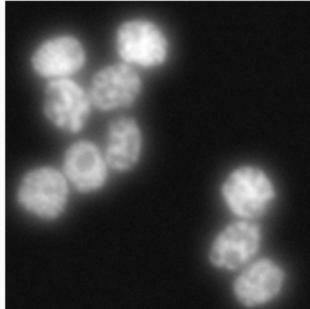
- Makes deep learning methods accessible
- Train, apply and retrain models
- Extensible

References i

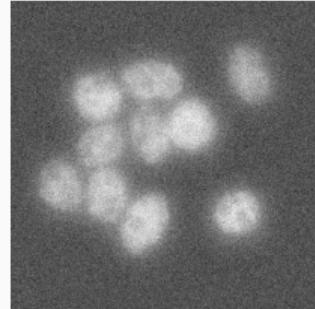
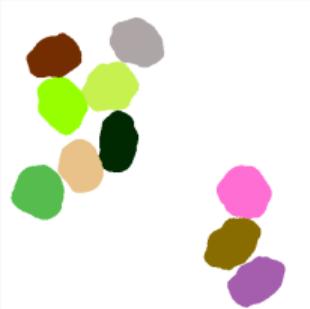
-  Bell, Suzanne and Keith Morris. *An Introduction to Microscopy*. CRC Press, Oct. 2009. doi: [10.1201/b15738](https://doi.org/10.1201/b15738). URL: <https://doi.org/10.1201/b15738>.
-  He, Kaiming et al. "Deep Residual Learning for Image Recognition". In: *2016 IEEE Conference on Computer Vision and Pattern Recognition (CVPR)*. IEEE, June 2016. doi: [10.1109/cvpr.2016.90](https://doi.org/10.1109/cvpr.2016.90). URL: <https://doi.org/10.1109/cvpr.2016.90>.
-  Ronneberger, Olaf, Philipp Fischer, and Thomas Brox. "U-Net: Convolutional Networks for Biomedical Image Segmentation". In: *Lecture Notes in Computer Science*. Springer International Publishing, 2015, pp. 234–241. doi: [10.1007/978-3-319-24574-4_28](https://doi.org/10.1007/978-3-319-24574-4_28). URL: https://doi.org/10.1007/978-3-319-24574-4_28.
-  Schmidt, Uwe et al. "Cell Detection with Star-Convex Polygons". In: *Medical Image Computing and Computer Assisted Intervention – MICCAI 2018*. Springer International Publishing, 2018, pp. 265–273. doi: [10.1007/978-3-030-00934-2_30](https://doi.org/10.1007/978-3-030-00934-2_30). URL: https://doi.org/10.1007/978-3-030-00934-2_30.

Questions?

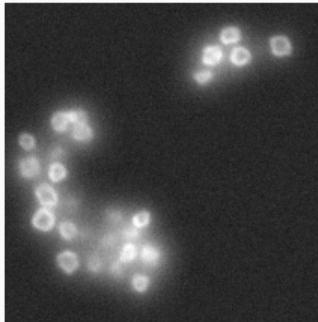
Datasets – Simulated Datasets



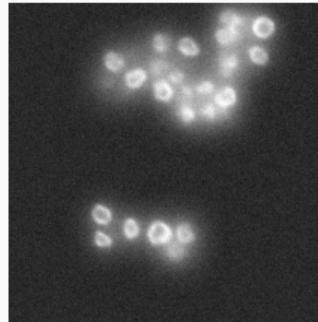
(a) HL60_LOW_NOISE



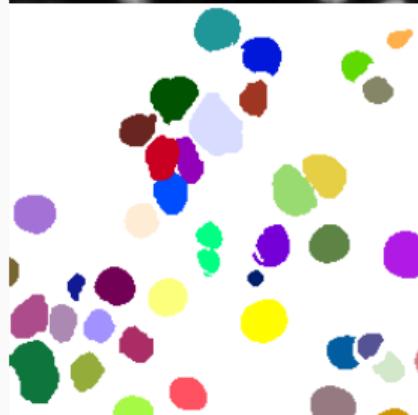
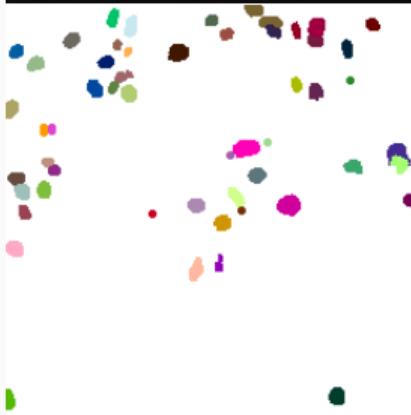
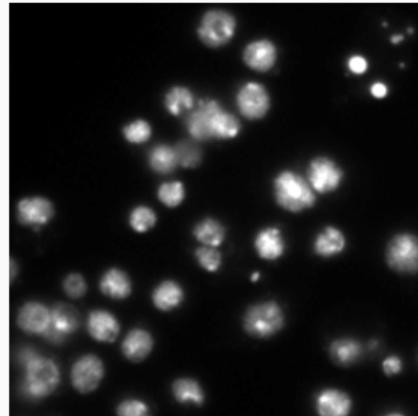
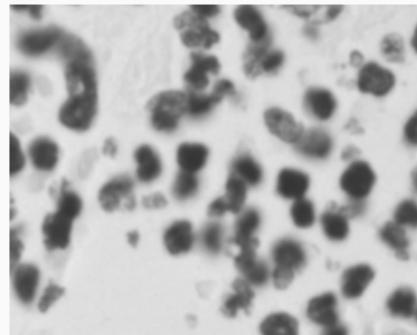
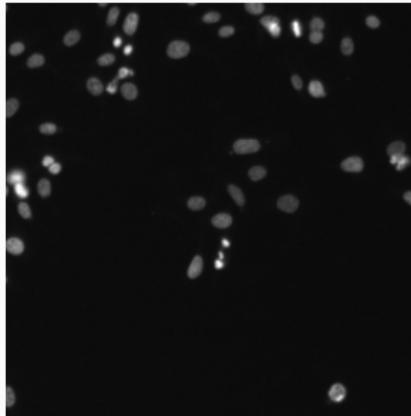
(b) HL60_HIGH_NOISE



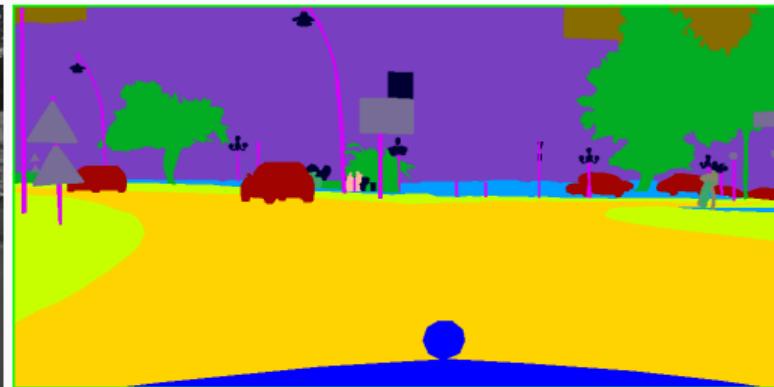
(c) GRANULOCYTE



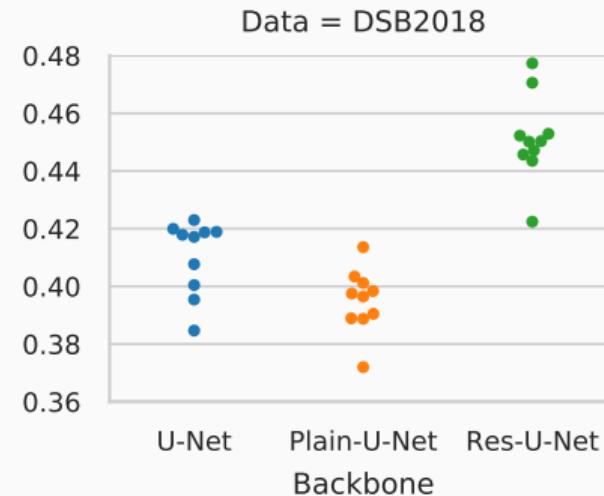
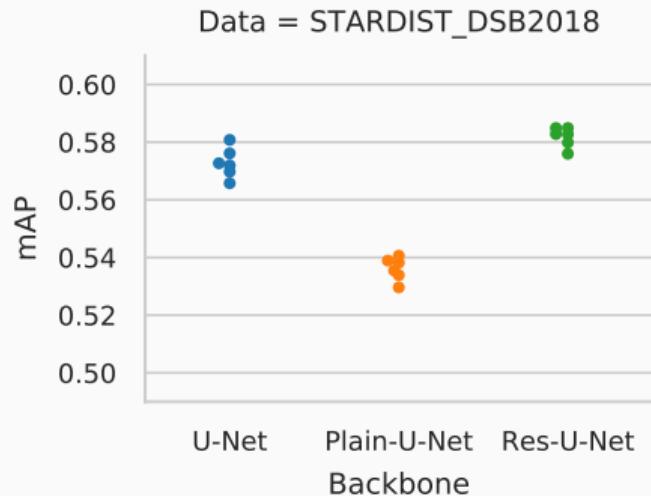
Datasets – DSB2018



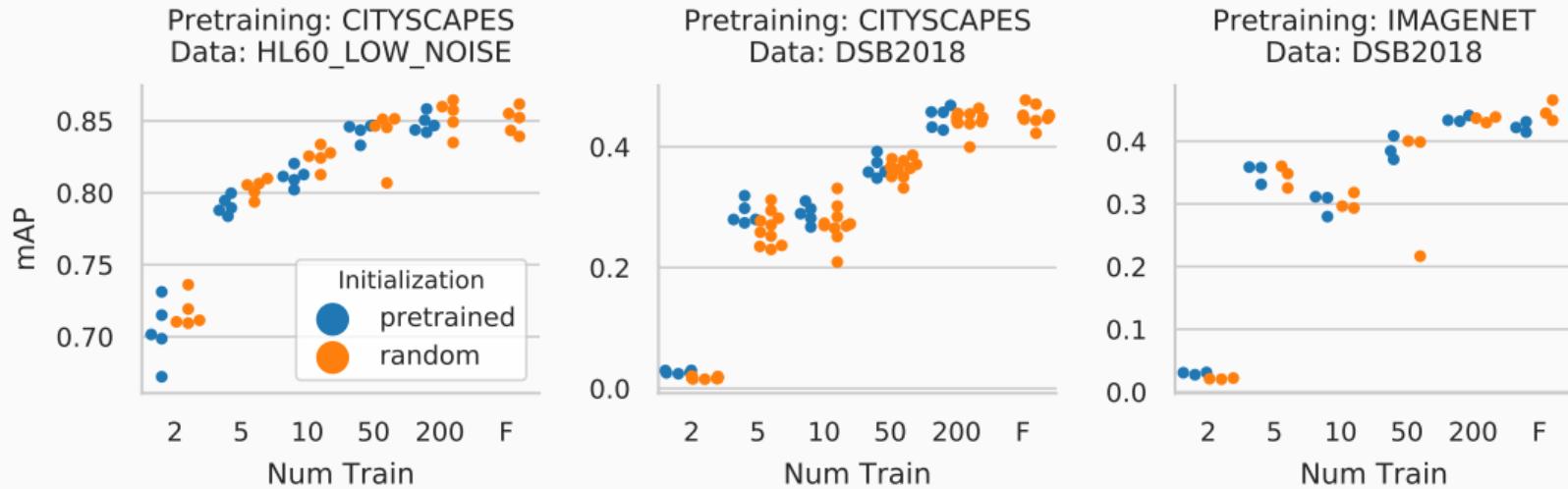
Datasets – CITYSCAPES



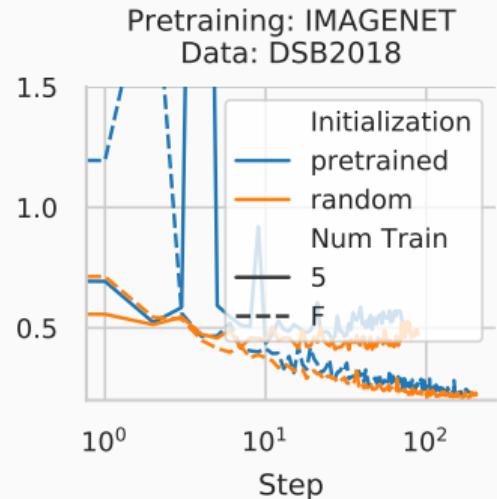
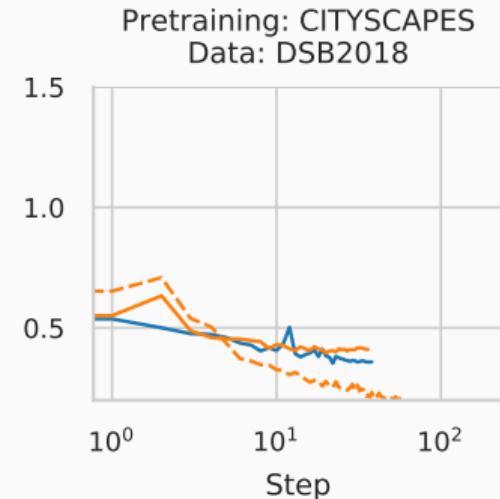
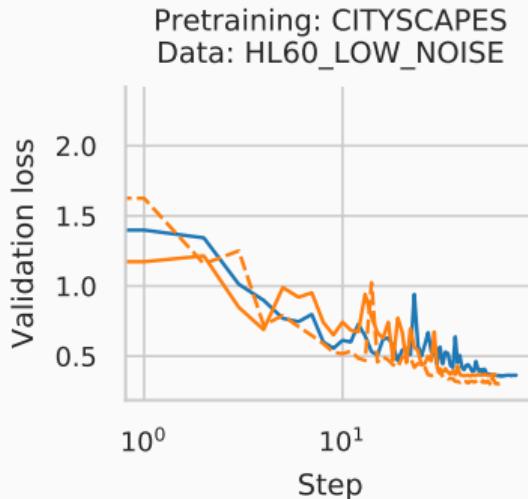
Experiment: StarDist with Res-U-Net Backbone



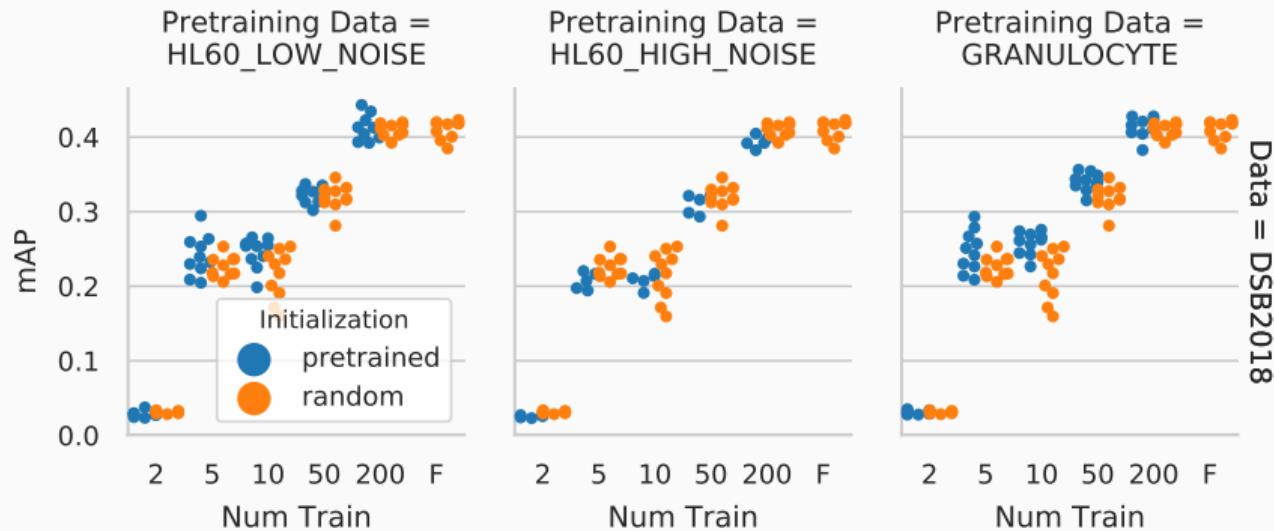
Experiment: Pretraining on Natural Images



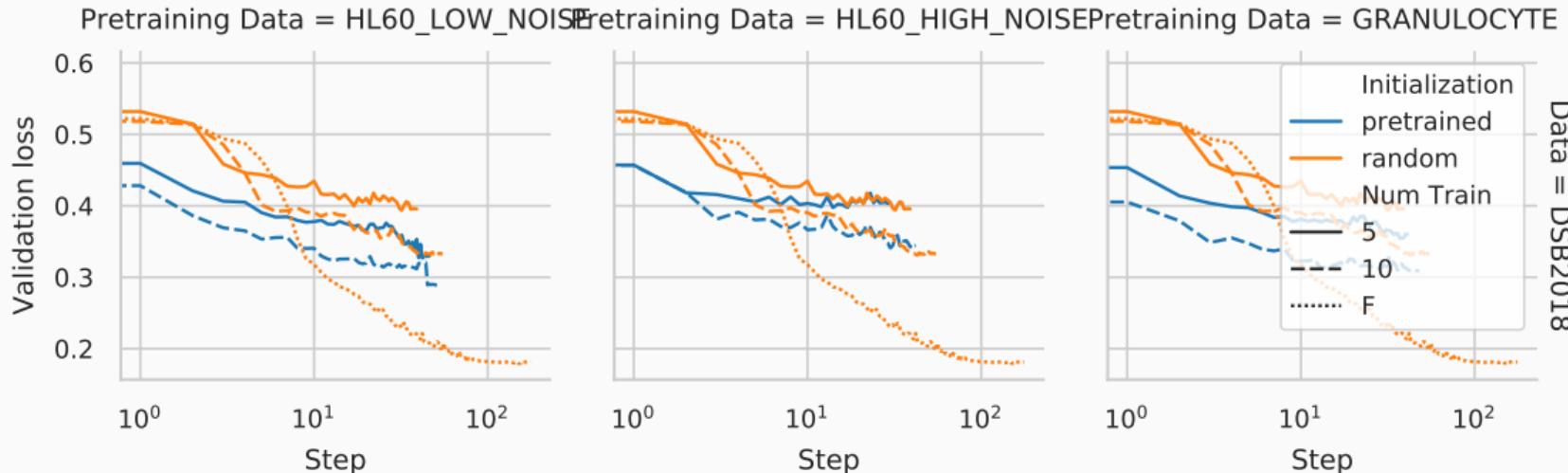
Experiment: Pretraining on Natural Images



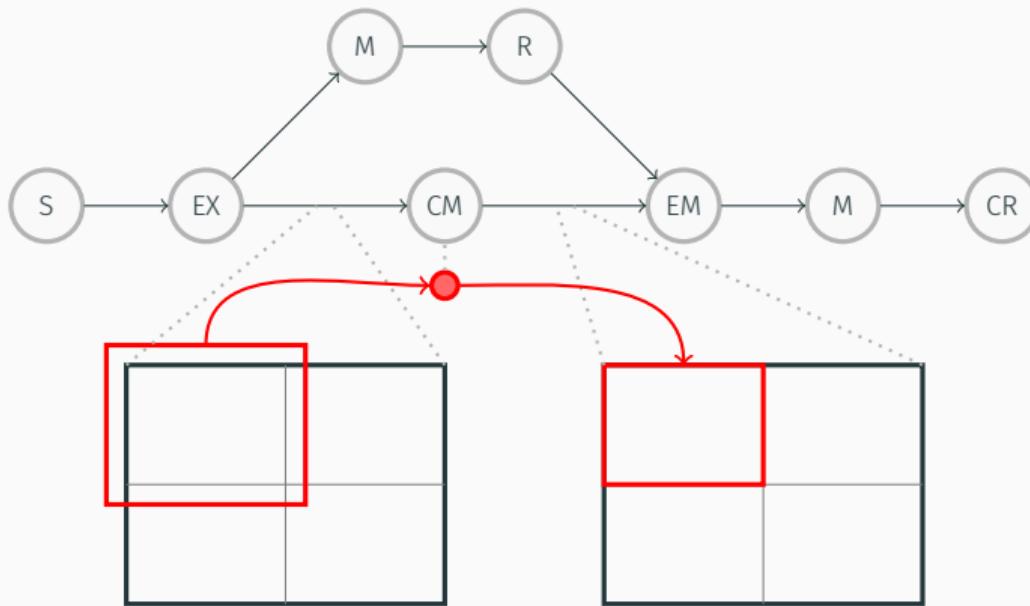
Experiment: Pretraining on Simulated Data



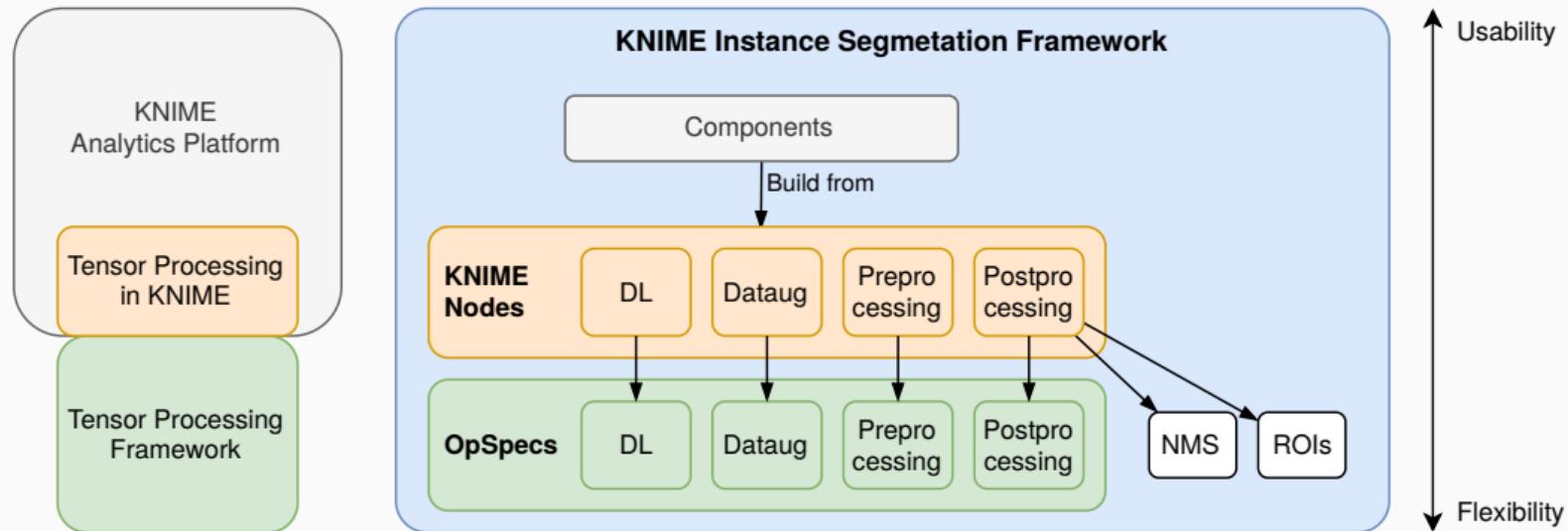
Experiment: Pretraining on Simulated Data



Tensor Processing Framework



KNIME Instance Segmentation Framework



KNIME Instance Segmentation Framework – Large Image Workflow

