Cell Cycle Classification using Imaging Flow Cytometry and Deep Learning

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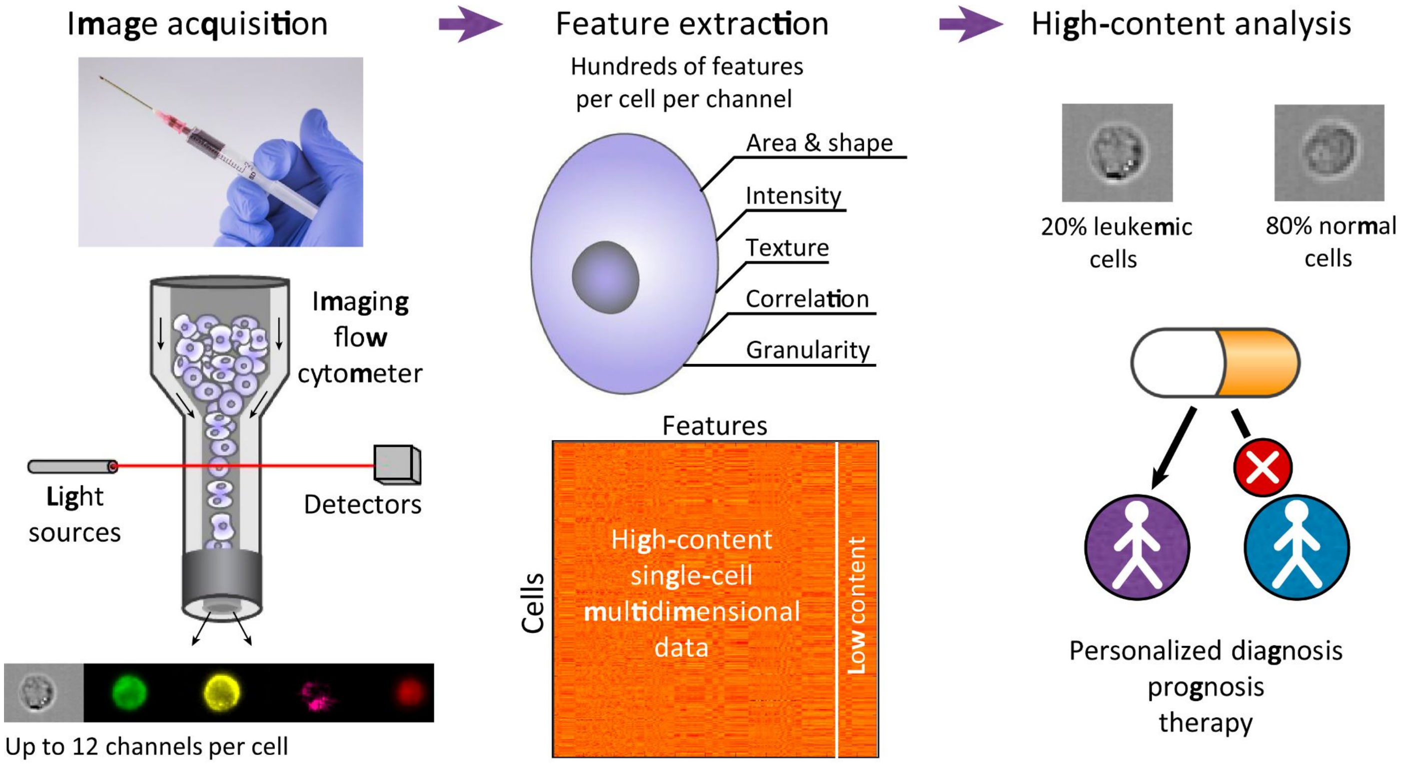
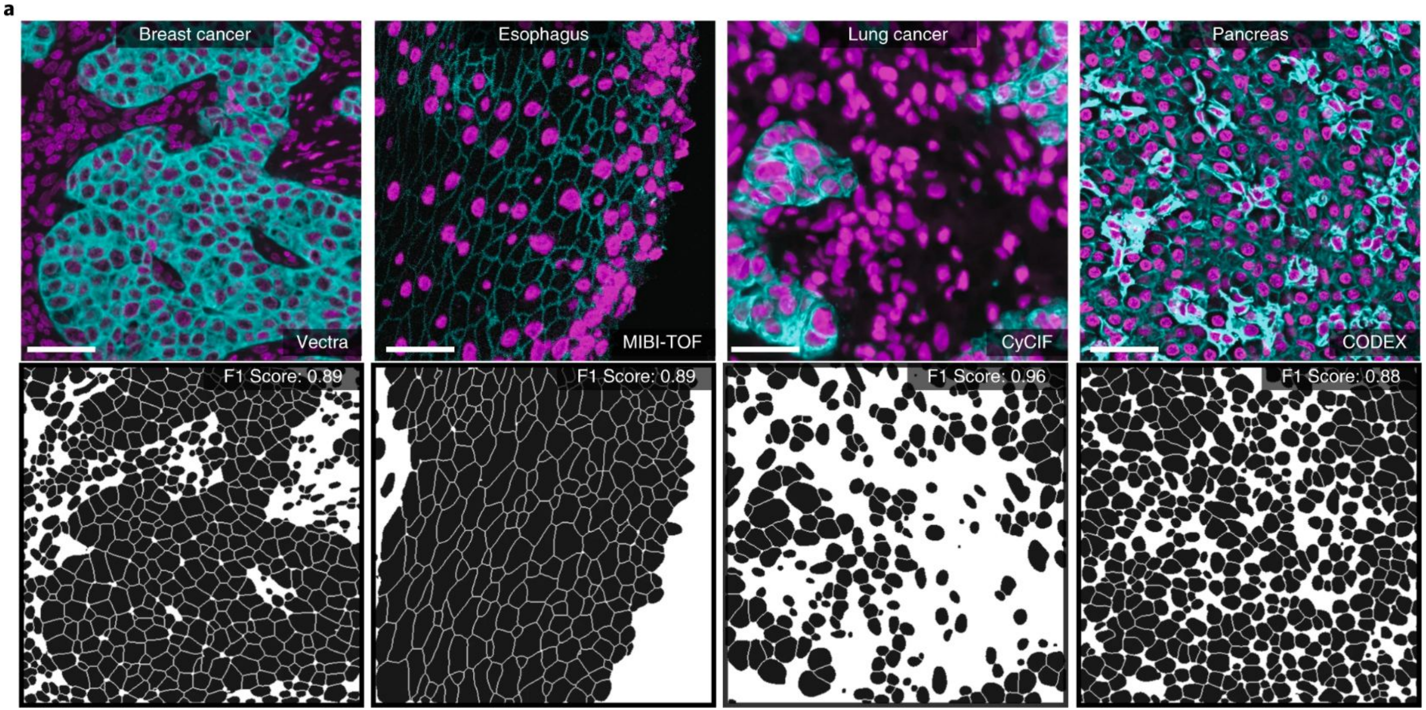
Imaging flow cytometry (IFC) is a promising imaging modality for research and diagnostics



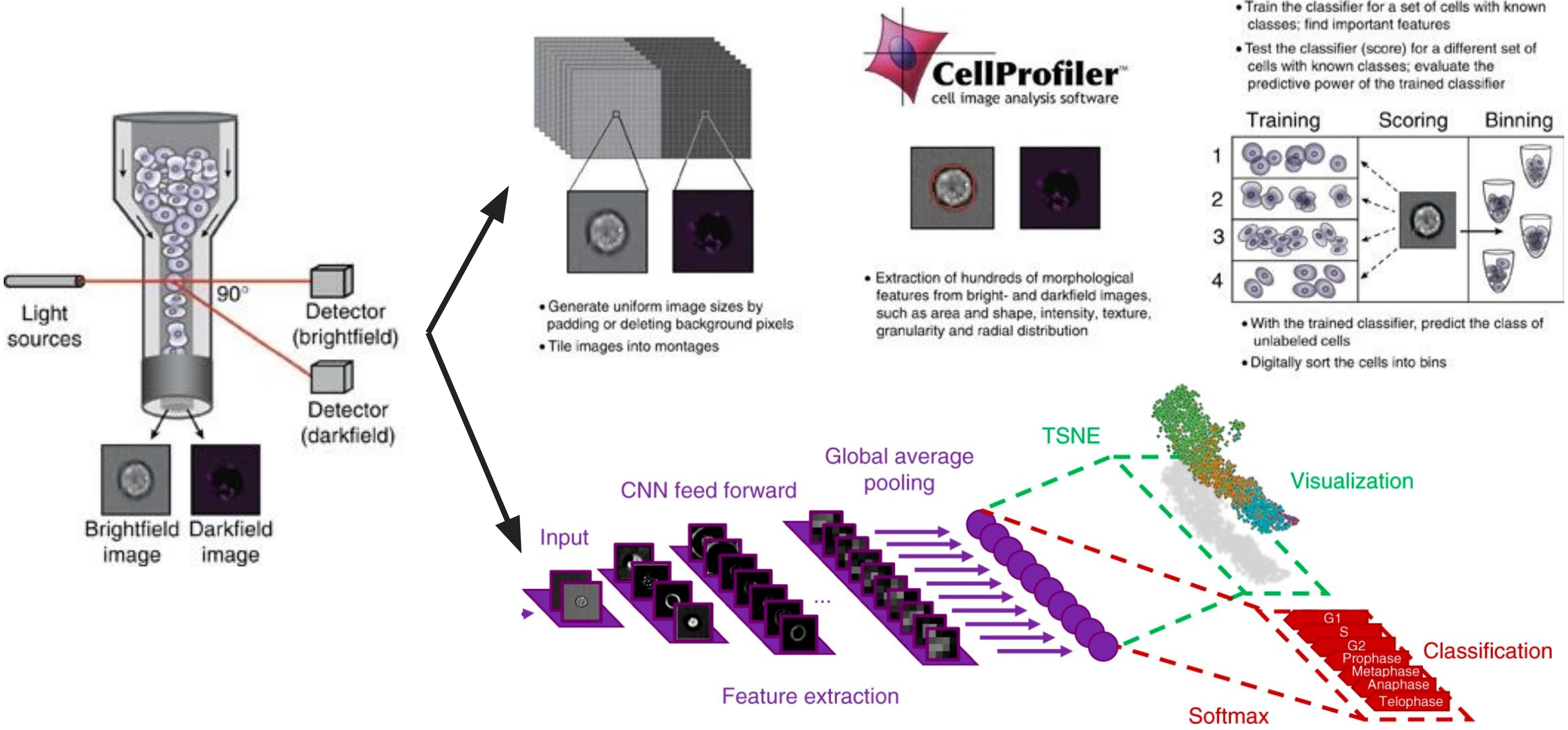
Doan et al.

Most computational methods for analysis of imaging data have been developed for tissue slides or cell plates



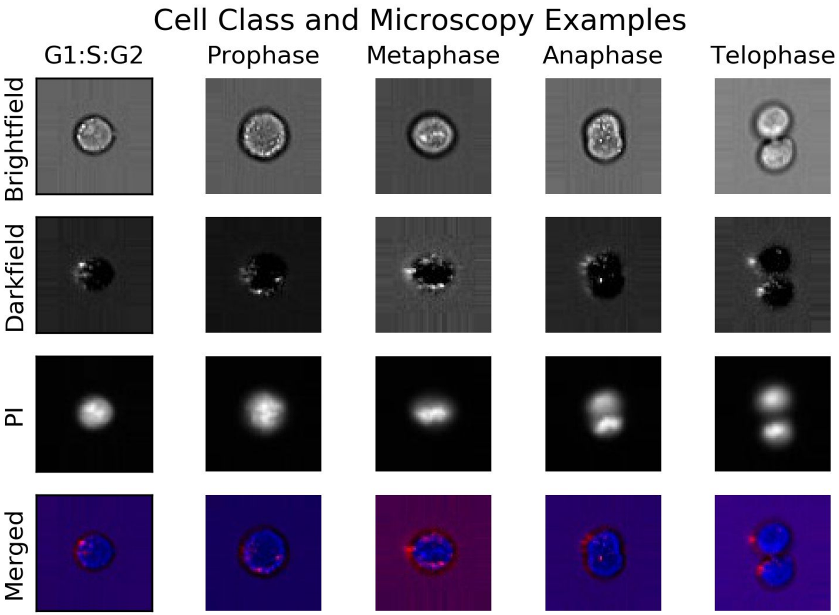
Greenwald et al.

Few computational methods for IFC have been developed, but deep learning methods have previously been used



Blasi et al.

In this work, I explored how effective compact models are for extracting meaningful features from bright-field IFC images for a multiclass classification task



Stage	Data Split		
	Training	Validation	Test
G1/S/G2	22084	3078	6388
Prophase	414	65	127
Metaphase	45	4	19
Anaphase	10	0	5
Telophase	17	2	8

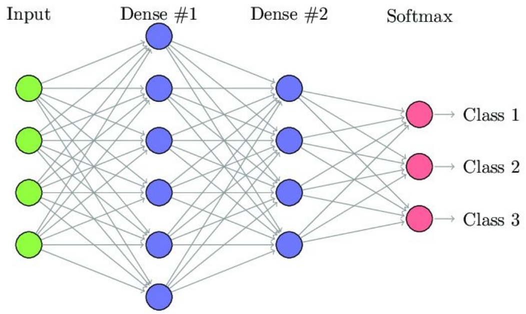
Inputs: 3x64x64 BF Images of Jurkat Cells

Outputs: 5 class probabilities

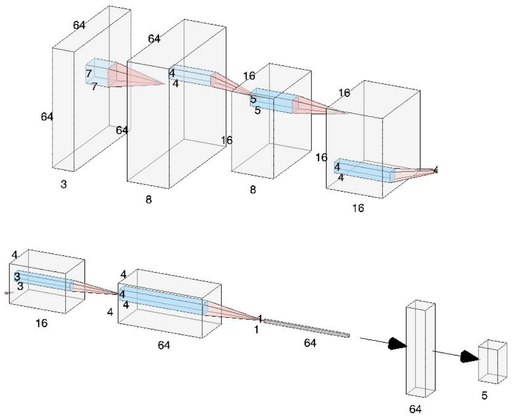
Metrics: Accuracy, Balanced Accuracy

I used 3 different deep-learning architectures including a fully-connected network, a convolutional neural network, and a vision transformer

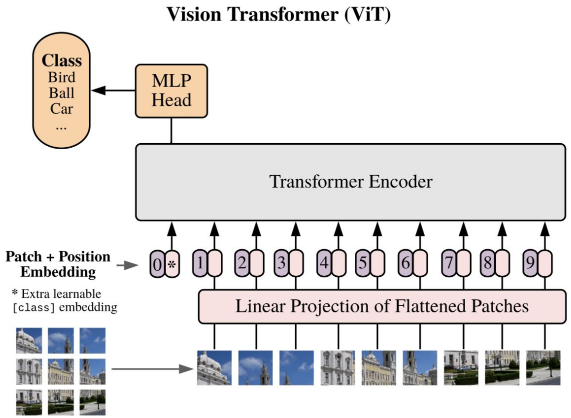
2-layer FC



3-layer CNN



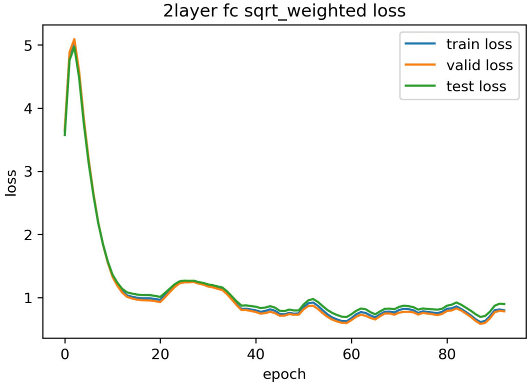
Simple ViT

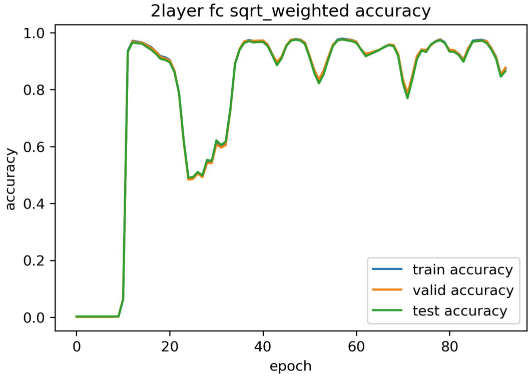


Dosovitskiy et al.

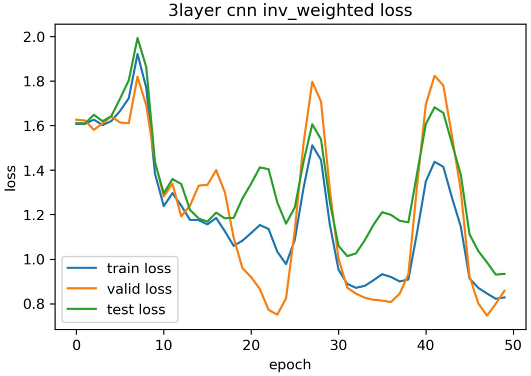
Models generally converged quickly, with training taking less than 30 minutes with early stopping and without exhibiting overfitting

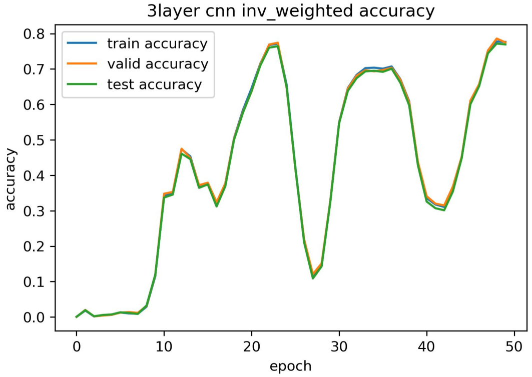
2-layer FC



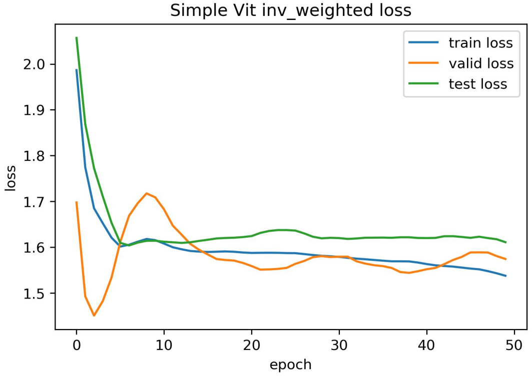


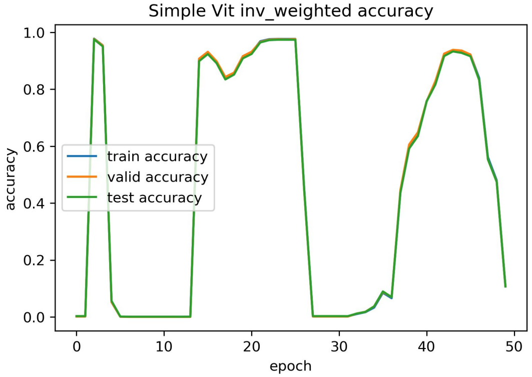
3-layer CNN





Simple ViT

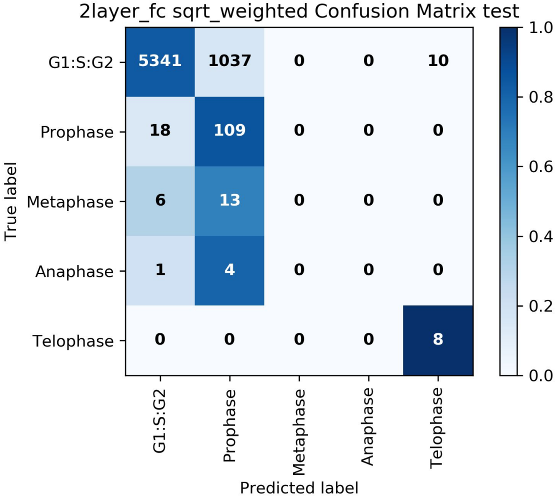




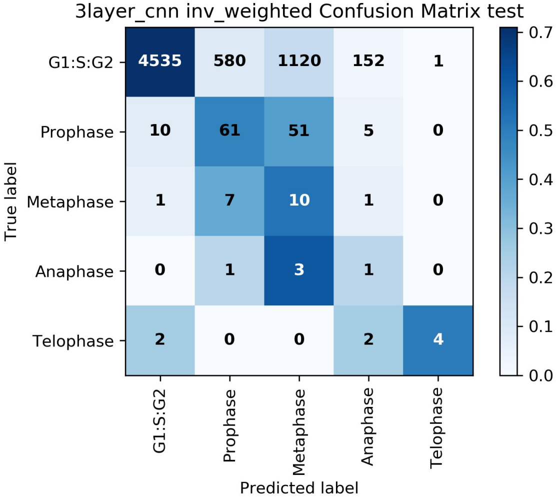
Surprisingly, the 2-layer FC network showed the best performance, while the 3-layer CNN had the broadest prediction quality

Method	Balanced Accuracy (%)		
	Training	Validation	Test
2-layer FC	53.64	54.50	**53.89**
3-layer CNN	**55.73**	**57.88**	48.27
Simple ViT	31.86	33.23	20.49

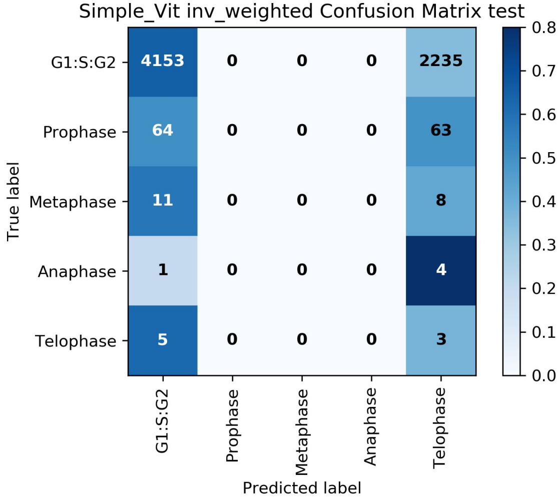
2-layer FC



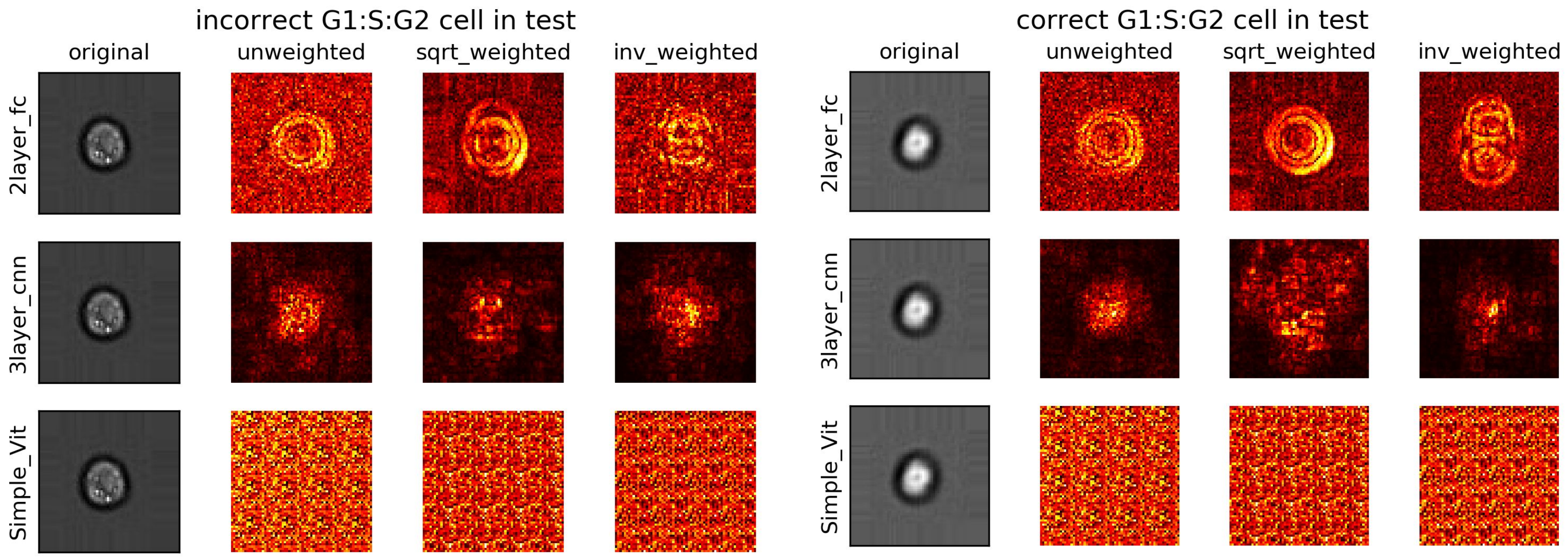
3-layer CNN



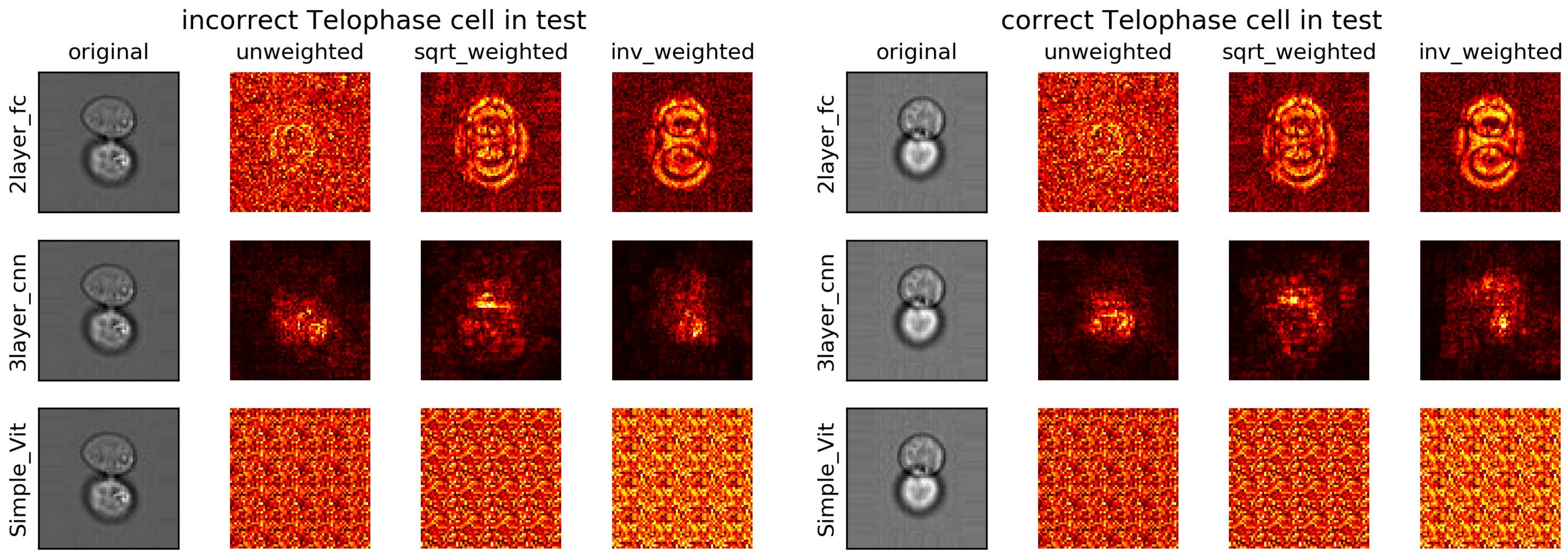
Simple ViT



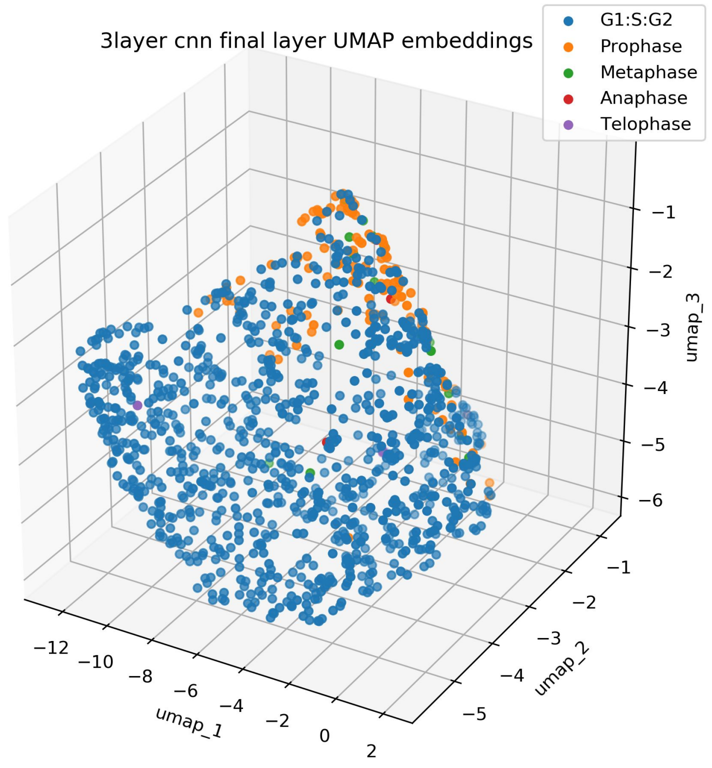
Both the FC network and the CNN were able to segment cells to differing degrees, aiding them in making classification decisions

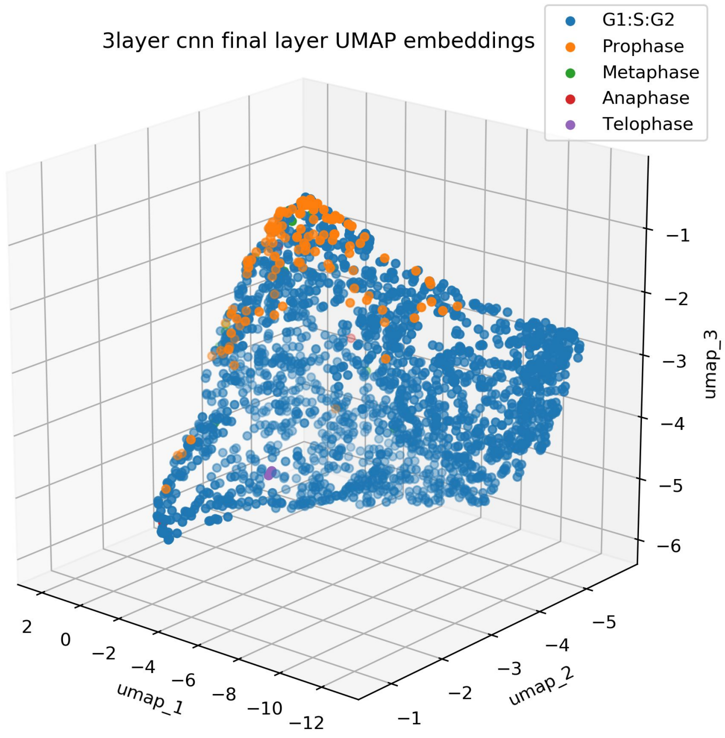


Saliency maps also revealed how the networks leveraged cell size in their predictions



A UMAP embedding of the final layer of the CNN showed separation of cells based on their class





Conclusions

- Deep learning can be used for feature extraction from BF images acquired by an IFC
- Simple models can achieve close to state-of-the-art performance in this task
- The vision transformer architecture from Simple ViT was not able to make meaningful progress in this task

Future Directions

- Collect more images to ameliorate the stark class imbalance
- Explore more data augmentation
- Leverage more compute to explore deeper models, particularly for transformer
- Use a transfer learning approach with other IFC datasets or pretrained models (e.g. ResNet)