Single Molecule Neural Net (SiMoNN)

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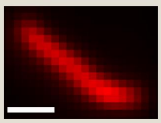
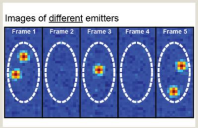
INTRO: Single Molecule Localization Microscopy (SMLM)

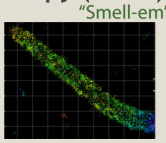


Problem: Diffraction of light limits our resolution ~250 nm, thus we can't resolve small objects in biological cells



Solution: Use a laser to isolate position of many single emitters in space & time

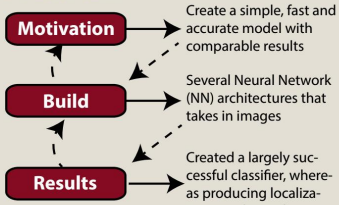
"Smell-em"



Awesome!...but

- ✕ Slow results (1-3 days) — Computational expensive
- ✕ Throw out data — Overlapping molecules/poor signal

OVERVIEW



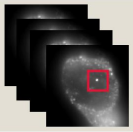
RESULTS:

Model	Train Error	Test Error	Tr/Te Split %	Total # Img
ANN	0.34%	0.01%	75% / 25%	10000
CNN	0.20%	0.68%	75% / 25%	20000
YOLO	Very high*	Very high*	99% / 1%	998

- Even a simple feed-forward ANN does a very nice job, while a CNN has a higher test error

* YOLO network even after many days of training produces large errors in localizing our molecules

DATA



$$f(x,y) = A * exp\left(-\left(\frac{(x-x_0)^2}{2\sigma_x^2} + \frac{(y-y_0)^2}{2\sigma_y^2}\right)\right) + B$$

2D Gaussian Fit

Post-processing

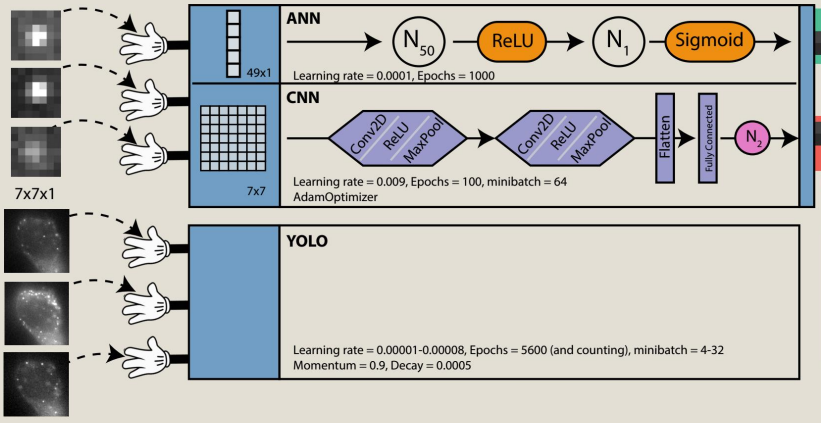
$$Features = (Amplitude, x_0, y_0, \sigma_x, \sigma_y, Background)$$

Molecules were classified as **Good** or **Bad** based on a reasonable Gaussian width threshold ($0.8 < \sigma < 1.05$)

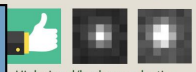
Tells us 2 things: (1) location and (2) profile width of molecule

FEATURES/MODELS

Architecture Schematic

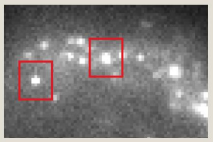


SiMoNN says...



High signal/background ratio
Well separated from other molecules

Low signal/background ratio
Overlapping with other molecules



...sniffed you out!

DISCUSSION

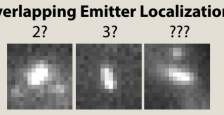
- √ All neural networks were overall simple to use
- √ High level of accuracy achieved on training/test sets
- √ (ANN/CNN) very fast training (~1-10 minutes)

- ✕ Training a YOLO network takes too long (~3-4 days)
- ✕ YOLO requires more fine tuning later on
- ✕ Low accuracy (at least for now)

FUTURE WORK

Get YOLO to work!!!

Overlapping Emitter Localization



3D Localization (???)

Acknowledgements:

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Citations

1. Bowen, B.P., *et.al.* Implementation of neural networks for the identification of single molecules. *J. Phys. Chem. A* **108**, 4799-4804 (2004)
2. Redmon, J., *et.al.* You Only Look Once: Unified, Real-Time Object Detection. *Arxiv* (2015)
3. Diezmann, A., Shechtman, Y., Moerner, W. E. Three dimensional localization of single molecules for super-resolution imaging and single-particle tracking. *Chemical Reviews*. (2017)
4. Ng., A., *et.al.* CS 230 Notes & Coursera (2018)