SpotNet — Learned iterations for cell detection in image-based immunoassays

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Fork this project's repository at https://github.com/poldap/SpotNet

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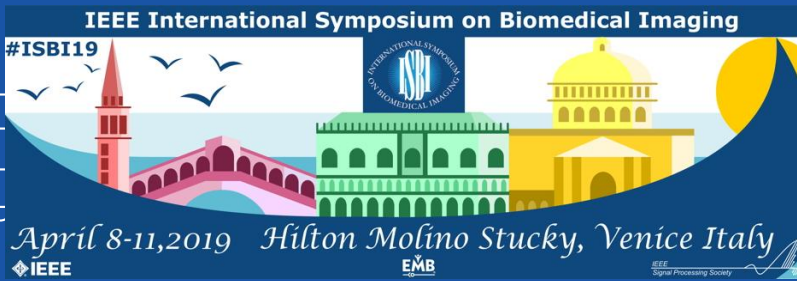
KTH Royal Institute of Technology



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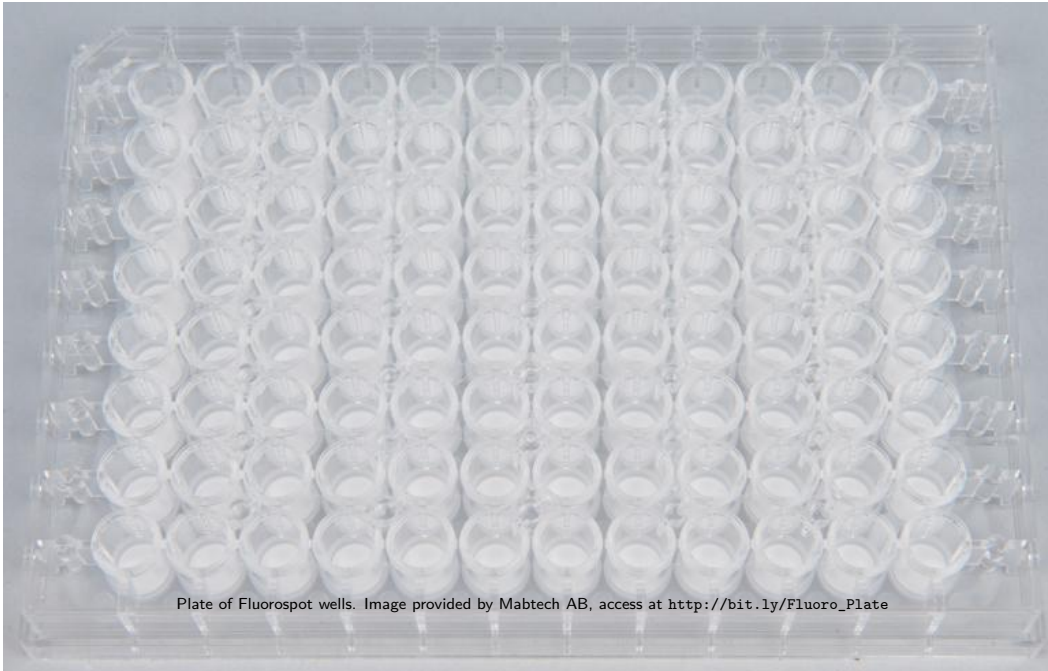
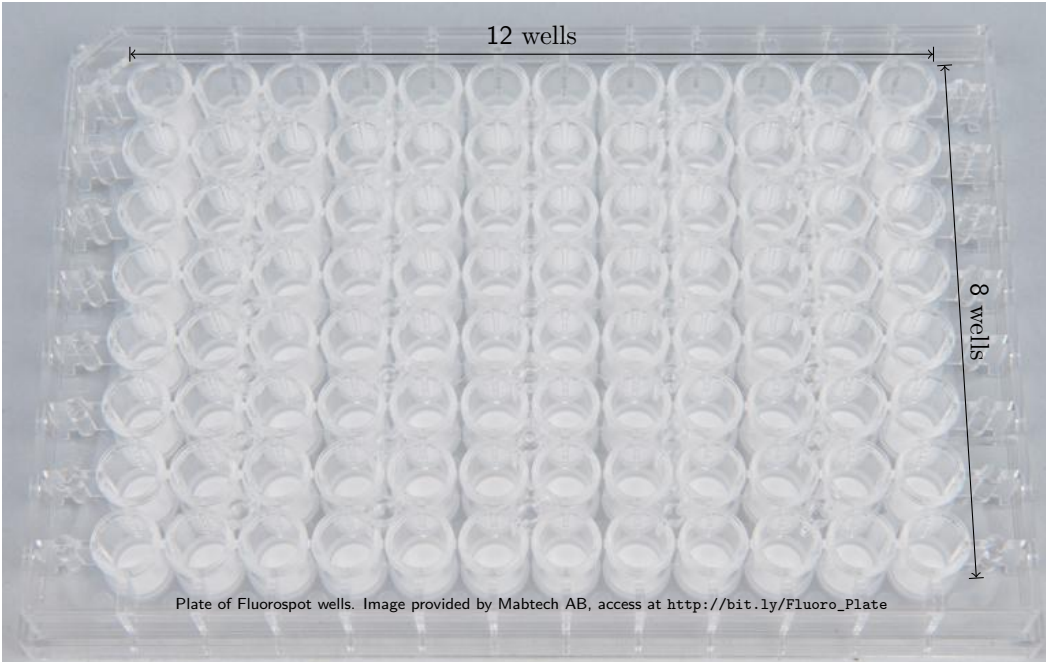


Plate of Fluorospot wells. Image provided by Mabtech AB, access at http://bit.ly/Fluoro_Plate



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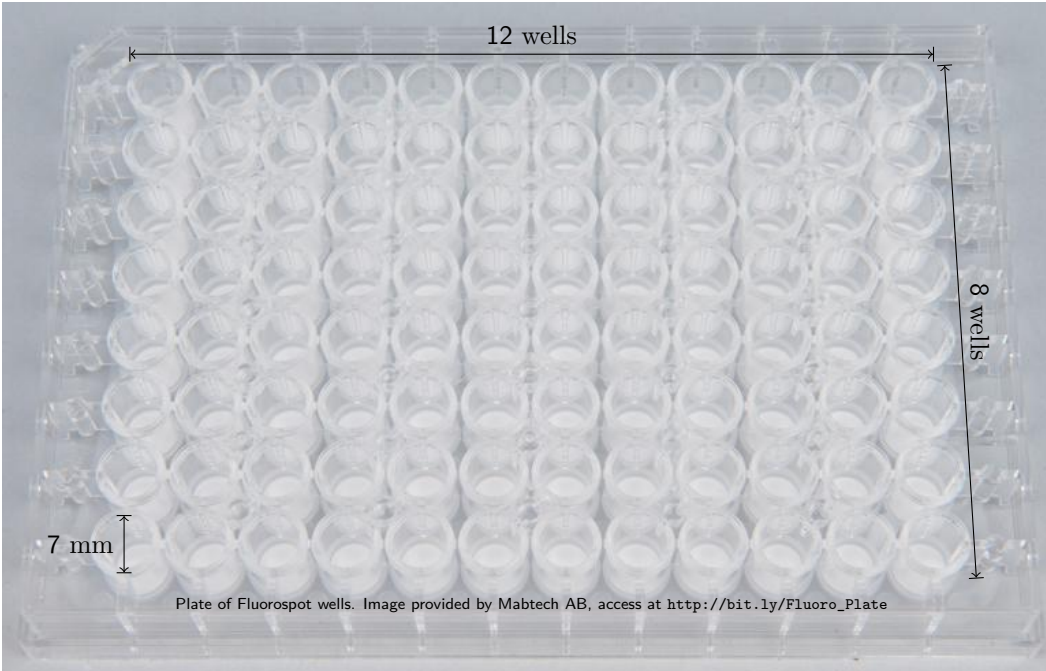

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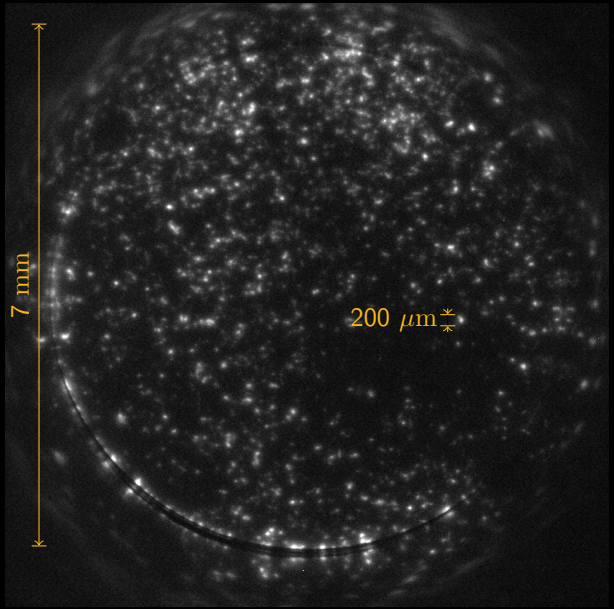
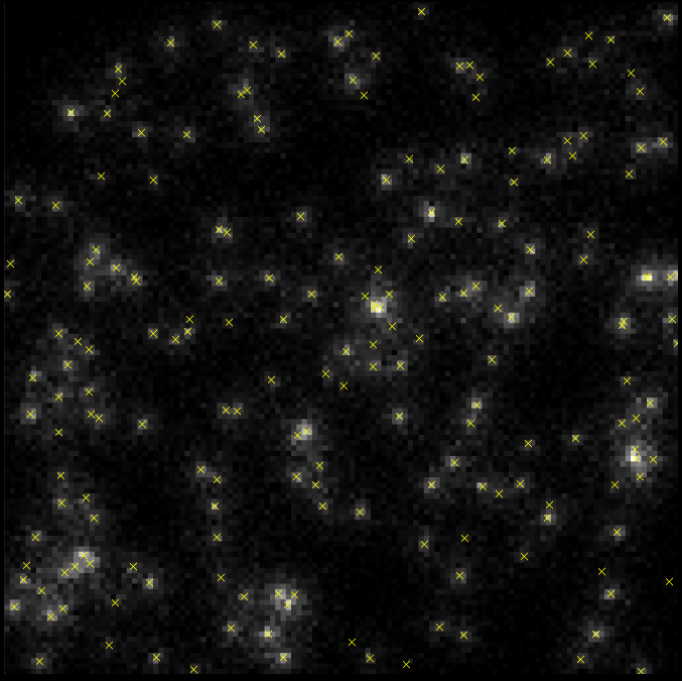
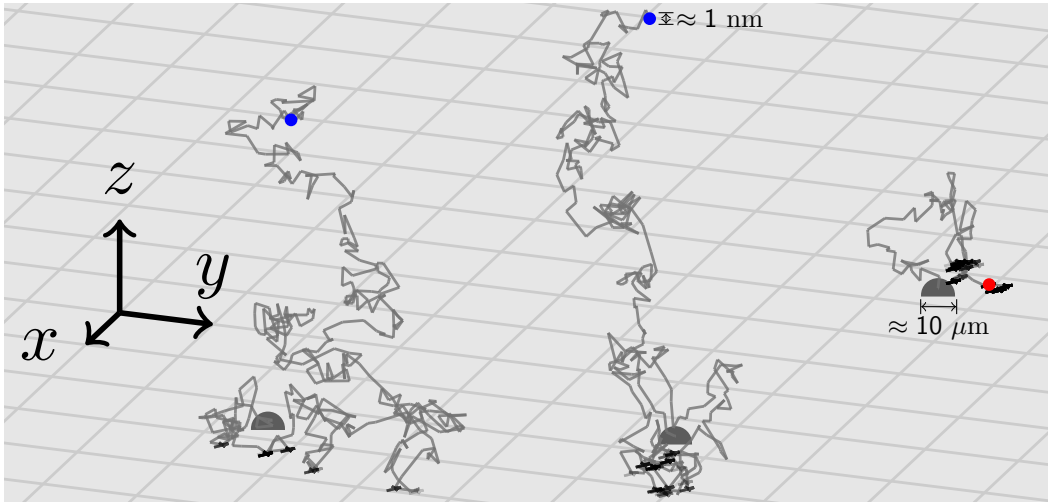


Fluorospot image, provided by Mabtech AB




z
y
x
≈ 1 nm
≈ 10 μm

An observation model for immunoassays

The image $s \in \mathbb{R}_+^{M,N}$ can be expressed as

$$s \approx \sum_{k=1}^{K} g_k \circledast x_k. \text{ Def. } \mathbf{x} \triangleq \left[x_k \in \mathbb{R}_+^{M,N} \right]_1^K.$$

$x_k \in \mathbb{R}_+^{M,N}$, spatial density of new particles at the k-th time window of an experiment.

Solve the convolutional (group-sparse) coding problem

$$\min_{\mathbf{x}} \left\{ \left\| \sum_{k=1}^{K} h_k \circledast x_k - s \right\|_2^2 + \lambda \mathcal{R}(\mathbf{x}) \right\}$$

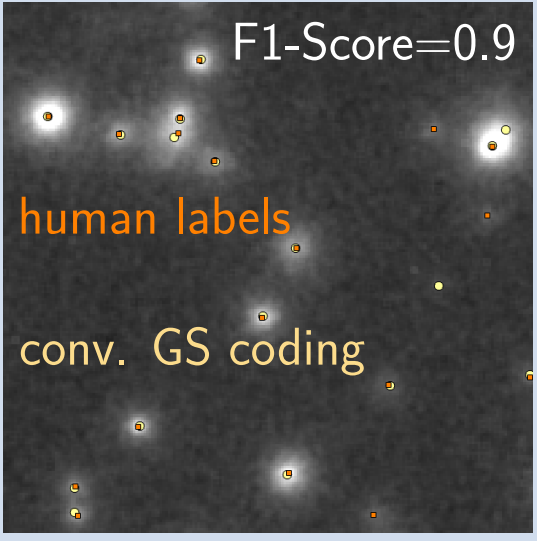
Accelerated proximal gradient for convolutional group-sparse coding

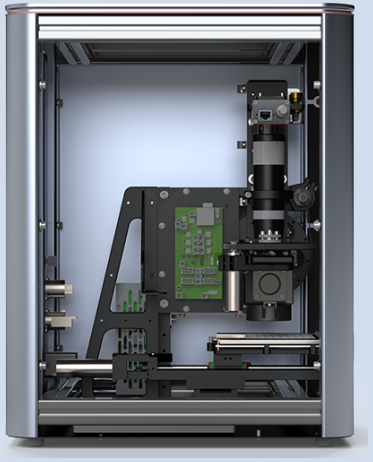
$$x_k^{(l)} \leftarrow \varphi_\lambda \left[z_k^{(l-1)} - \tilde{h}_k \circledast \left(\sum_{q=1}^{K} h_q \circledast z_q^{(l-1)} - s \right) \right]$$

with $\varphi_\lambda(\cdot)$ the operator $\mathrm{prox}_{\lambda\mathcal{R}}(\cdot)$, and then

$$z_k^{(l)} \leftarrow x_k^{(l)} + \alpha^{(l)} \left(x_k^{(l)} - x_k^{(l-1)} \right)$$

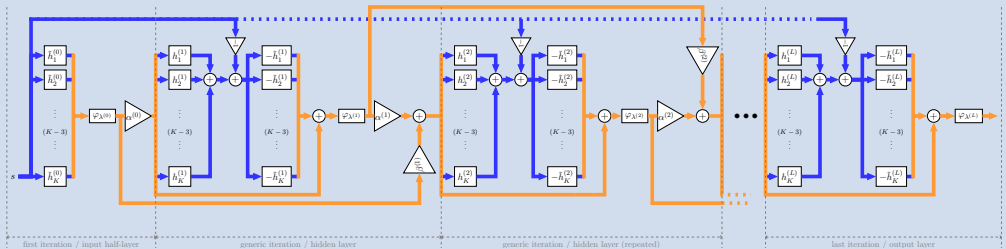
Results on real data and a real product





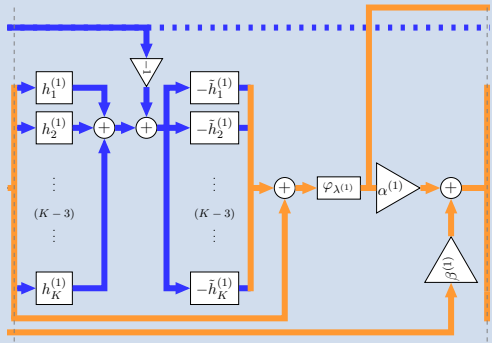
MabTech IRIS™

Learned iterations for faster inverse problems (SpotNet)

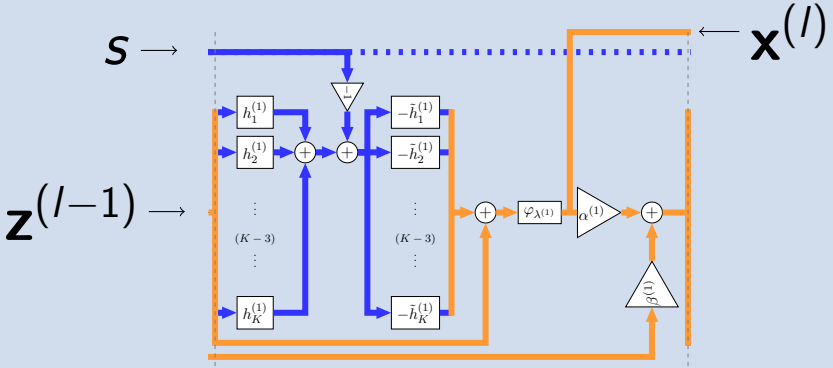


Learned iterations, loop unrolling or learning to learn. Find the optimum faster.

Learned iterations for faster inverse problems (SpotNet)

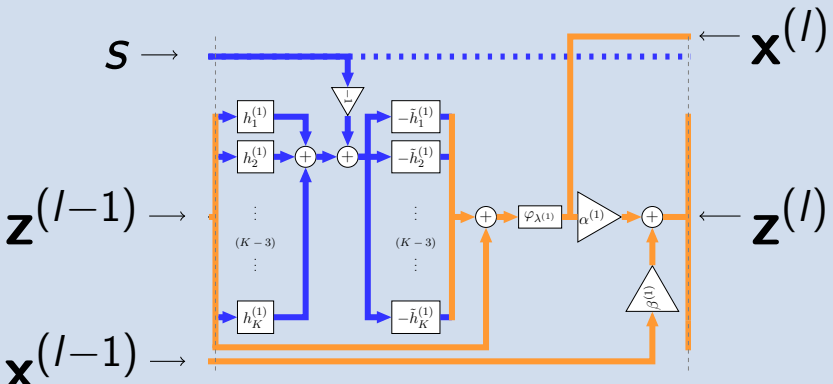


Learned iterations for faster inverse problems (SpotNet)



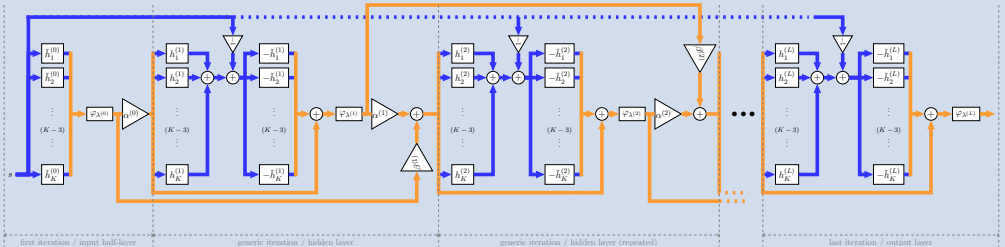
$$x_k^{(l)} \leftarrow \varphi_\lambda \left[z_k^{(l-1)} - \tilde{h}_k \circledast \left(\sum_{q=1}^{K} h_q \circledast z_q^{(l-1)} - s \right) \right]$$

Learned iterations for faster inverse problems (SpotNet)



$$z_k^{(l)} \leftarrow x_k^{(l)} + \alpha^{(l)} \left(x_k^{(l)} - x_k^{(l-1)} \right)$$

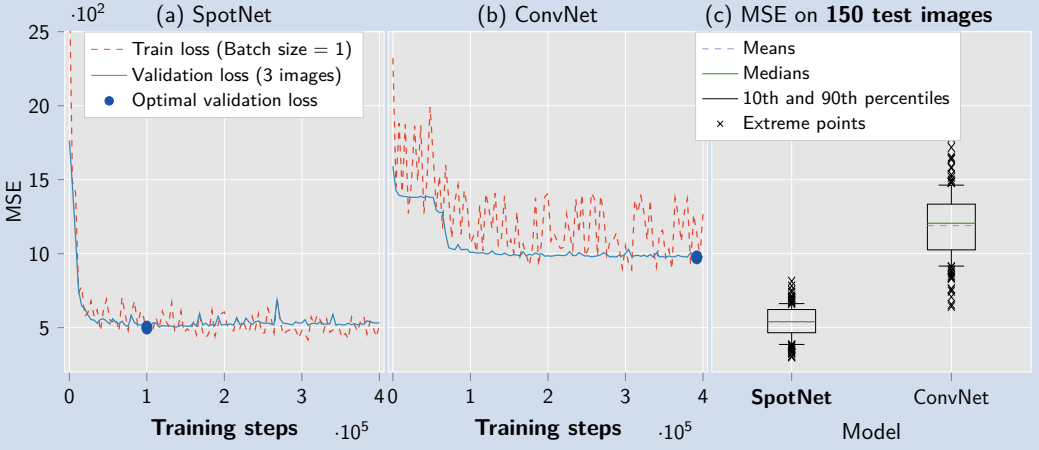
Learned iterations for faster inverse problems (SpotNet)



Based on LISTA from (Gregor and LeCun, 2010). Explored recently by (Giryes, Eldar et al., 2018) and others.

See the details at `https://github.com/poldap/SpotNet`.

Results for SpotNet with $L = 3$ and smaller kernels



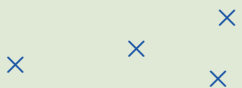
- SpotNet vs generic ConvNet trained on $\mathrm{MSE}\{\hat{\mathbf{x}}\}$.
- **Training on 7 synthetic images** with 1250 cells. Testing on 150 images containing 250, 750 or 1250 cells.

Evaluation on synthetic data

Tolerance of $\Delta = 3$ pix. Detection metrics

$$\mathrm{pre} = \frac{\mathrm{TP}}{\mathrm{TP} + \mathrm{FP}}, \; \mathrm{rec} = \frac{\mathrm{TP}}{\mathrm{TP} + \mathrm{FN}}, \text{ and } \mathrm{F1} = \frac{2\,\mathrm{pre} \cdot \mathrm{rec}}{\mathrm{pre} + \mathrm{rec}}.$$

Example



×: Real cells

Evaluation on synthetic data

Tolerance of $\Delta = 3$ pix. Detection metrics

$$\mathrm{pre} = \frac{\mathrm{TP}}{\mathrm{TP} + \mathrm{FP}}, \; \mathrm{rec} = \frac{\mathrm{TP}}{\mathrm{TP} + \mathrm{FN}}, \text{ and } \mathrm{F1} = \frac{2\,\mathrm{pre} \cdot \mathrm{rec}}{\mathrm{pre} + \mathrm{rec}}.$$

Example

×: Real cells +: Detections

Evaluation on synthetic data

Tolerance of $\Delta = 3$ pix. Detection metrics

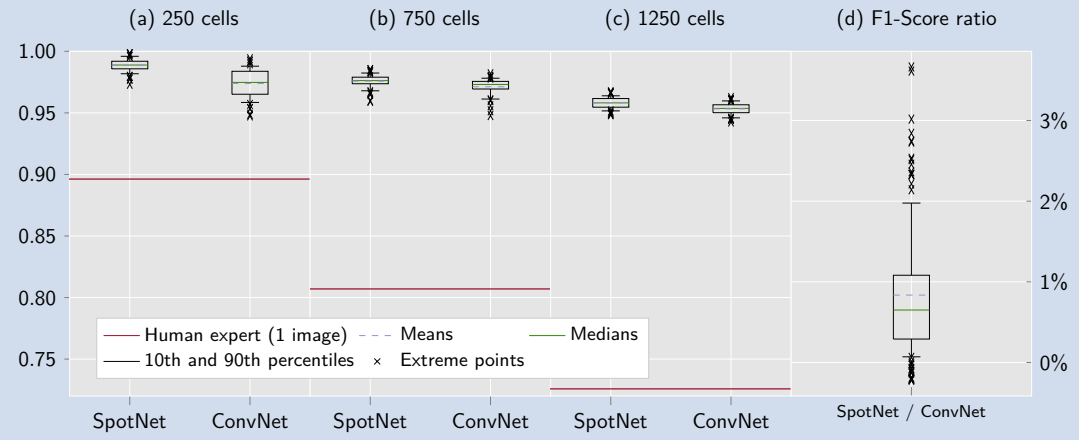
$$\mathrm{pre} = \frac{\mathrm{TP}}{\mathrm{TP} + \mathrm{FP}}, \ \mathrm{rec} = \frac{\mathrm{TP}}{\mathrm{TP} + \mathrm{FN}}, \text{ and } \mathrm{F1} = \frac{2\,\mathrm{pre} \cdot \mathrm{rec}}{\mathrm{pre} + \mathrm{rec}}.$$

Example

$$\mathrm{pre} = \mathrm{rec} = \mathrm{F1} = \frac{3}{4}.$$

×: Real cells +: Detections

Results for SpotNet with $L = 3$ and smaller kernels



- SpotNet vs generic ConvNet in $\mathrm{F1}$ score.
- Trained on 7 images with 1250 cells.

Thank you

Please, feel free to ask questions.

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