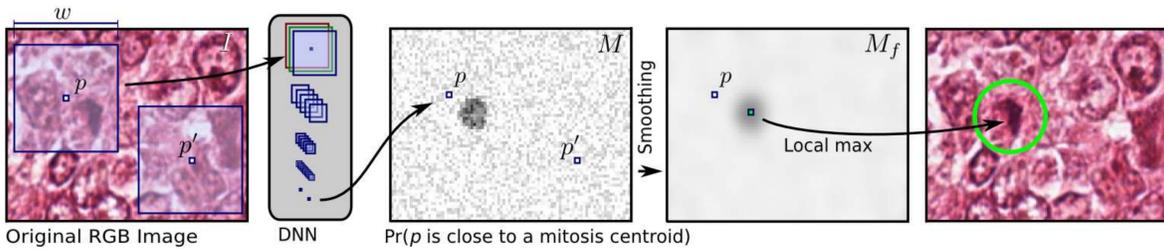
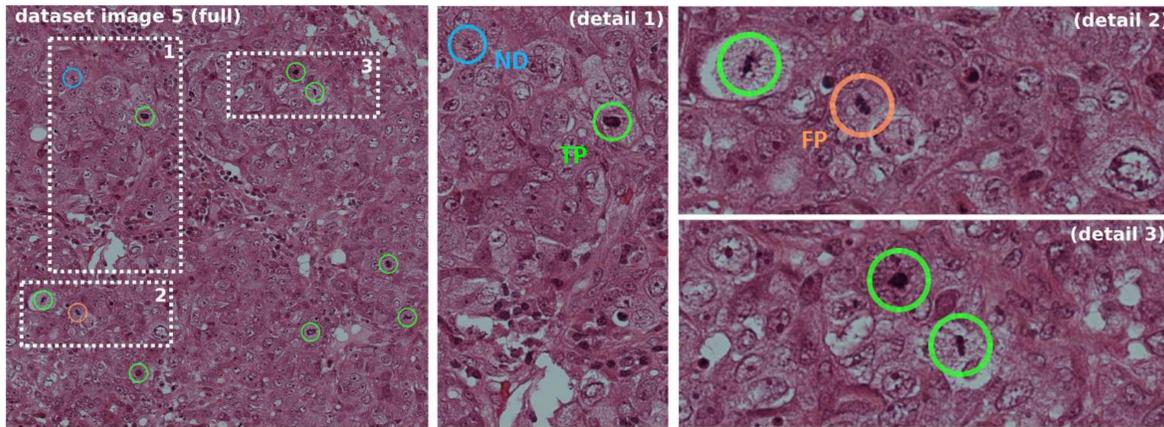


Mitosis Detection in Breast Cancer Histology Images with Deep Neural Networks

Dan C. Cireşan, Alessandro Giusti, Luca M. Gambardella, Jürgen Schmidhuber
IDSIA, USI and SUPSI, Lugano, Switzerland – {dan, alessandro, luca, juergen}@idsia.ch

We describe the method that won the ICPR 2012 Mitosis Detection Competition, outperforming other methods by a significant margin. We use deep max-pooling convolutional neural networks to detect mitosis in breast histology images. The networks are trained to classify each pixel in the images, using as context a patch centered on the pixel. Simple postprocessing is then applied to the network output. **New: the same method also won the first place at MICCAI 2013 Grand Challenge: Assessment of Mitosis Detection Algorithms**



Method. Given an input RGB image, the problem is to find a set of detections, each reporting the centroid coordinates for a single mitosis. The problem is solved by training a detector on training images with given ground truth information about the centroid of each visible mitosis. Each pixel is assigned one of two possible classes, mitosis or non-mitosis, the former to pixels at (or close to) mitosis centroids, the latter to all other pixels. For any given pixel p , the DNN predicts its class using raw RGB values in a square image window centered on p .

Deep Neural Networks (DNN) trained on GPU

- 4 x NVIDIA GTX 580 1.5GB RAM, more than 6 TFLOPS (maximum theoretical speed)
- 50x speed-up compared with a single threaded CPU version of the DNN program (one day on GPU vs two months on CPU)



- Training each net requires ~1 day. Less than 30 epochs are needed to minimize error on validation data
- Detecting mitosis in a single 4 Mpixel image requires ~8 minutes with our MATLAB implementation (see ICIP 2013)

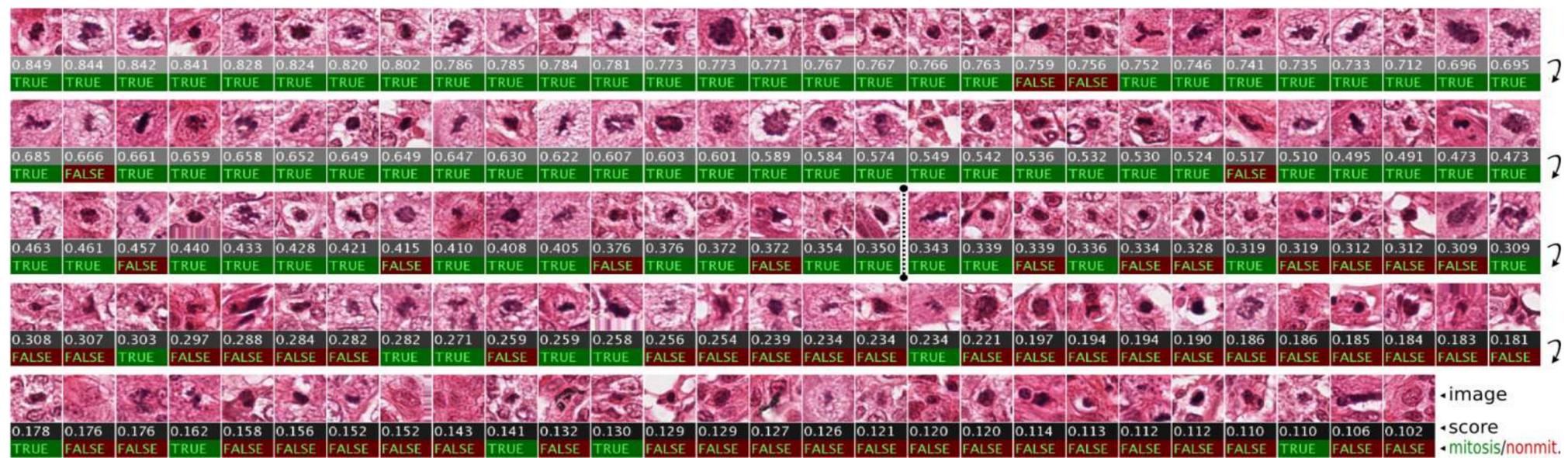
Network Architectures

I – input C – convolutional MP – max-pooling FC – fully connected

Layer Type	Maps and neurons	Filter size	Weights	Connections
0	I	3M x 101x101N	—	—
1	C	16M x 100x100N	2x2	2080000
2	MP	16M x 50x50N	2x2	—
3	C	16M x 48x48N	3x3	2320
4	MP	16M x 24x24N	2x2	—
5	C	16M x 22x22N	3x3	1122880
6	MP	16M x 11x11N	2x2	—
7	C	16M x 10x10N	2x2	10400
8	MP	16M x 5x5N	2x2	—
9	C	16M x 4x4N	2x2	16640
10	MP	16M x 2x2N	2x2	—
11	FC	100N	1x1	6500
12	FC	2N	1x1	202

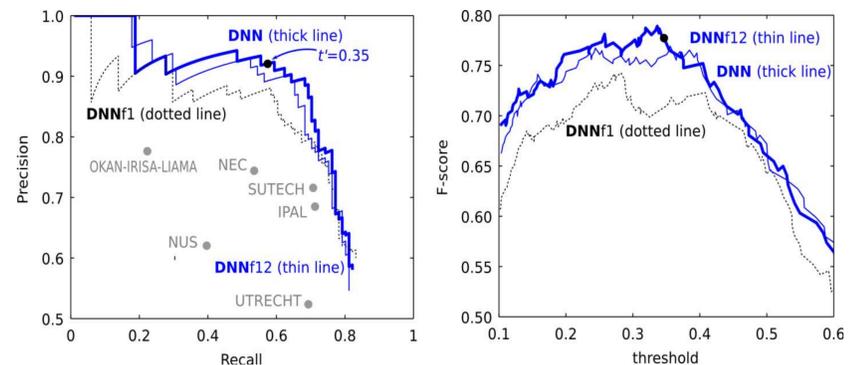
Layer Type	Maps and neurons	Filter size	Weights	Connections
0	I	3M x 101x101N	—	—
1	C	16M x 98x98N	4x4	784
2	MP	16M x 49x49N	2x2	—
3	C	16M x 46x46N	4x4	4112
4	MP	16M x 23x23N	2x2	—
5	C	16M x 20x20N	4x4	4112
6	MP	16M x 10x10N	2x2	—
7	C	16M x 8x8N	3x3	2320
8	MP	16M x 4x4N	2x2	—
9	FC	100N	1x1	25700
10	FC	2N	1x1	202

Performance results on the evaluation dataset



Our F-score (**0.782**) is significantly higher than the closest competitor's (**0.718**). Even significant deviations from the optimal threshold yield limited performance loss.

method	precision	recall	F_1 score	method	precision	recall	F_1 score
DNN	0.88	0.70	0.782	NUS	0.63	0.40	0.490
DNNf12	0.85	0.68	0.758	ISIK [19]	0.28	0.68	0.397
DNNf1	0.78	0.72	0.751	ETH-HEILDERBERG [18]	0.14	0.80	0.374
IPAL [9]	0.69	0.74	0.718	OKAN-IRISA-LIAMA	0.78	0.22	0.343
SUTECH	0.70	0.72	0.709	IITG	0.17	0.46	0.255
NEC [12]	0.74	0.59	0.659	DREXEL	0.14	0.21	0.172
UTRECHT [20]	0.51	0.68	0.583	BII	0.10	0.32	0.156
WARWICK [10]	0.46	0.57	0.513	QATAR	0.00	0.94	0.005



Conclusions

- Our approach outperforms competing techniques by a large margin
- A general technique for bio-medical image segmentation (also used for EM segmentation – see NIPS 2012)
- Won four other competitions:
 - MICCAI 2013: *Assessment of Mitosis Detection Algorithms*
 - ISBI 2012: *Neuronal Membrane Segmentation from Electron Microscopy images*
 - ICDAR 2011: *Offline Chinese Character Recognition*
 - IJCNN 2011: *The German Traffic Sign Recognition Benchmark*

Future work

- Applying the method to other bio-medical problems
- Validating our approach on larger datasets, and comparing its performance to the one of expert histologists (already done successfully on the MICCAI Mitosis Detection Challenge)
- Bring automated mitosis detection into clinical practice

More info <http://www.idsia.ch/~ciretan>

