Introduction

Global cancer statistics 2020

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Males

Incidence

Lung 14.3%

Prostate 14.1%

Colorectum 10.6%

Stomach 7.1%

Liver 6.3%

Bladder 4.4%

Esophagus 4.2%

Non-Hodgkin lymphoma 3.0%

Kidney 2.7%

Leukemia 2.7%

Other cancer 30.7%
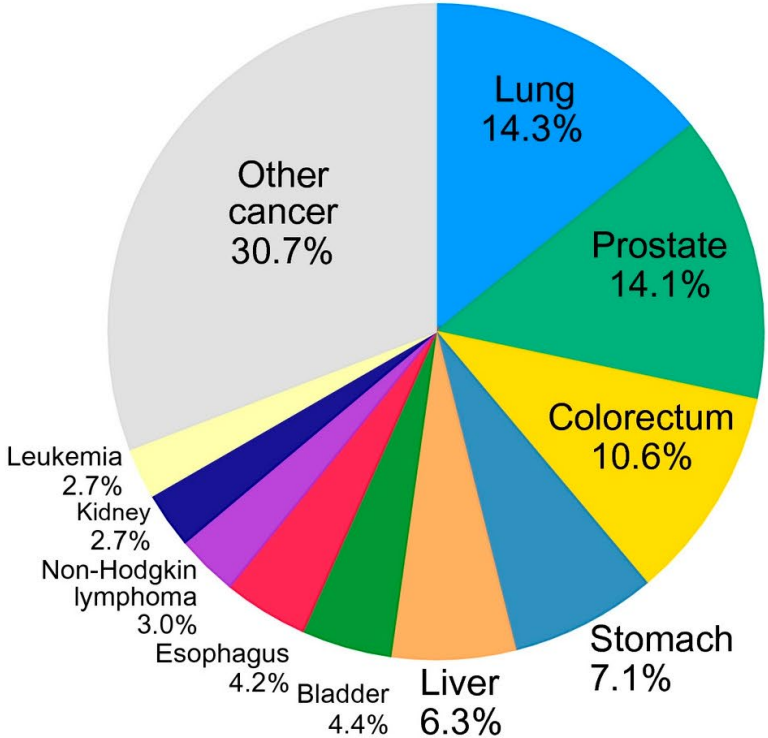
10.1 million
new cases

Mortality

Lung 21.5%

Liver 10.5%

Colorectum 9.3%

Stomach 9.1%

Prostate 6.8%

Esophagus 6.8%

Pancreas 4.5%

Leukemia 3.2%

Bladder 2.9%

Non-Hodgkin lymphoma 2.7%

Other cancer 22.9%

5.5 million
deaths

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Diagnostic process

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Biopsy > **Obtaining samples** > **Microscope observation** > **Diagnosis**

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Gleason scale

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Healthy tissue

Gleason grade 3

Gleason grade 4
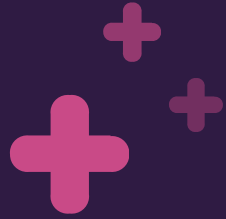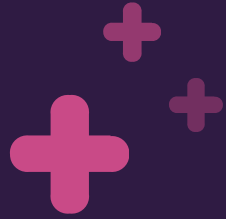
Gleason grade 5
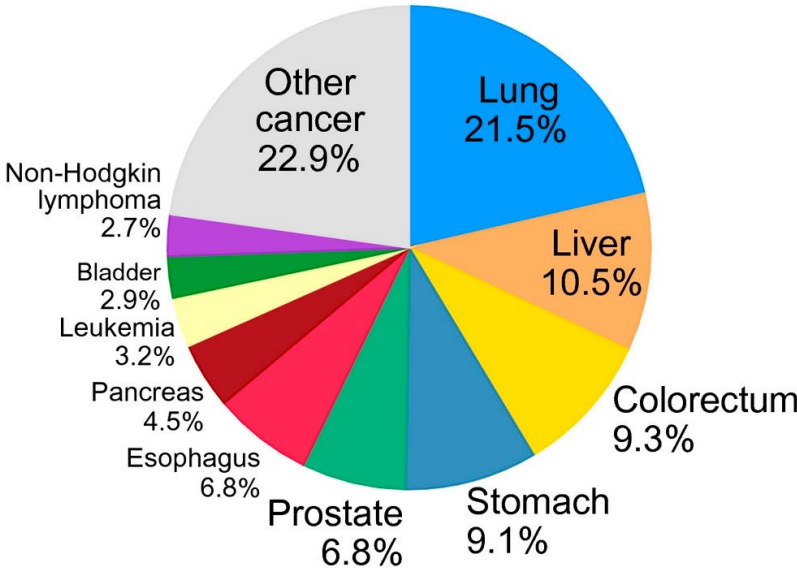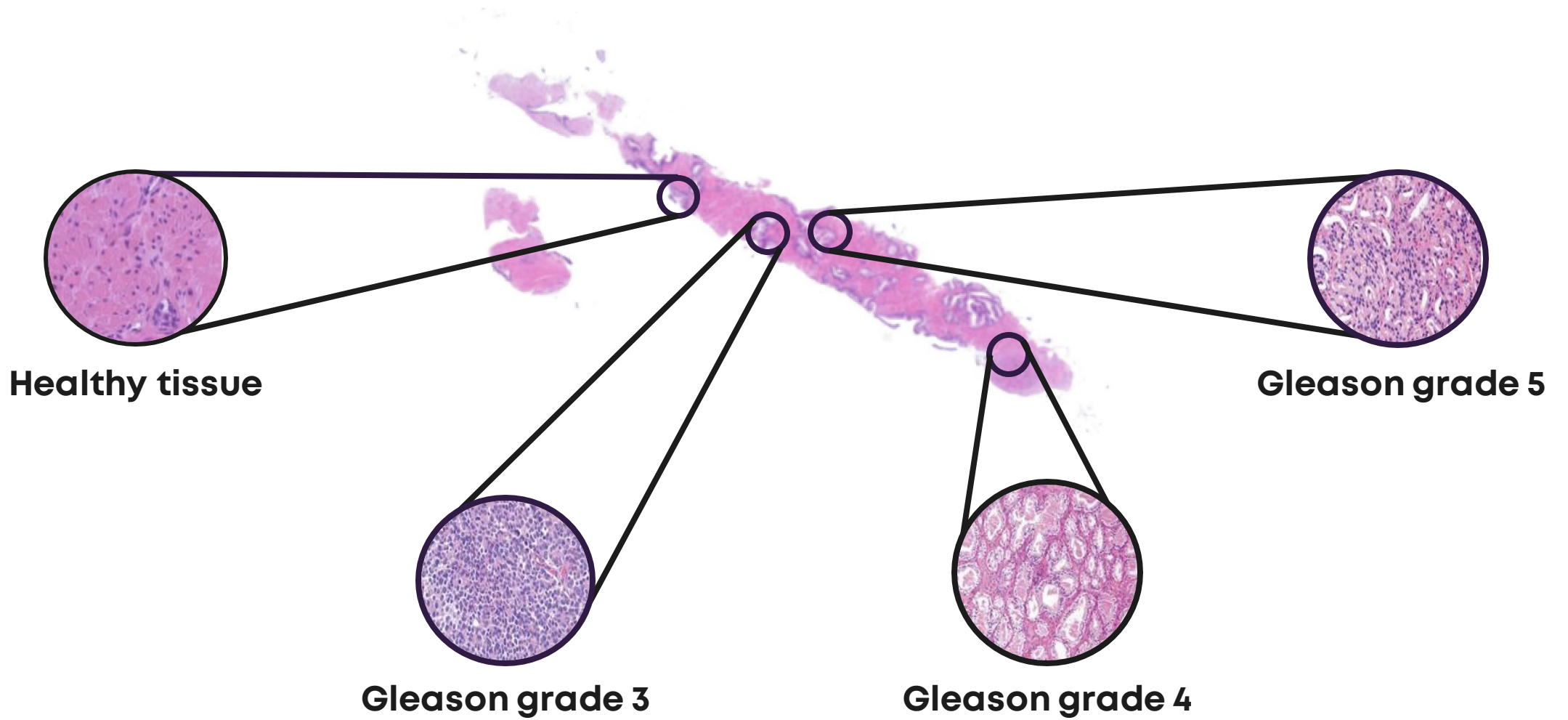
Objective

Development of an intelligent guided diagnosis computerized system based on Deep Learning (Convolutional Neural Networks) capable of detecting cancer in histological images in order to support the pathologist in their decision making.

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Methodology

Diagnostic process

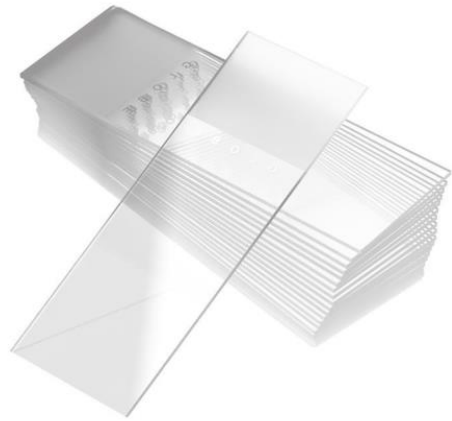++++++

Phase 1

1. Sample digitization
2. Image annotation
3. Dataset creation

Phase 2

1. Algorithm design
2. System evaluation

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Phase 1

Sample digitization

Portas

Scanner
Roche iScan HT Window

Whole-Size-Image

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Phase 1

Dataset creation I

Digitization — Malignant / Normal

Labeling — Not labeled

Patch extraction — D: patch discarded

Patch scoring — Score = 1 if patch ∩ ROI ≥ 80% ; Score = TP×CF×SVF (Eq. 1)

Score ≥ 0.7

Color normalization — source → mapped

Data augmentation — horizontal flip, vertical flip, rotations

CNN

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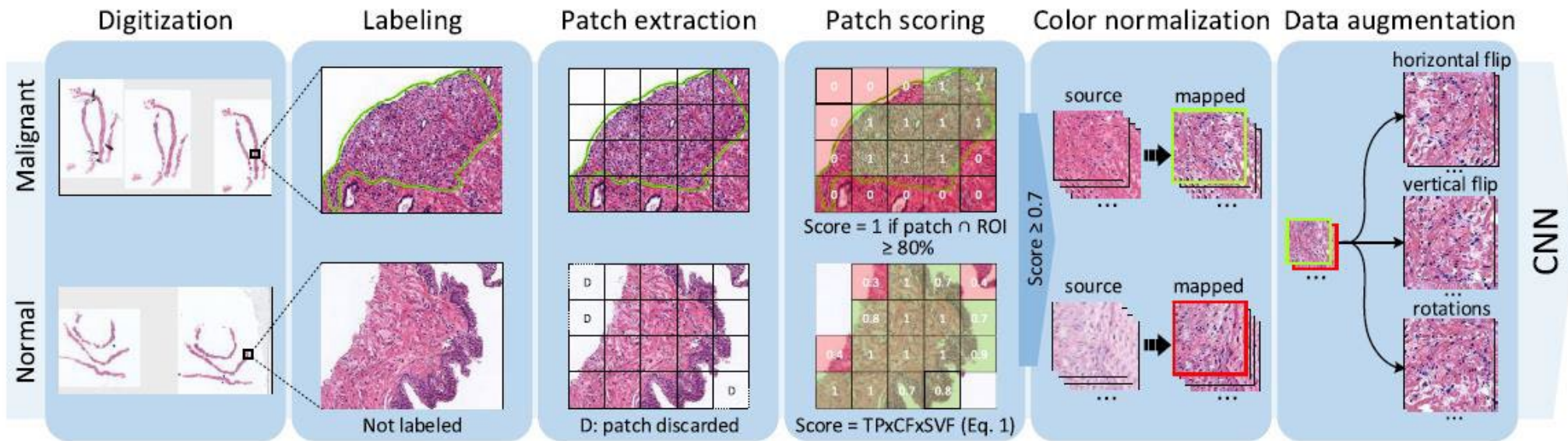
Phase 1

Dataset creation II

DATASET

80%

TRAIN

29.195 images

20%

TEST

7.135 images

Increase in the number of images

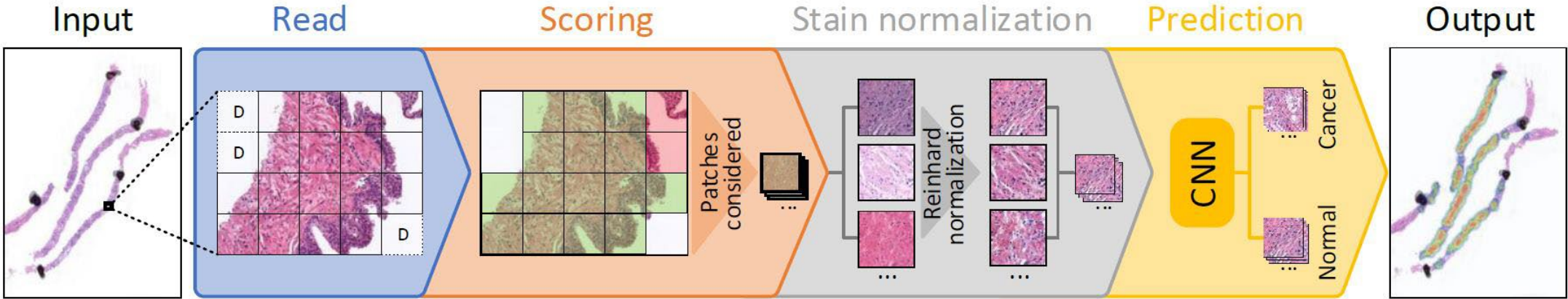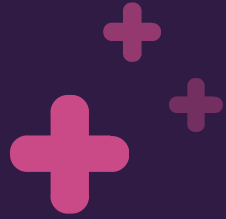87.585 images

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Phase 2

Convolutional Neural Network Design

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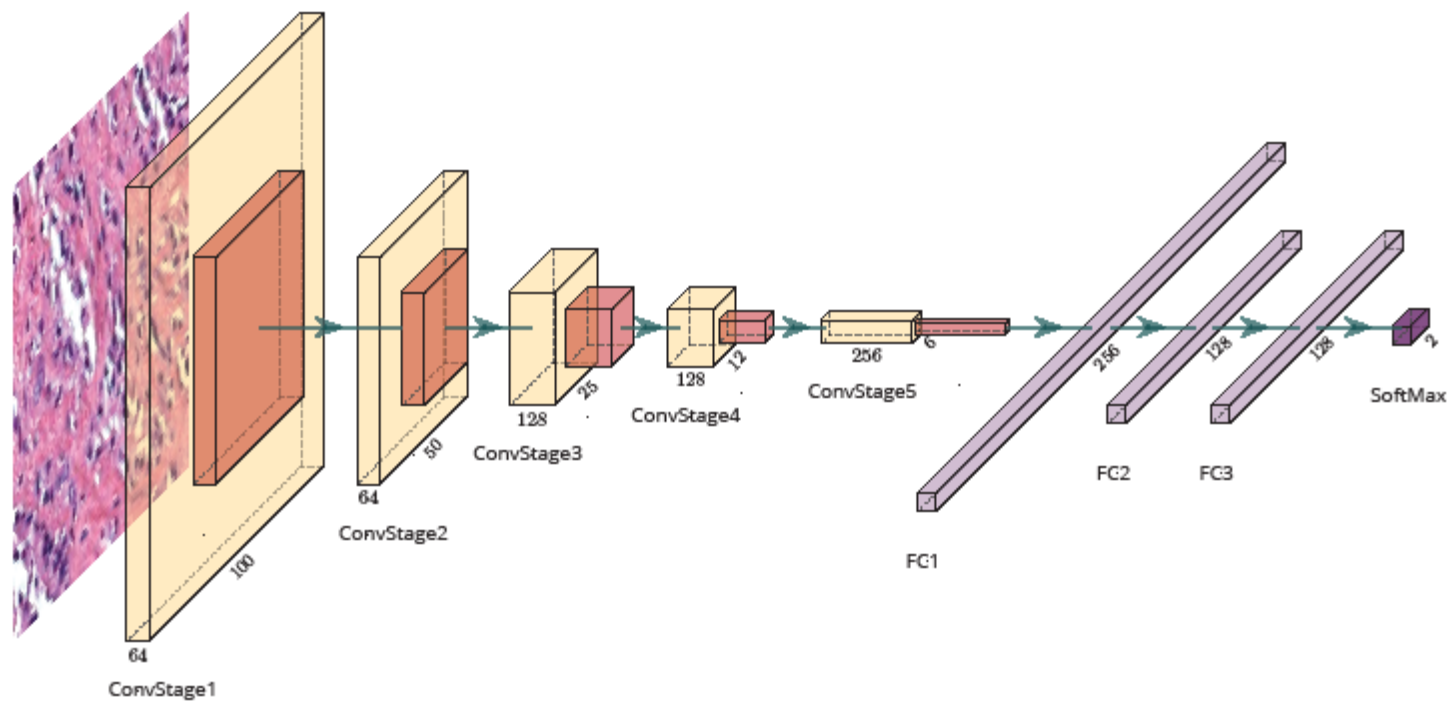
CNN utilization procedure

Input | Read | Scoring | Stain normalization | Prediction | Output

Results

Evaluation of the results obtained

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	Set	Dataset	Accuracy (%)	Specificity (%)	Sensitivity (%)	Precision (%)	F1 score (%)	AUC
Cross-validation	1st fold	Stain-normalized	97.43	97.42	97.44	97.47	97.45	0.995
		Not normalized	98.54	98.99	98.11	99.00	98.55	0.994
	2nd fold	Stain-normalized	96.7	97.85	95.63	97.85	96.73	0.995
		Not normalized	99.24	100.00	98.50	100.00	99.24	0.999
	3rd fold	Stain-normalized	95.35	96.25	94.49	96.28	95.37	0.990
		Not normalized	96.43	95.10	97.72	95.34	96.52	0.994
	Average	**Stain-normalized**	**96.49**	**97.17**	**95.83**	**97.2**	**96.51**	**0.993**
		Not normalized	**98.07**	**98.03**	**98.11**	**98.11**	**98.10**	**0.996**
Final test	**Test**	**Stain-normalized**	**99.14**	**99.18**	**99.10**	**99.27**	**99.19**	**0.999**
		Not normalized	**99.98**	**100**	**99.97**	**100**	**99.98**	**0.999**

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Performance evaluation on different computer architectures

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Average processing time per WSI
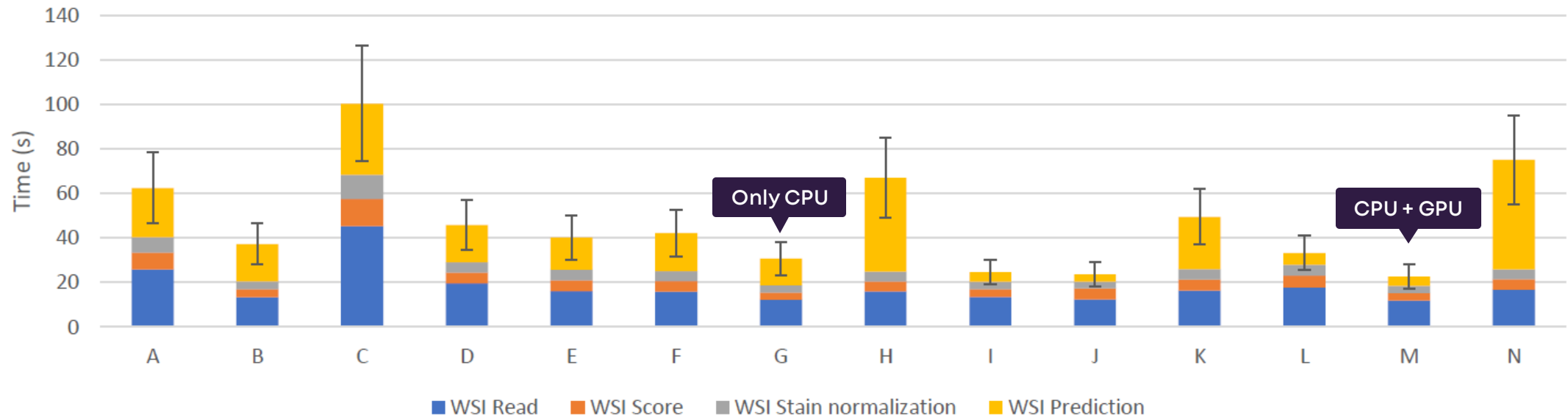
Performance evaluation on different computer architectures

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Device	CPU	GPU
A	Intel® Core™ i7-8850U @ 1.80 GHz 4 cores, 8 threads	-
B	Intel® Core™ i9-7900X @ 3.30 GHz 10 cores, 20 threads	-
C	Intel® Core™ i7-6700HQ @ 1.20 GHz 4 cores, 8 threads	-
D	Intel® Core™ i7-6700HQ @ 2.60 GHz 4 cores, 8 threads	-
E	Intel® Core™ i5-6500 @ 3.20 GHz 4 cores, 4 threads	-
F	Intel® Core™ i7-4770K @ 3.50 GHz 4 cores, 8 threads	-
G	Intel® Core™ i7-8700K @ 3.70 GHz 6 cores, 12 threads	-
H	Intel® Core™ i7-4970 @ 3.60 GHz 4 cores, 8 threads	-
I	Intel® Core™ i9-7900X @ 3.30 GHz 10 cores, 20 threads	NVIDIA® GeForce™ GTX 1080 Ti 11 GB GDDR5X
J	AMD® Ryzen™ 9 3900X @ 4.20 GHz 12 cores, 24 threads	NVIDIA® GeForce™ GTX 1080 Ti 11 GB GDDR5X
K	Intel® Core™ i5-6500 @ 3.20 GHz 4 cores, 4 threads	NVIDIA® GeForce™ GT 730 2 GB GDDR5
L	Intel® Core™ i7-4770K @ 3.50 GHz 4 cores, 8 threads	NVIDIA® GeForce™ GTX 1080 Ti 11 GB GDDR5X
M	Intel® Core™ i7-8700K @ 3.70 GHz 6 cores, 12 threads	NVIDIA® GeForce™ GTX 1080 Ti 11 GB GDDR5X
N	Intel® Core™ i7-4970 @ 3.60 GHz 4 cores, 8 threads	NVIDIA® GeForce™ RTX 2060 6 GB GDDR6

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Performance evaluation compared to other networks

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Average processing time per WSI
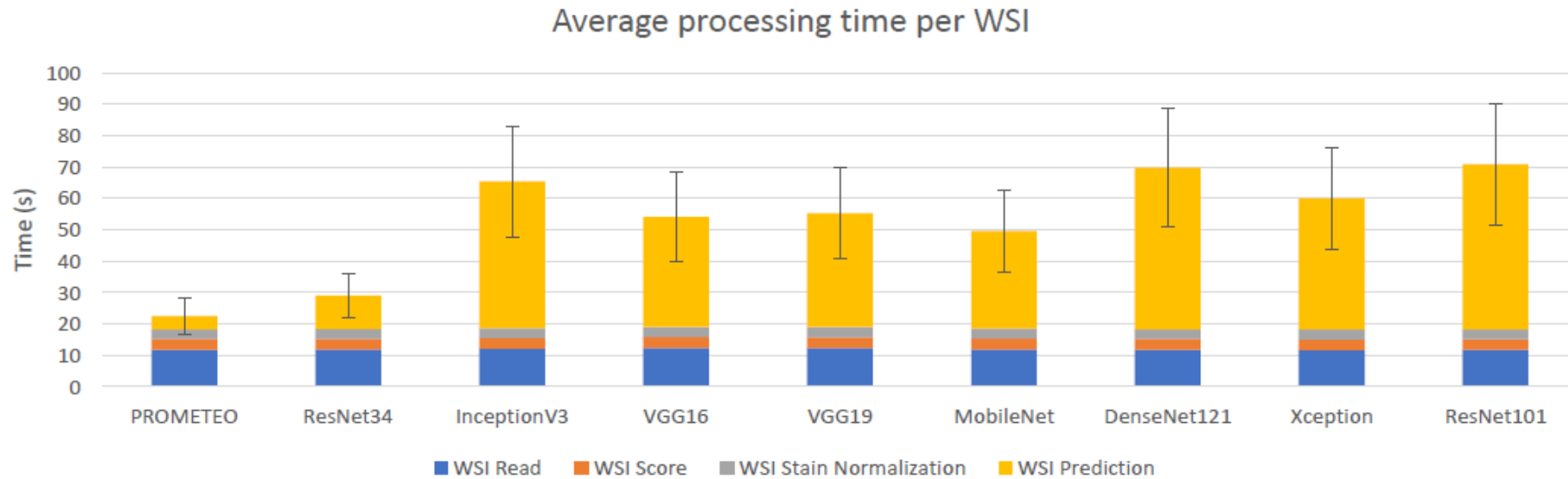
Performance evaluation compared to other networks

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Model	Avg. Prediction Time (patch)	Avg. Prediction Time (WSI)	Slowdown *	Trainable Parameters
PROMETEO	3.054 ± 4.845 ms	4.201 ± 1.739 s	$1\times$	1,107,010
ResNet34	8.982 ± 10.086 ms	10.712 ± 3.134 s	$2.55\times$	21,800,107
InceptionV3	41.301 ± 44.282 ms	49.076 ± 14.353 s	$11.68\times$	23,851,784
VGG16	28.664 ± 9.241 ms	34.921 ± 10.160 s	$8.31\times$	138,357,544
VGG19	29.931 ± 9.305 ms	36.250 ± 10.536 s	$8.63\times$	143,667,240
MobileNet	25.689 ± 10.986 ms	31.110 ± 9.030 s	$7.41\times$	4,253,864
DenseNet121	42.489 ± 16.859 ms	51.483 ± 14.945 s	$12.25\times$	8,062,504
Xception	34.050 ± 11.789 ms	41.764 ± 12.175 s	$9.94\times$	22,910,480
ResNet101	43.287 ± 14.679 ms	52.517 ± 15.266 s	$12.50\times$	44,707,176

* Calculated by using the average prediction time per WSI and taking the PROMETEO architecture as reference. A slowdown of $A\times$ means that model B is A times slower than PROMETEO.

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Barebone

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Especs

CPU AMD Ryzen 5 5600X

Hard Drive SSD M.2 1TB

RAM 16GB DDR4 3200 MHz

GPU NVIDIA GTX 1660 6GB DDR5

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Conclusions

- Our Prometeo system recognizes with a 99.98% percentage of success images of healthy and cancerous tissue.
- Our algorithm could be very useful in supporting the Pathologist when making a decision.
- Prometeo has been validated by expert Pathologists.
- Performance of 15" per image (20" on average).

Next steps

- This technique can be applied to other Pathology Anatomy Images.

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diagnosis support

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