

# Hands-on Introduction to Deep Learning

Raúl Benítez, PhD  
[raul.benitez@upc.edu](mailto:raul.benitez@upc.edu)



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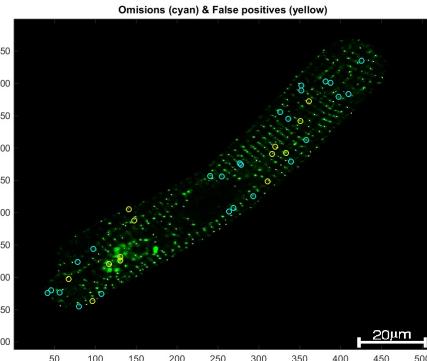
Centre de Recerca en Enginyeria Biomèdica



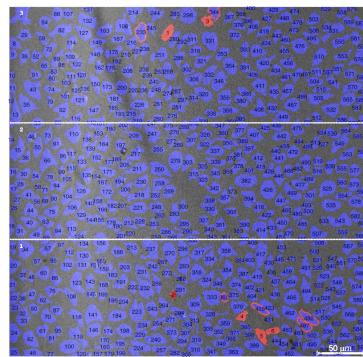
16th International Work-Conference on Artificial Neural Networks IWANN 2021  
(June, 16th-18th, 2021, virtual conference)

# ANALYSIS OF MEDICAL & BIOLOGICAL IMAGES

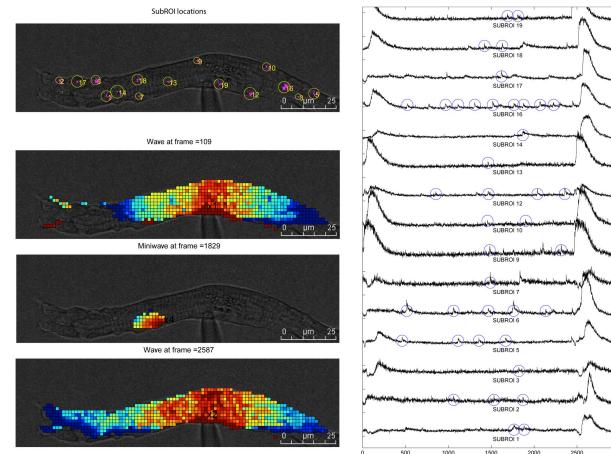
Molecular receptors



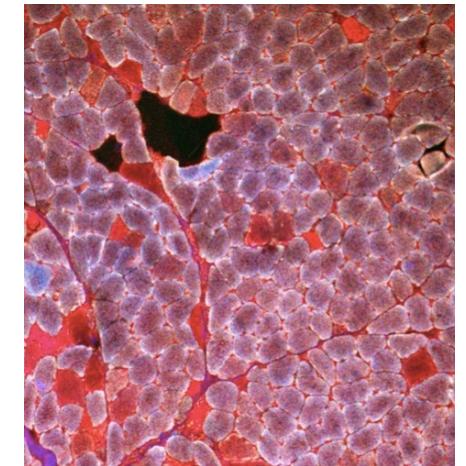
Cell cultures



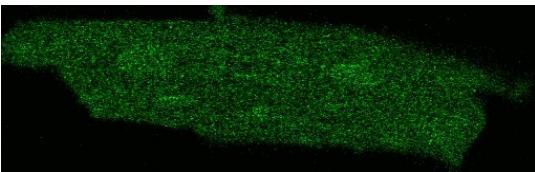
Calcium dynamics



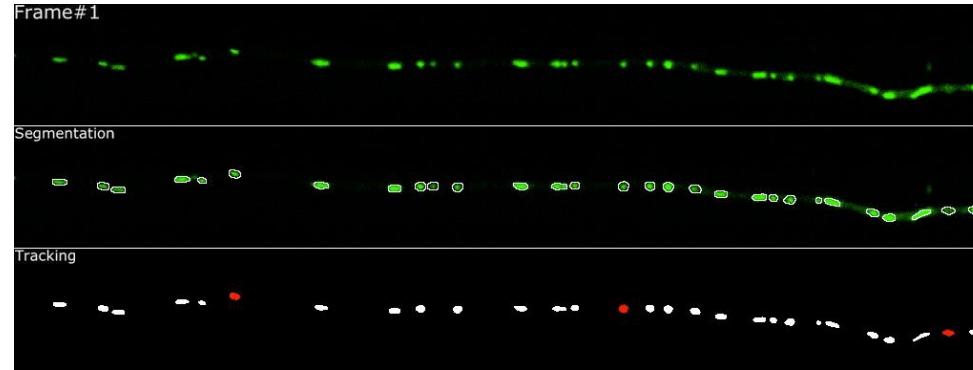
Digital Pathology



Single-cell experiments

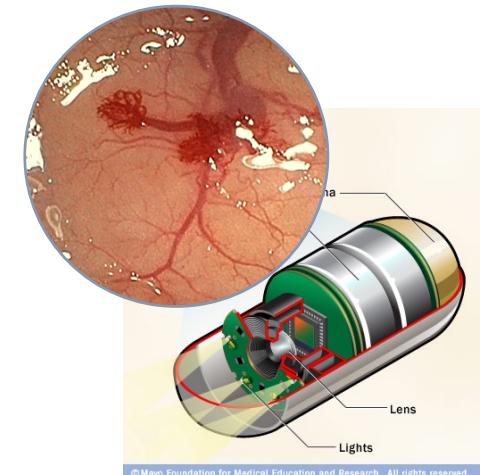


Mitochondrial transport



Extraction & analysis of multiscale biomarkers

Wireless endoscopy



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# SCOPE

**YES**

DL for image analysis – Computer vision  
Convolutional Neural Networks  
Basic interpretability methods

**NO**

Recurrent networks – LSTM –Time signals  
Generative Adversarial Networks (GAN)  
No deep Reinforcement Learning

# Overview and methodology

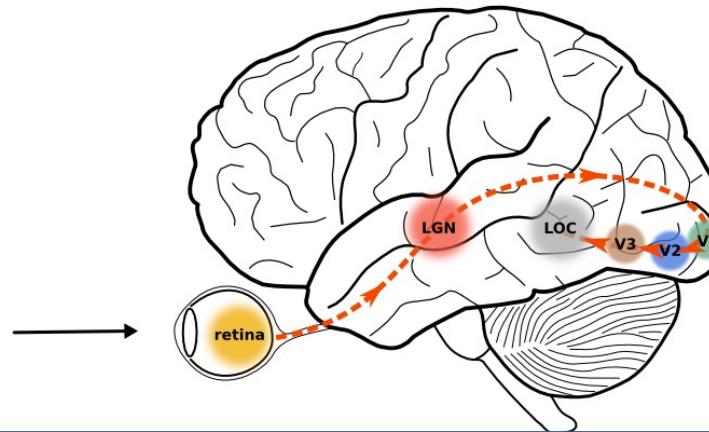
- General introduction
- MNIST data exploration
- The Traditional ML approach
- The DL approach: Transfer learning vs. Trained features
- DL interpretability



[https://github.com/raulbenitez/IWANN2021\\_DL\\_tutorial](https://github.com/raulbenitez/IWANN2021_DL_tutorial)

# CHANGE IN PARADIGM

Human pattern  
recognition



UPC Mug

Traditional  
Machine Learning

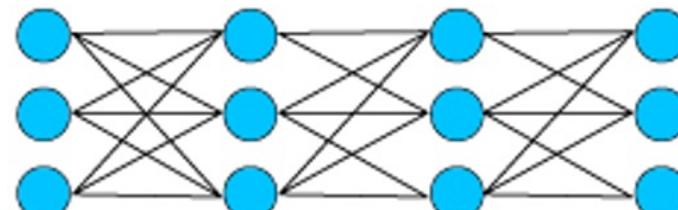


Feature Extraction  
(texture, size,  
shape, orientation)

Supervised  
Classifier

UPC  
Mug

Deep Learning



Feature extraction + Classification

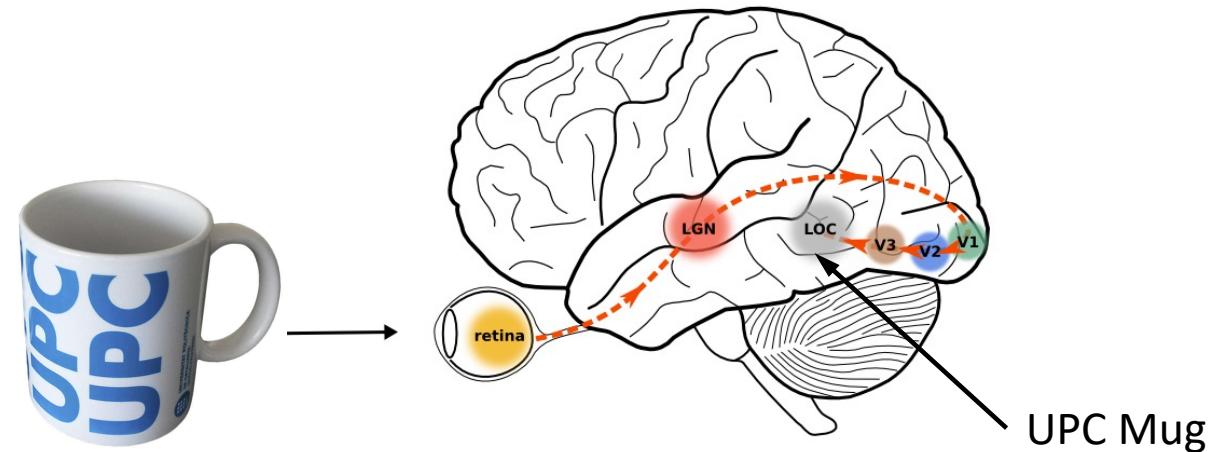
UPC Mug

# Deep Learning – Convolutional Neural Networks

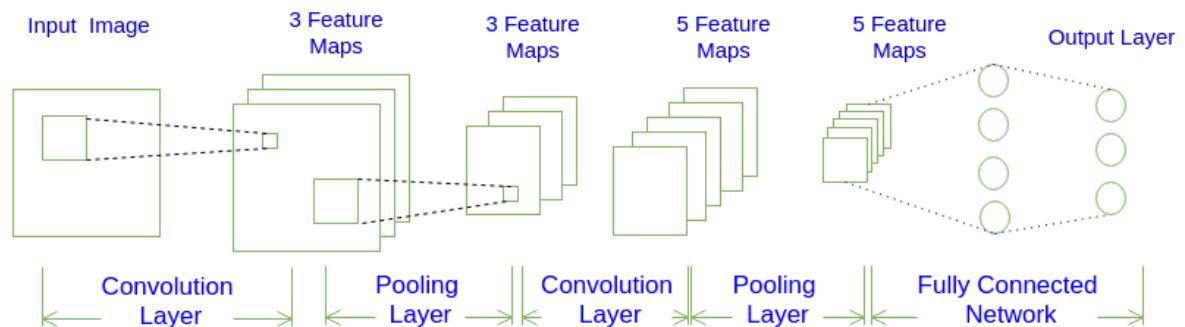
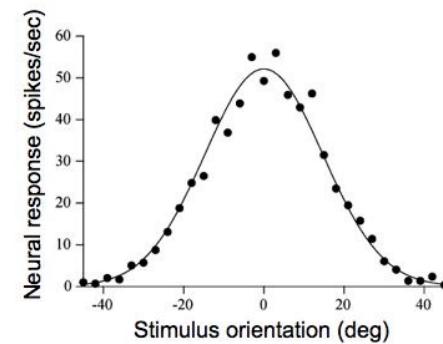
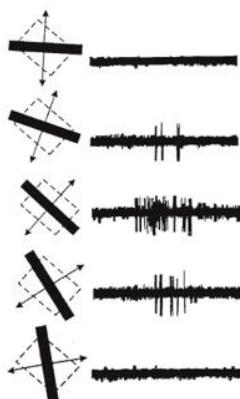
Hubel & Wiesel: Neural basis of visual perception

LGN: Lateral Geniculate Nucleus

V1: Primary Visual cortex

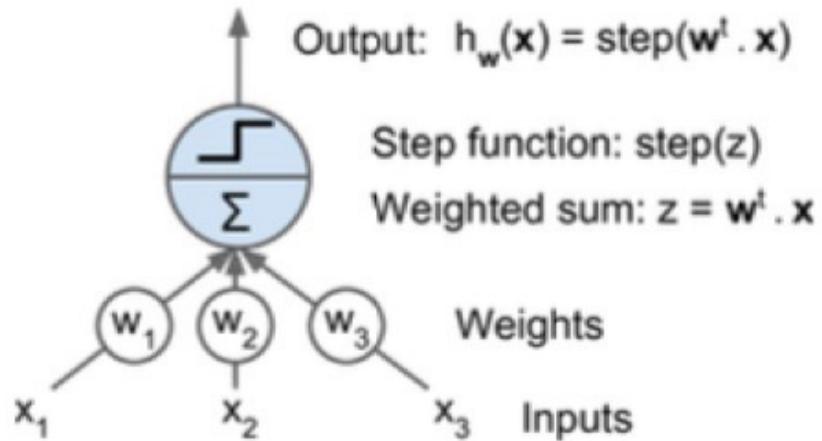


V1 physiology: orientation selectivity

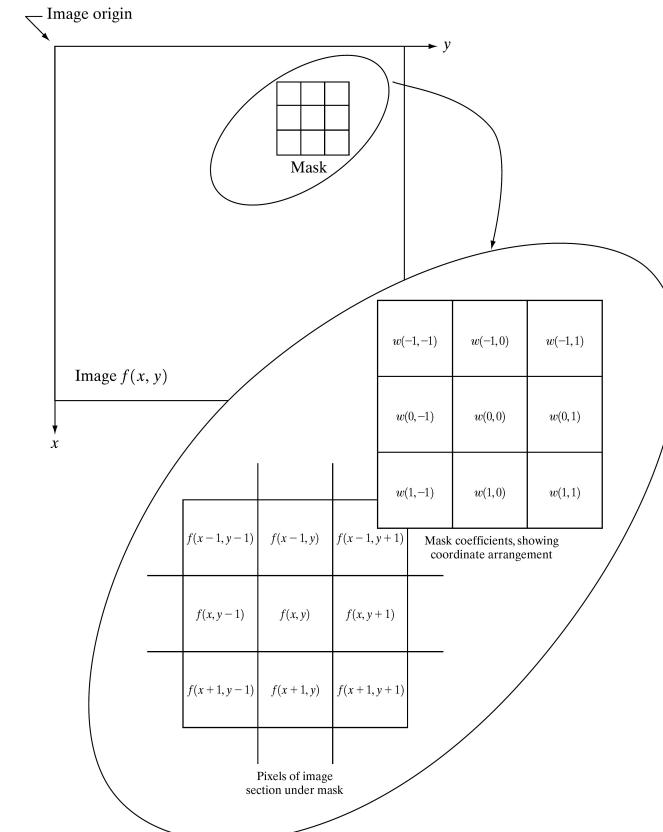


# Convolutional filters

## Neural Network



Training / learning weights:  
Hebbian rule “wiring by firing”

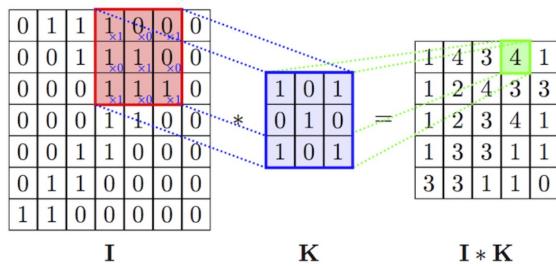


$$g(x,y) = \sum_{s=-a}^a \sum_{t=-b}^b w(s,t) \cdot f(x+s, y+t)$$

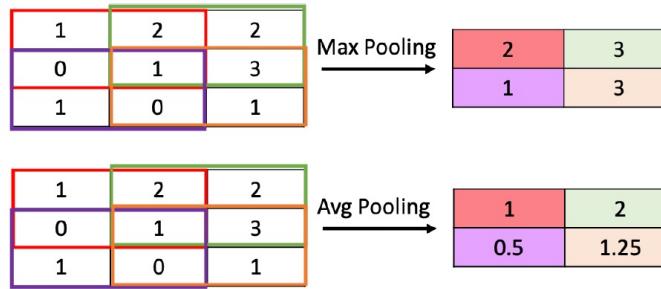


# Basic elements of a CNN architecture

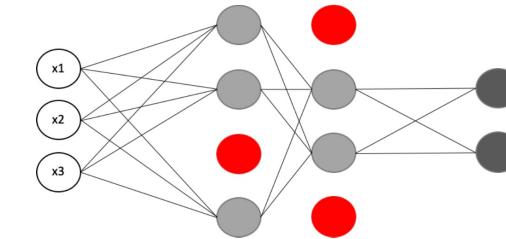
Convolutional layers



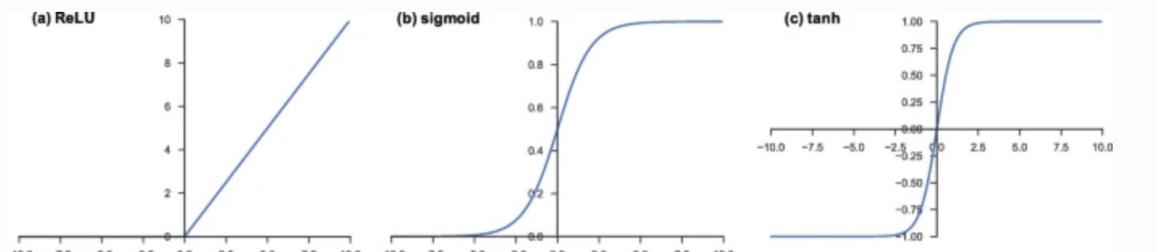
Pooling layers



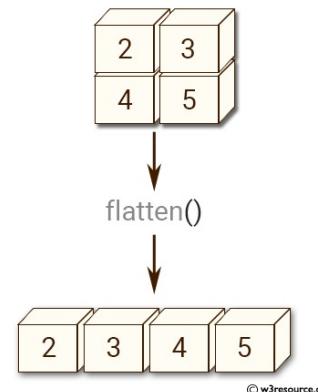
dropout layers



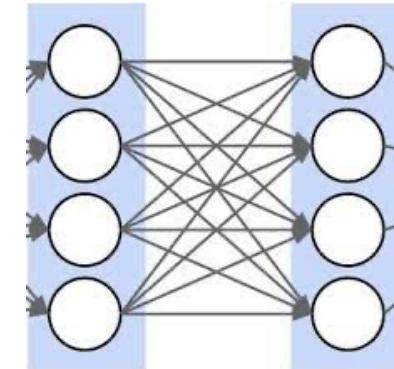
Activation layers



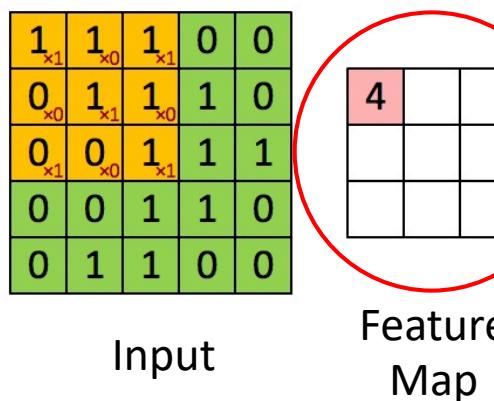
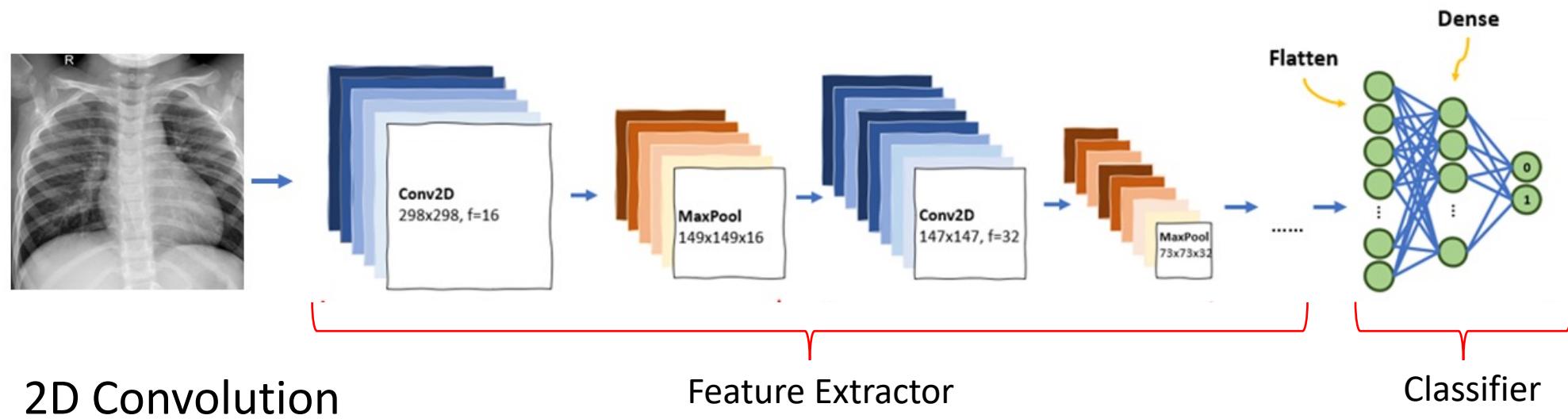
flatten layers



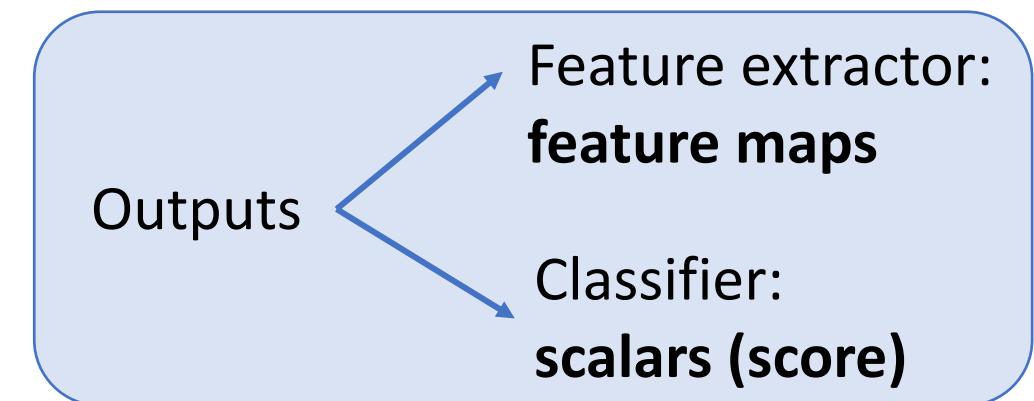
Fully connected layers  
(Classification)



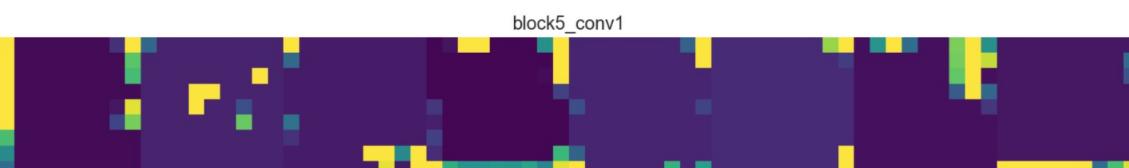
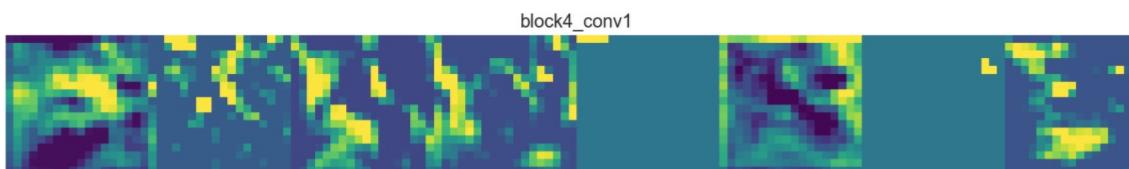
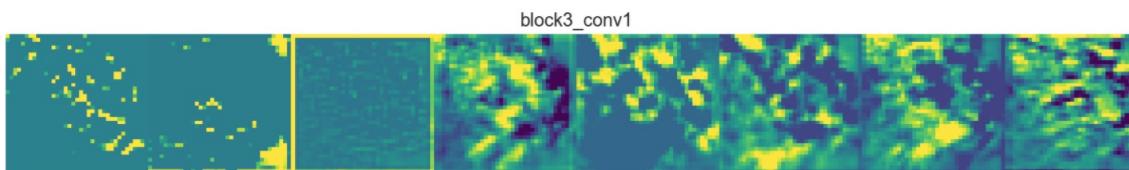
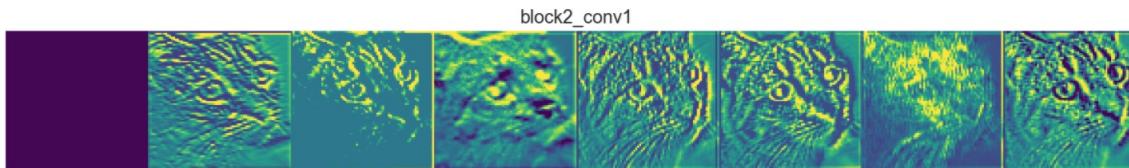
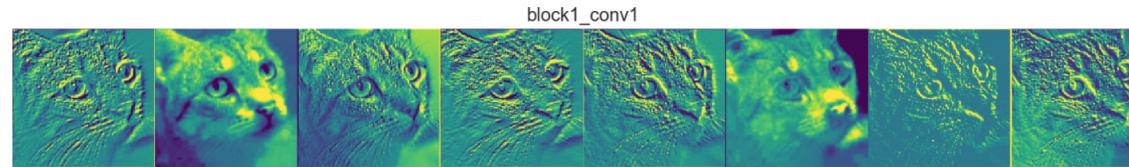
# CONVOLUTIONAL NEURAL NETWORKS



retain spatial  
information of  
the input

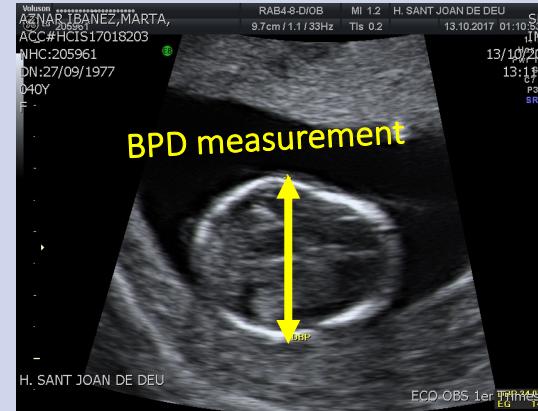
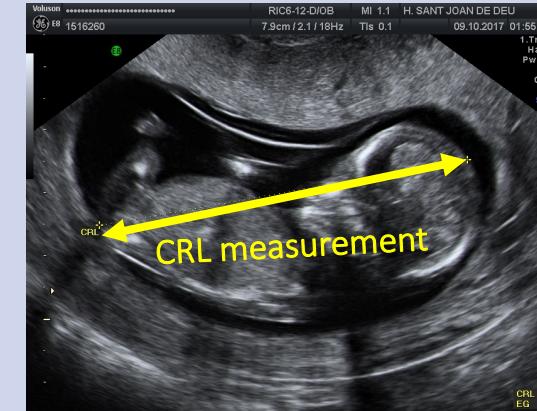
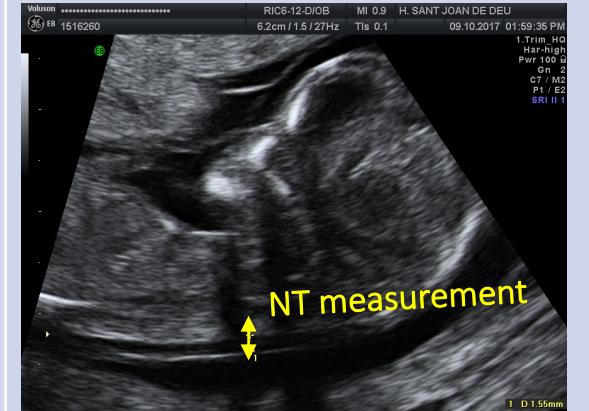


# CNN: FEATURE MAPS



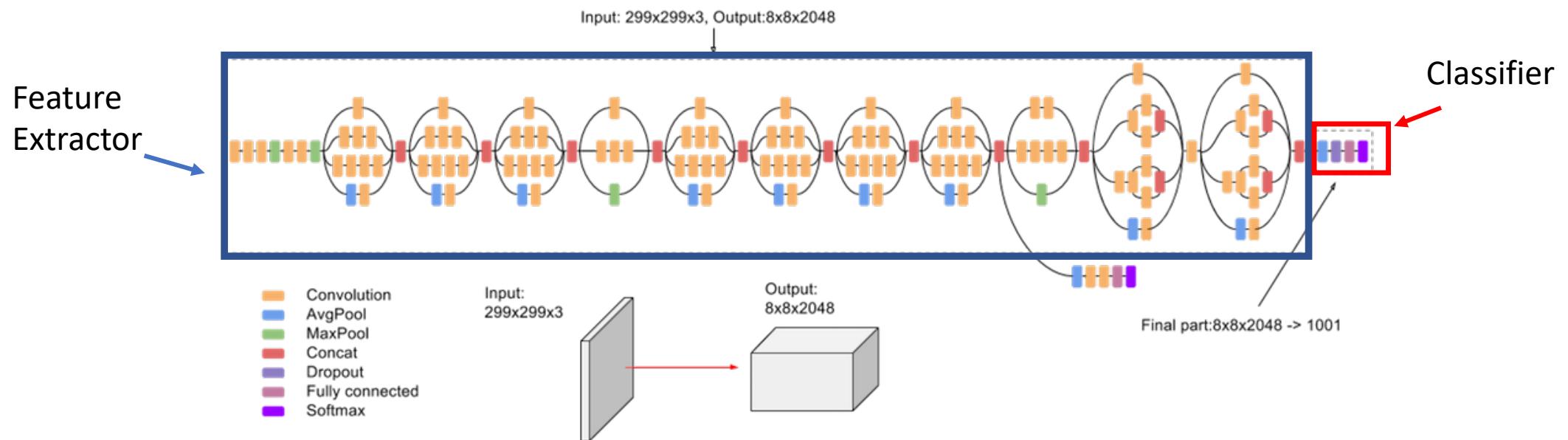
abstraction

# EXAMPLE: FETAL BIOMETRIC PLANES

PLANE	BPD	CRL	NT
MEASUREMENT	Biparietal Diameter (BPD)	Crown-Rump length (CRL)	Nuchal Translucency (NT)
MAIN UTILITY	Check fetal development and establish gestational age	Establishes gestational age	Detect chromosomal anomalies
EXAMPLE	 <p>BPD measurement</p>	 <p>CRL measurement</p>	 <p>NT measurement</p>

# TRANSFER LEARNING WITH INCEPTION V3

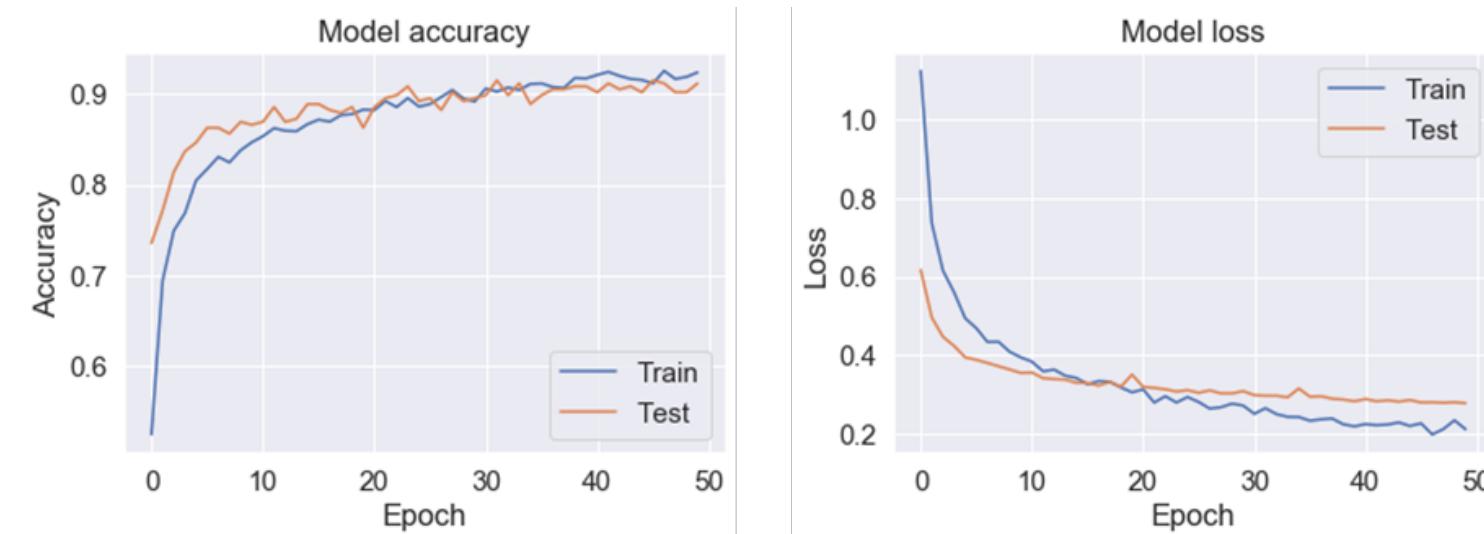
- Inception V3 was trained with ImageNet dataset (1.2M images of 1000 different classes)



- Trainable Parameters: 24M  $\rightarrow$  6127

# 4. EXPERIMENTAL RESULTS AND ANALYSIS

## MODEL PERFORMANCE



A confusion matrix table showing the performance of the model across three classes: BPD, CRL, and NT. The columns represent the Predicted class and the rows represent the True class. The matrix is color-coded, with darker shades indicating higher values. A bracket on the left indicates that the first row corresponds to the True class.

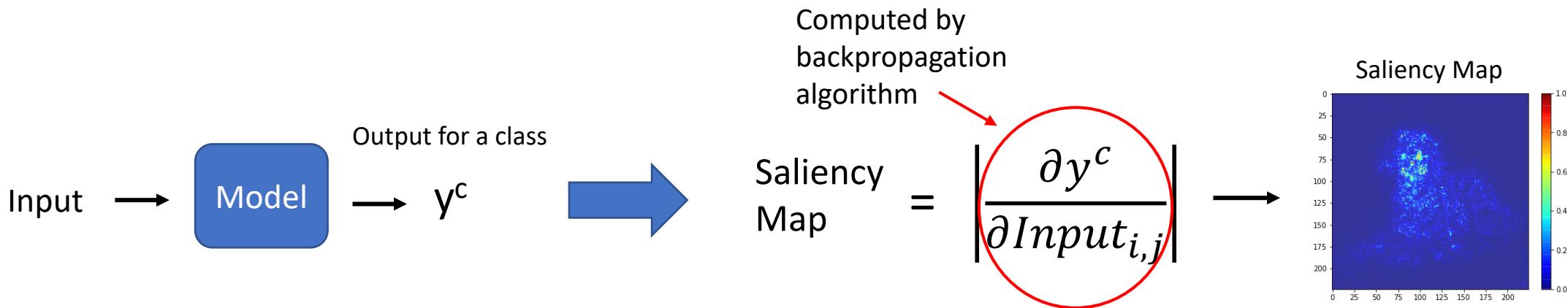
True class	Predicted class		
	BPD	CRL	NT
BPD	0.90	0.05	0.05
CRL	0.03	0.93	0.04
NT	0.02	0.06	0.92

# INTERPRETABILITY METHODS

FINAL MASTER THESIS: VISUAL INTERPRETABILITY  
OF DEEP LEARNING ALGORITHMS IN MEDICAL  
APPLICATIONS, Christian Jorba, MASTER IN ENGINEERING  
PHYSICS - UPC

# SALIENCY MAPS

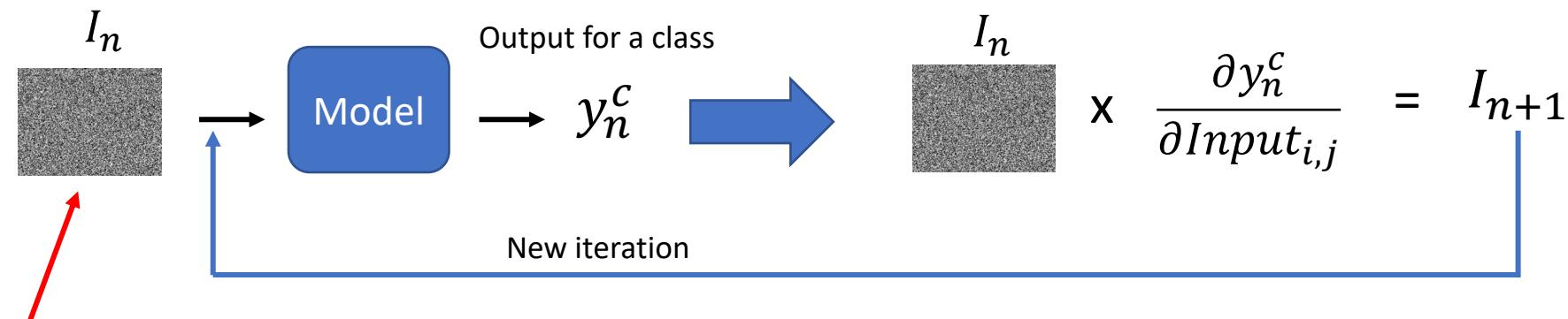
- This method shows the most sensible parts of the input image for the model



- High values represent the most important features or regions of the input to be classified in an specific class
- Fast to compute

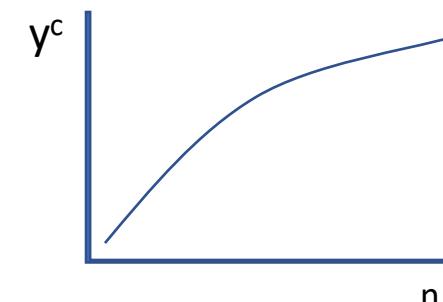
# ACTIVATION MAXIMIZATION

- Method that allows to obtain an input that maximizes the score of a certain class
- Useful to see what patterns of the input are characteristics of each class



Starts with a neutral  
image (noise)

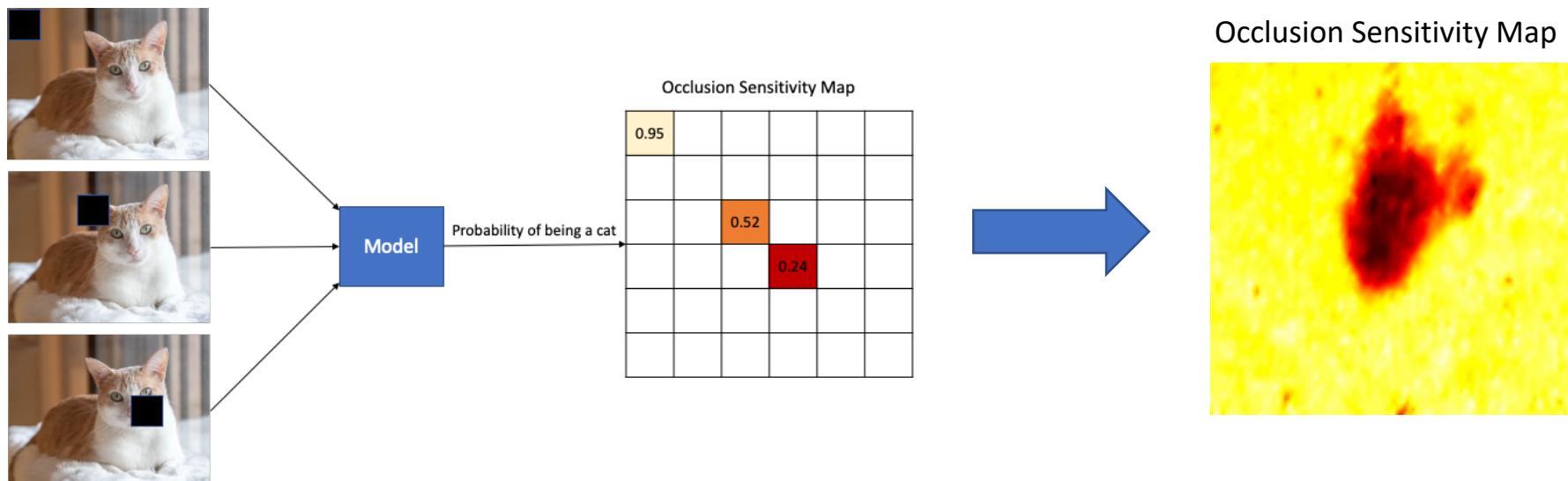
- Slow performance



We are getting the image  
that best represents a class

# OCCLUSION SENSITIVITY MAPS

- Technique based on dividing the input image into a grid, and hiding each cell to make a prediction with the model
- High score → unimportant feature | Low score → important feature



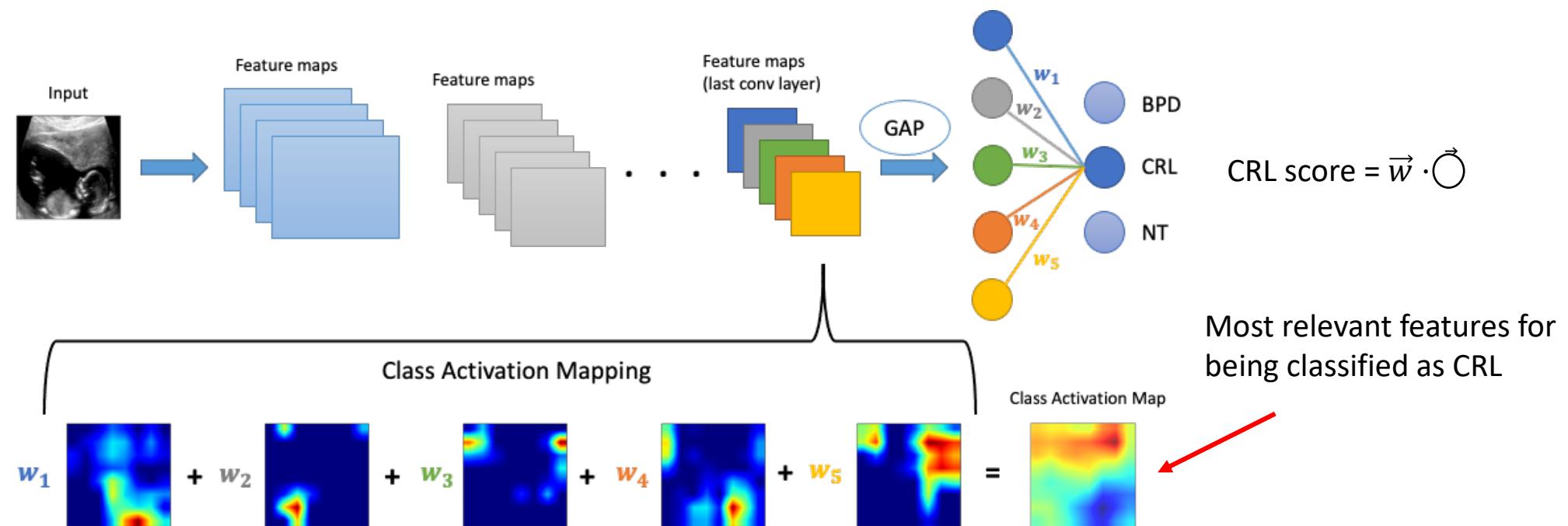
- Slow process

# CLASS ACTIVATION MAPPING

Locate in which parts the classifier is focusing to decide that a sample belongs to one class or another

- CAM takes advantage of

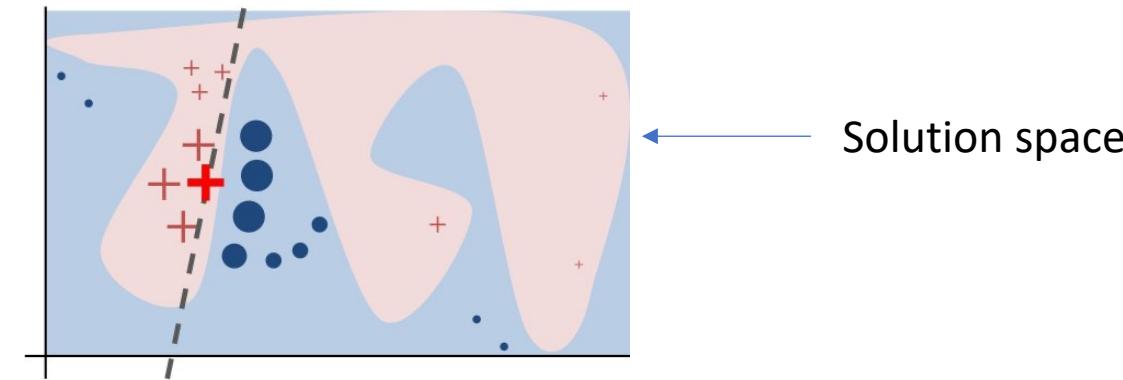
- An specific CNN architecture (GradCAM generalizes it)
- Feature maps retain spatial information



- Very fast to compute

# Local interpretable model-agnostic explanations (LIME)

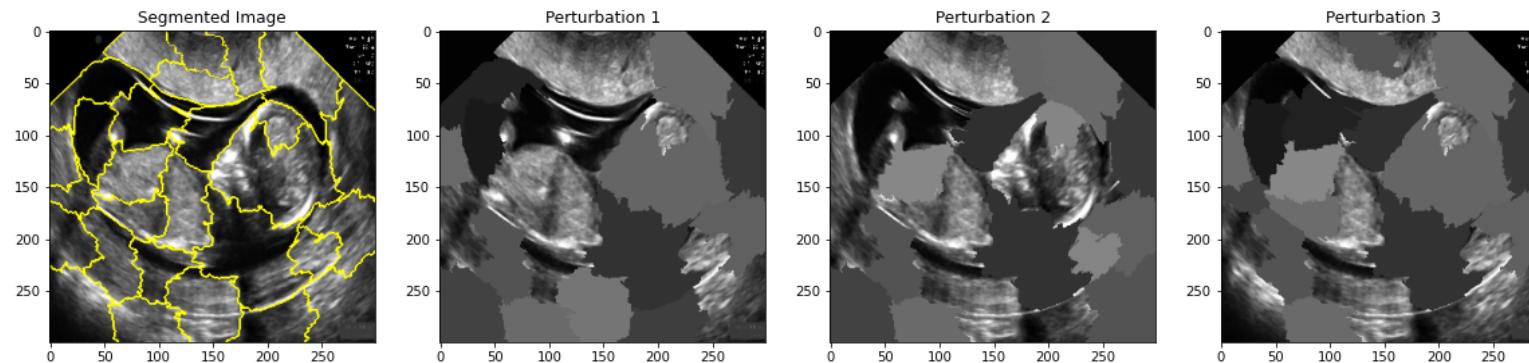
- This method consists of building a simpler model, normally a linear model, on top of the CNN
- By doing that, we can interpret the complex model using the simple one



- How can we obtain the points near the prediction of the simple that we want to interpret? → **Superpixels**

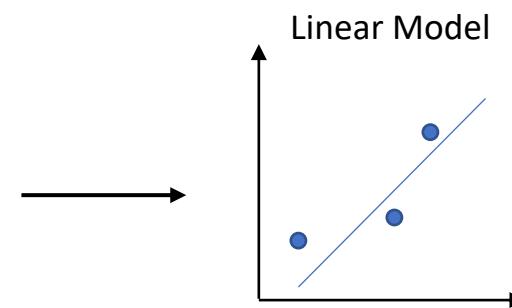
# LIME

- Superpixels are obtained by segmentation and they are disturbed randomly



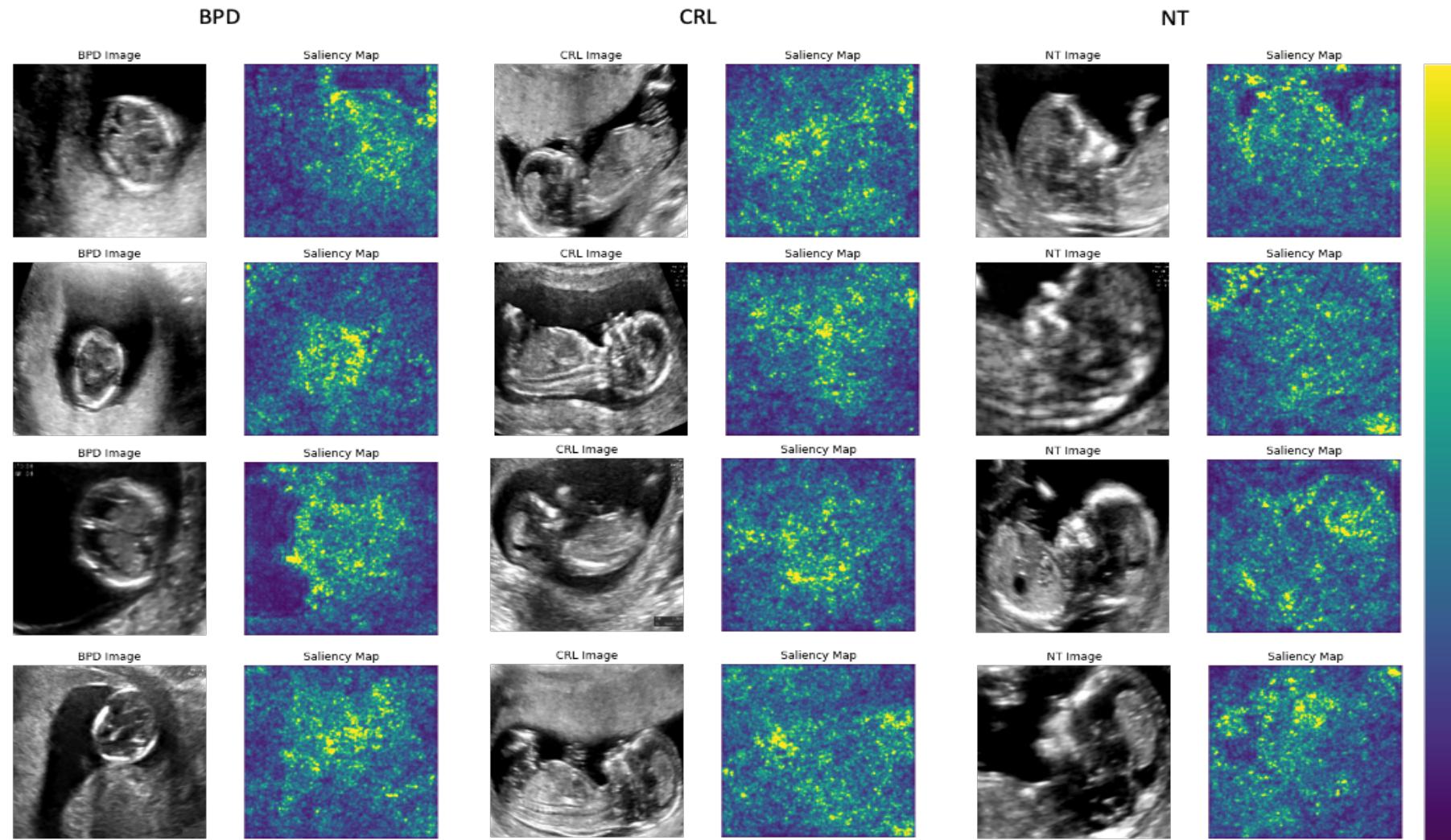
- Disturbed superpixels are encoded with a 0 in the feature vector, while the active pixels with a 1

Feature Vectors	Score
(0, 1, 1, 0, ....)	→ 0.91
(1, 1, 1, 0, ....)	→ 0.74
(0, 0, 1, 1, ....)	→ 0.55



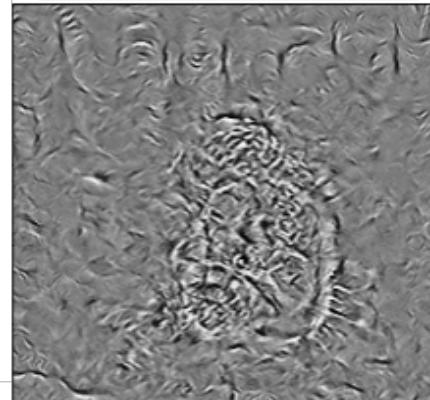
- Very slow

# SALIENCY MAPS

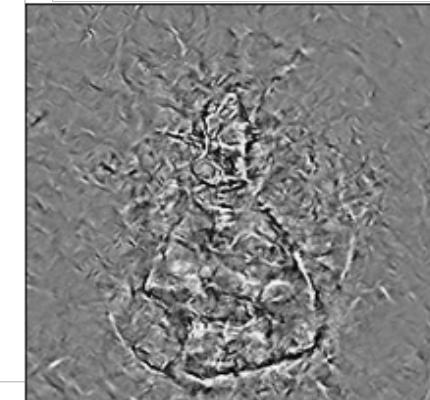


# ACTIVATION MAXIMIZATION

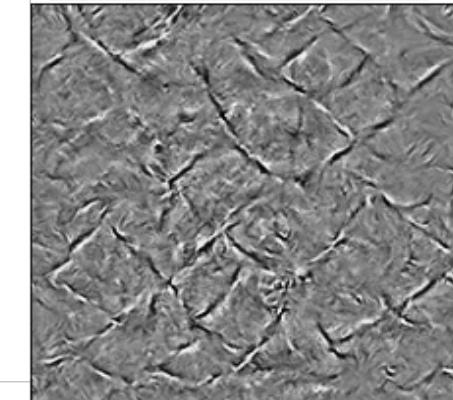
BPD class Maximization



CRL class Maximization



NT class Maximization



BPD image example



CRL image example

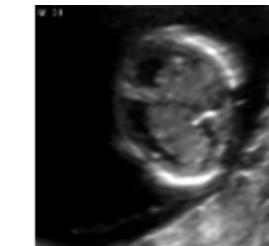
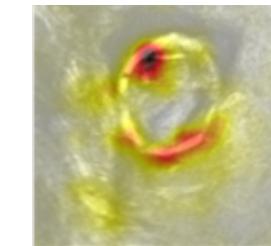
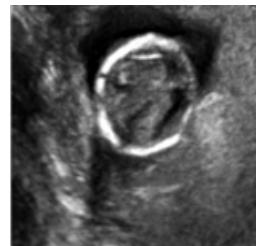


NT image example

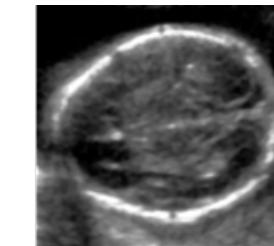
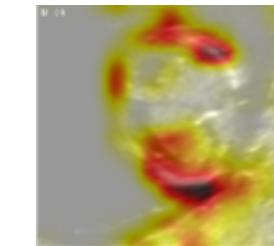
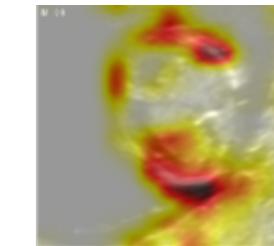


# OCCLUSION SENSITIVITY

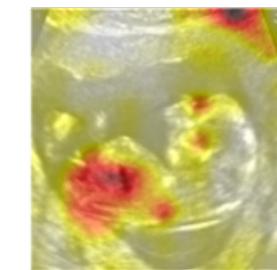
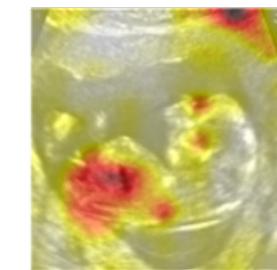
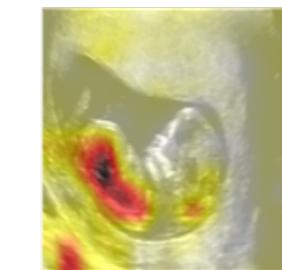
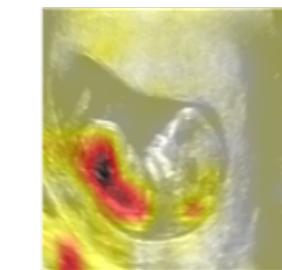
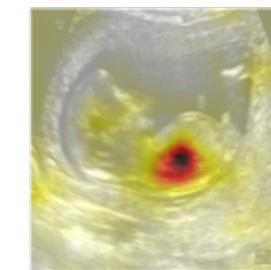
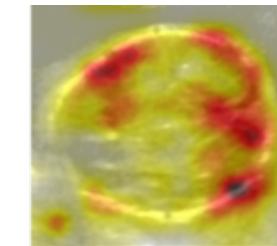
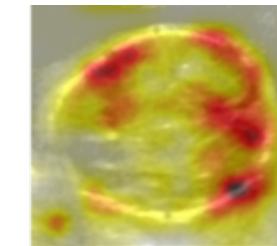
Example 1



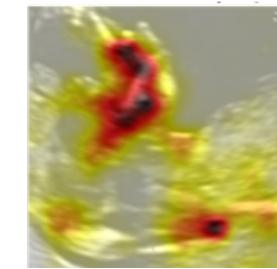
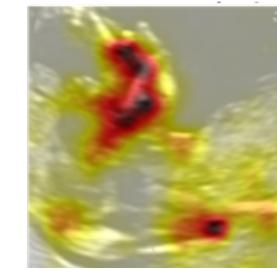
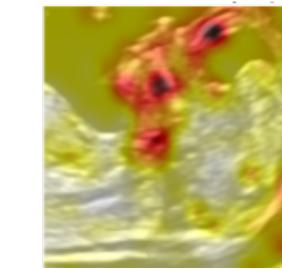
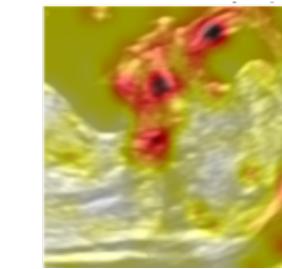
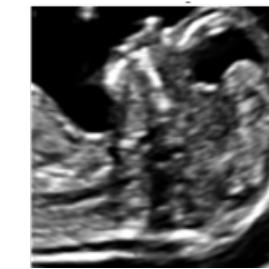
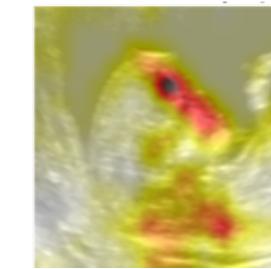
Example 2



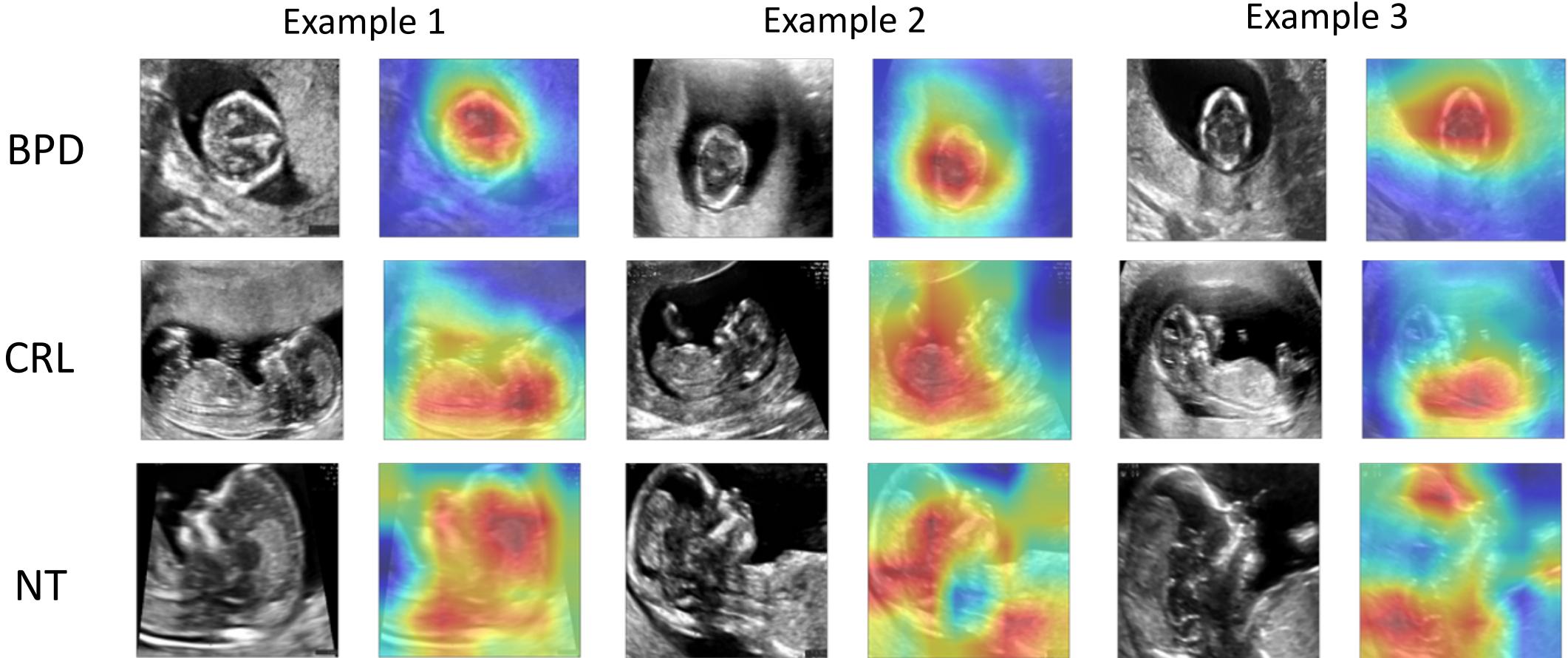
Example 3



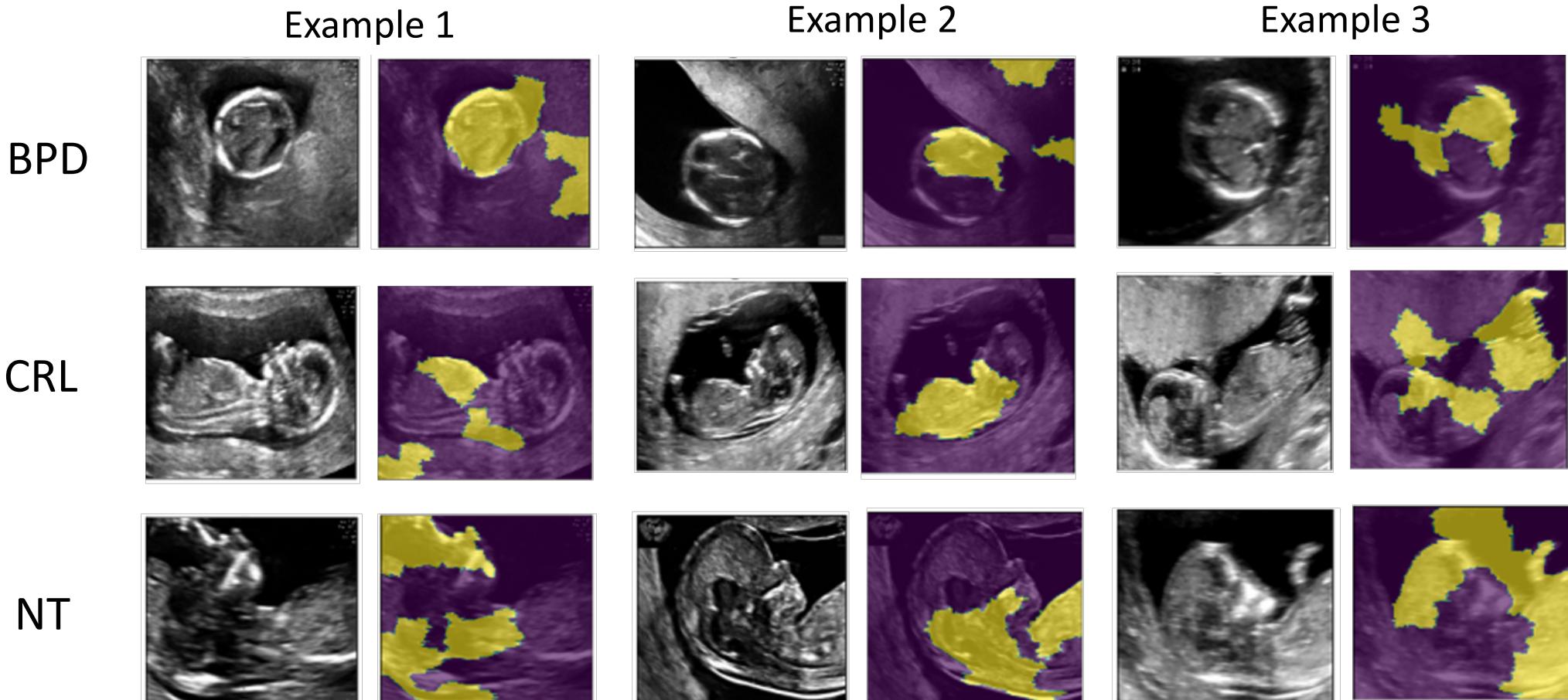
NT



# CLASS ACTIVATION MAPPING

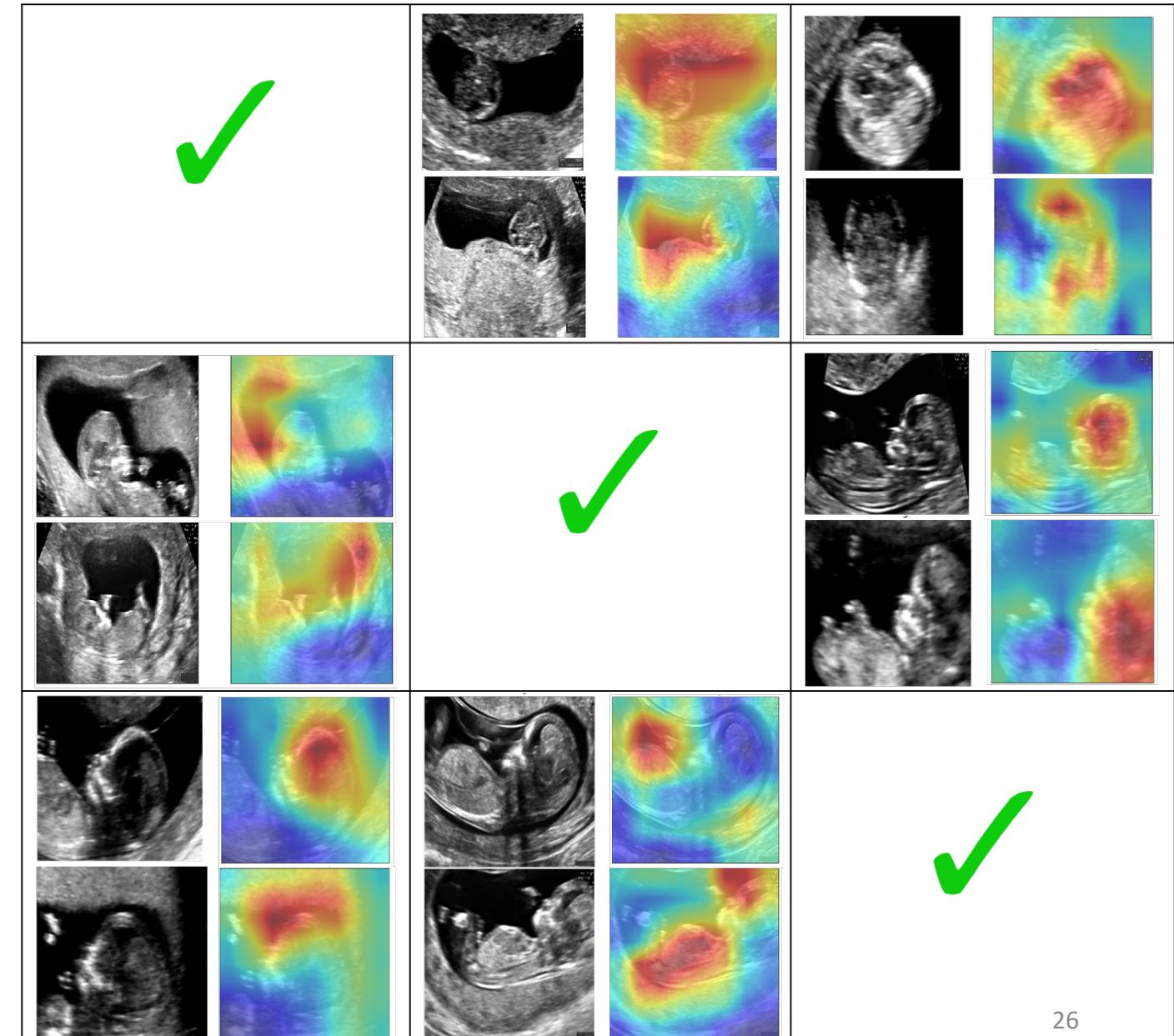


# LIME



# MISCLASSIFICATIONS

		Predicted class		
		BPD	CRL	NT
Correct class	BPD	✓	✗	✗
	CRL	✗	✓	✗
	NT	✗	✗	✓



# CONCLUSIONS

- Transfer Learning works very well with ultrasound images
- All interpretation techniques gives you valid information
- Our results are extrapolable to other problems
- Occlusion method gives us the best results for well classified samples
- CAM works well to explain misclassified samples