An Improved CNN Steganalysis Architecture based on "Catalyst Kernels" and Transfer Learning

Rabii El Beji Marwa Saidi Houcemeddine Hermassi Rhouma Rhouma

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Université de Tunis El Manar, Ecole Nationale d'Ingénieurs de Tunis, LR16ES07 Robotique, Informatique et Systèmes Complexes, Tunis, Tunisia

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Introduction to Steganograpy and Steganalysis

What's Stenography?

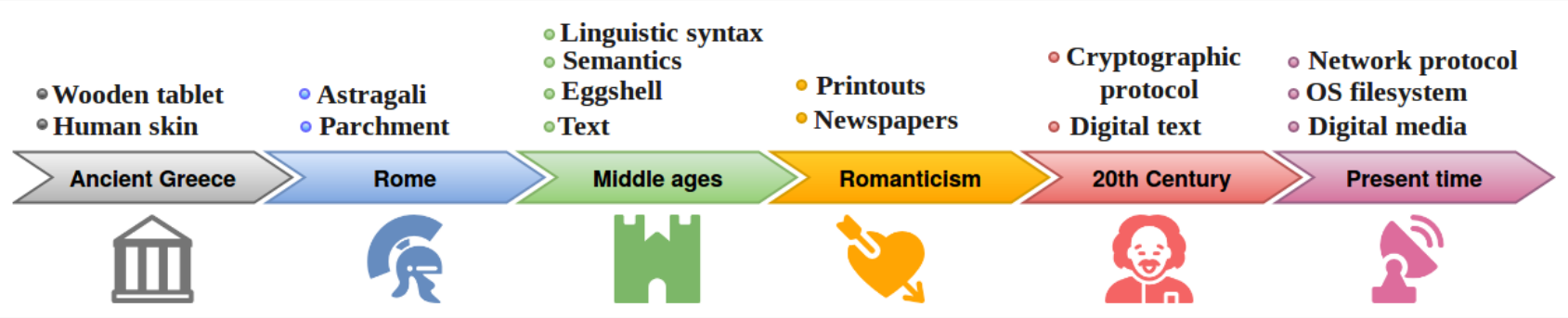
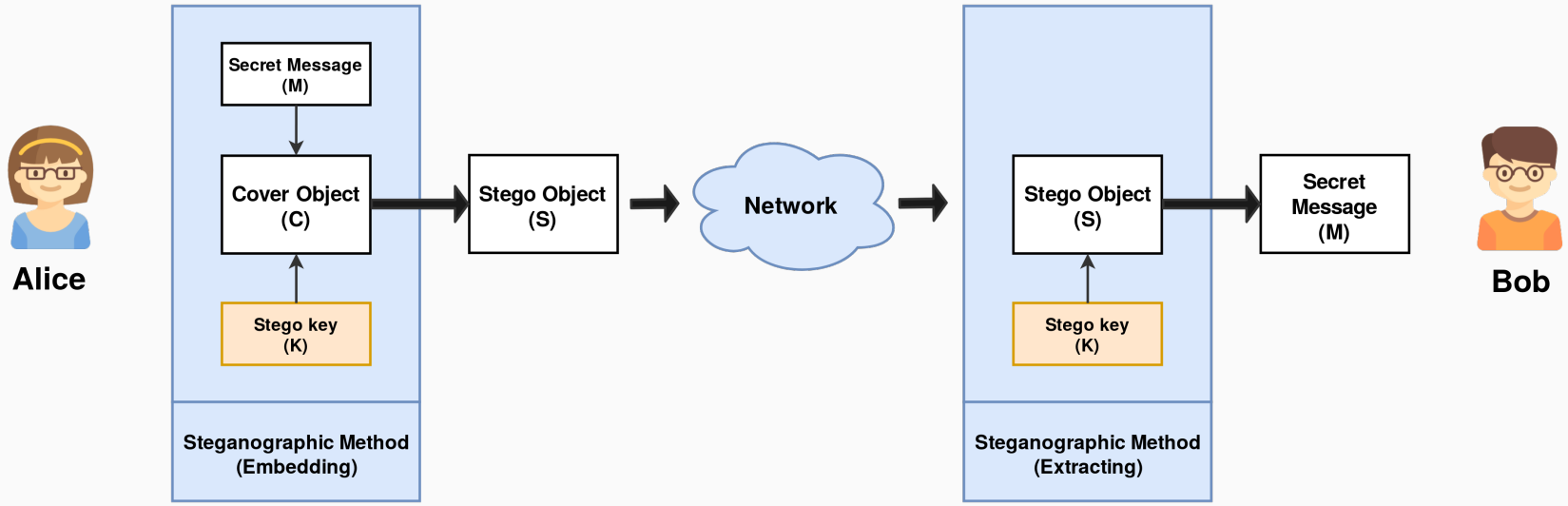


Figure: A timeline of the evolution of steganographic techniques

Recently, Four main trends of development of the so-called digital steganography can be distinguished:

- Linguistic steganography
- File system steganography
- Network steganography
- **Digital media steganography**

A Stegosystem !

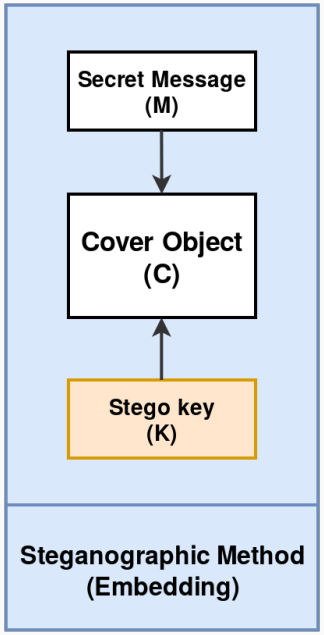


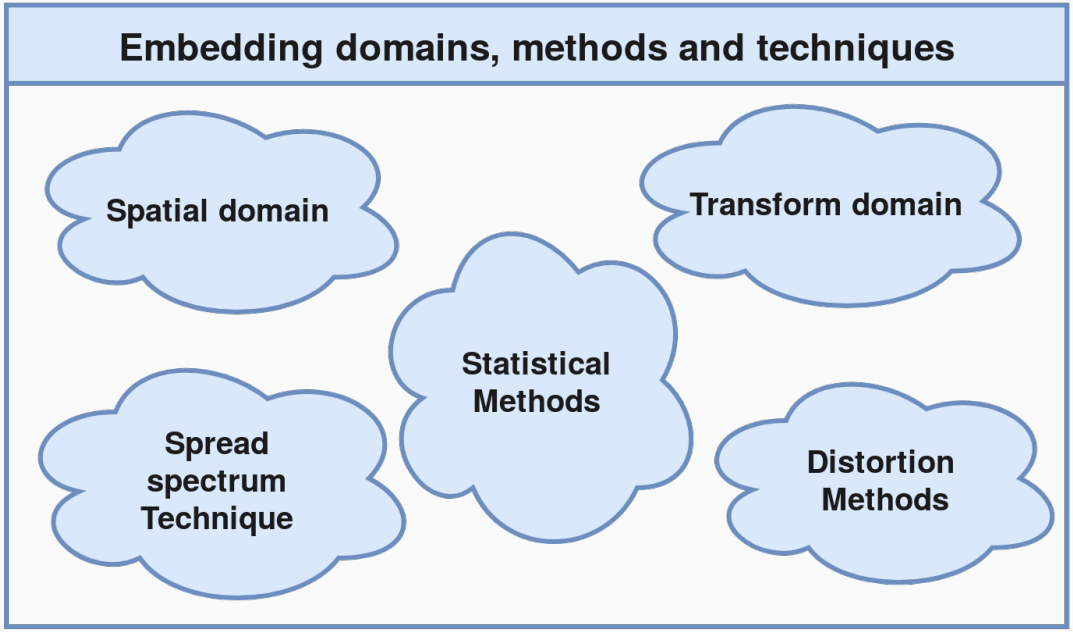
The main keywords used in the most stegosystems are:

- Cover Object
- Stego Object
- Stego Key
- Embedding Domain

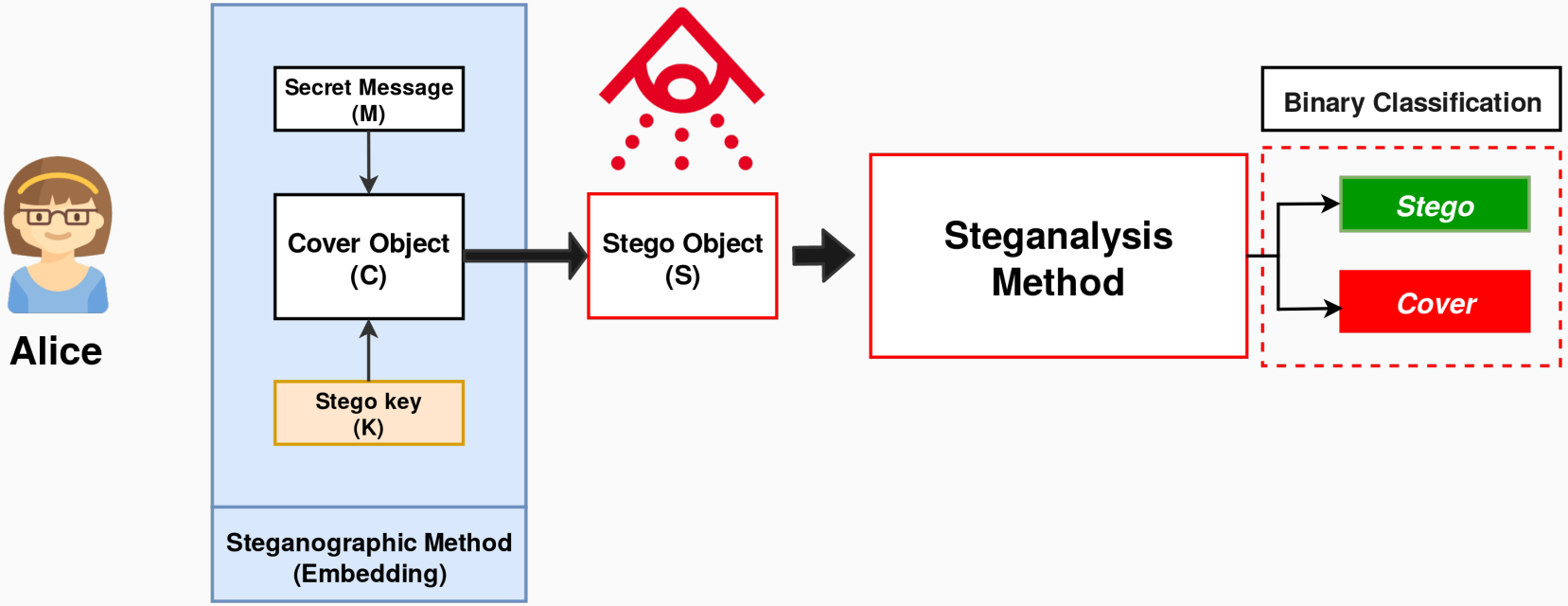
Steganographic Embedding Domains

Alice

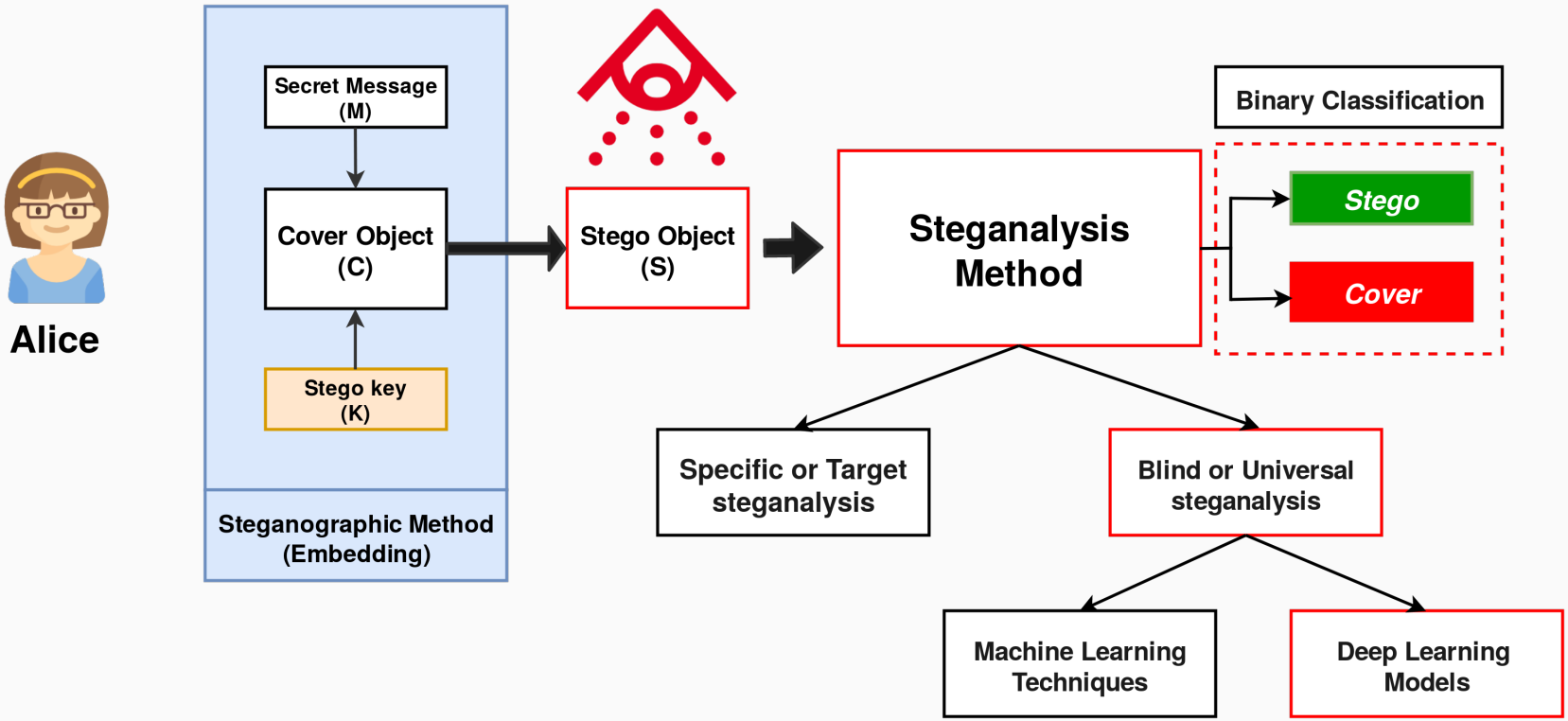




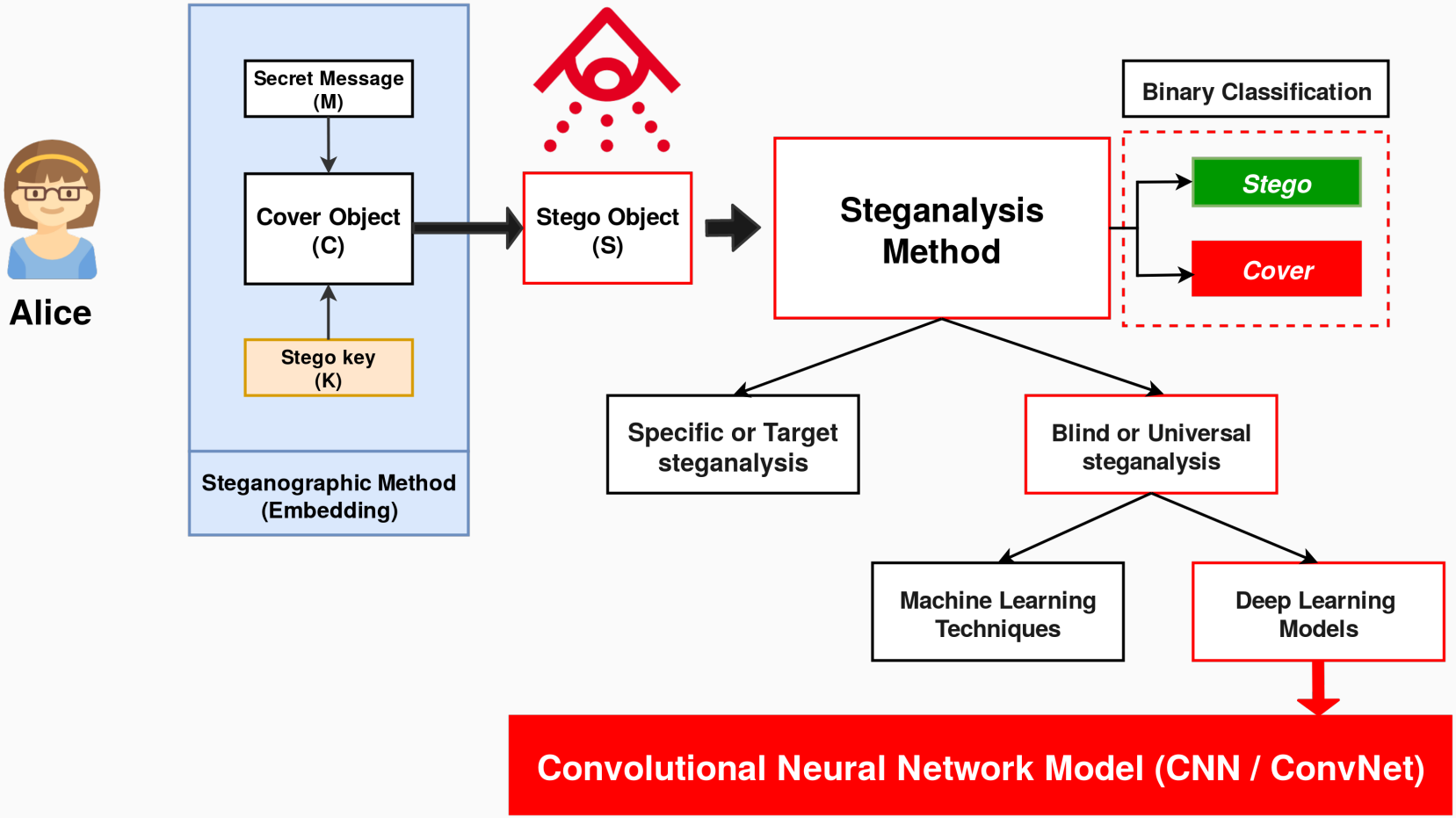
Steganalysis



steganalysis

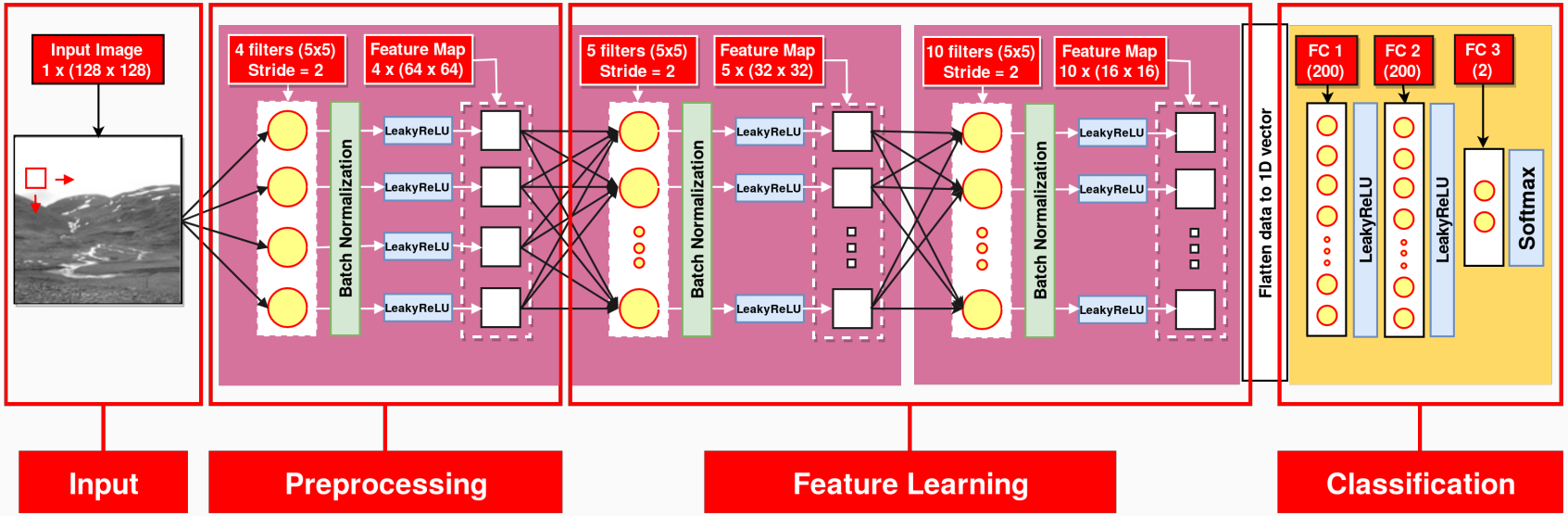


steganalysis



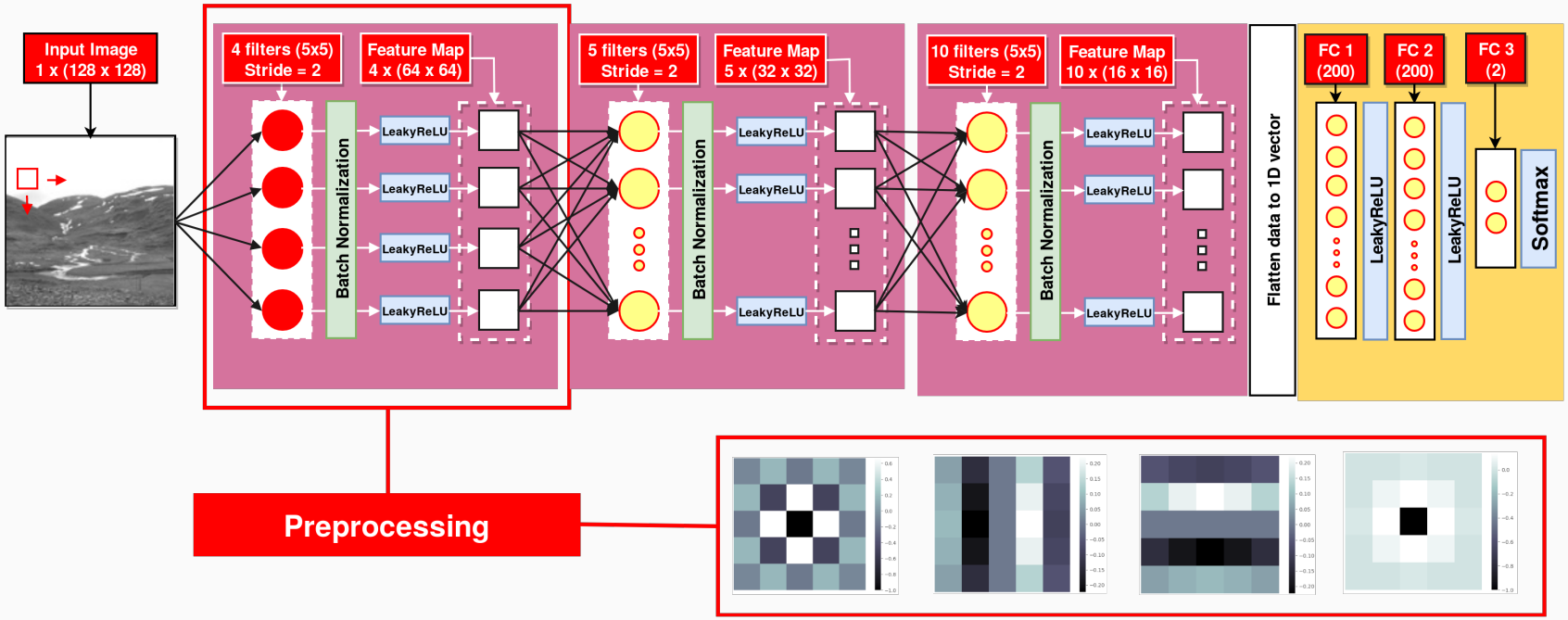
Proposed CNN Model

Proposed CNN Model



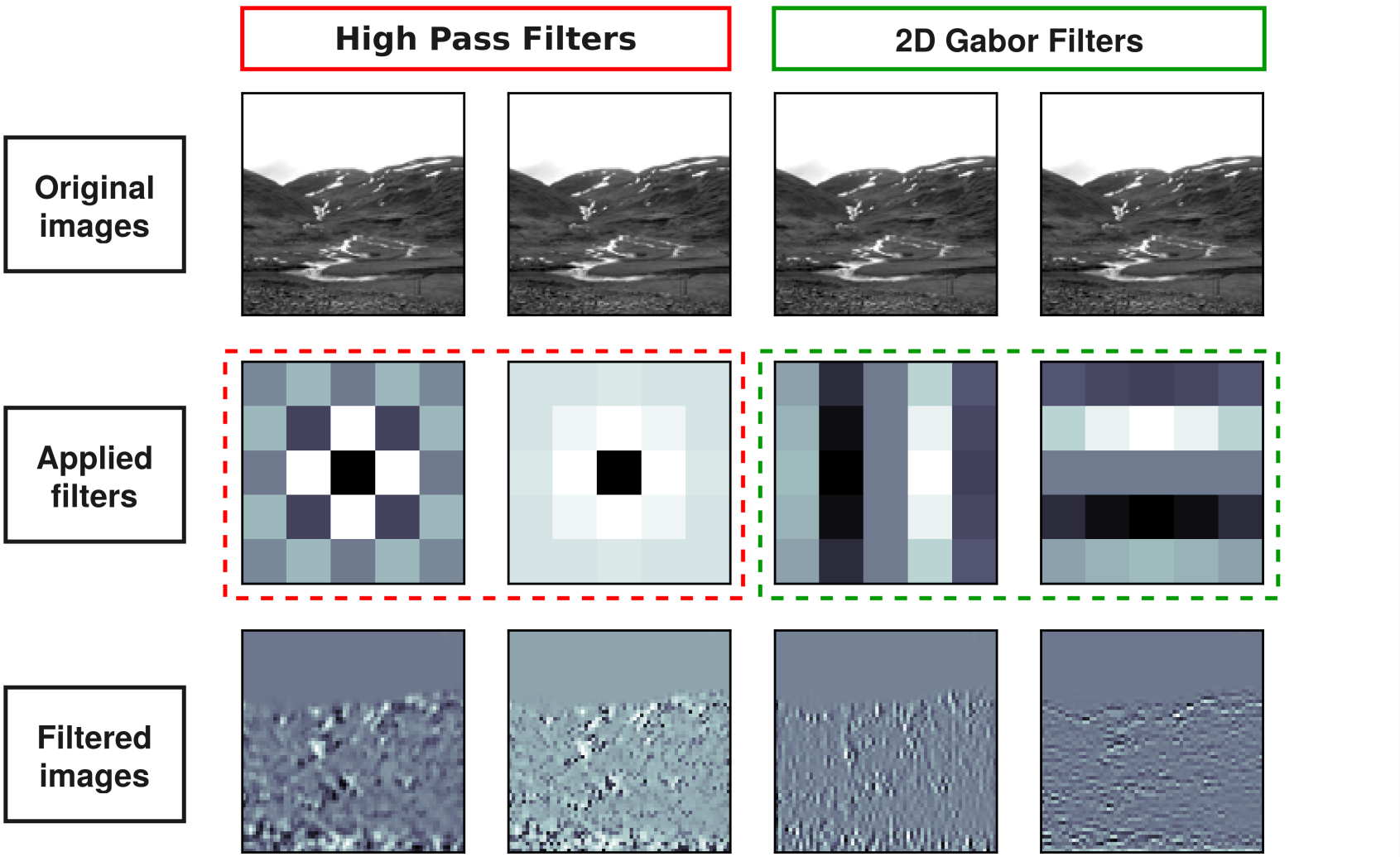
- An input image in grayscale with a size of 128×128 pixels
- Three hidden or convolution layers
  - One convolution layer for preprocessing
  - Two convolution layers for dynamic learning
- Three fully connected layers for classification + *Softmax* classifier

Preprocessing layer using "Catalyst Kernels"

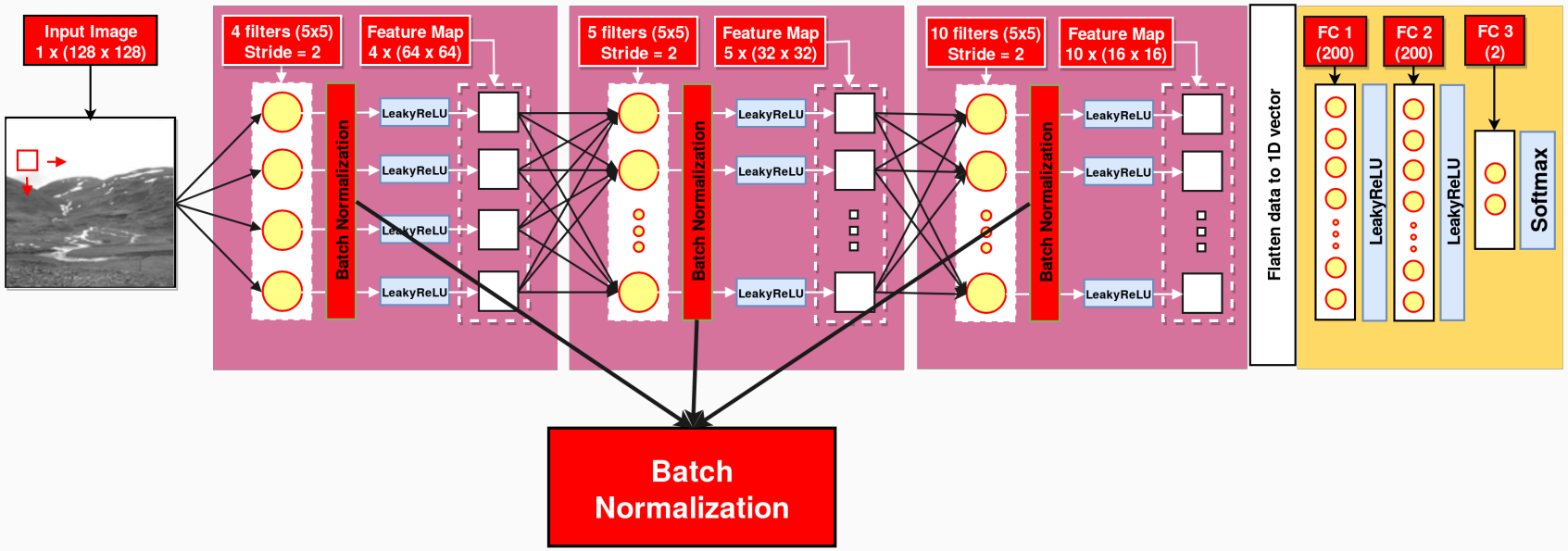


- Increase the *SNR* between the cover and the stego objects
- Reduce as much as possible the similarity between stego and cover objects

Preprocessing layer using “Catalyst Kernels”

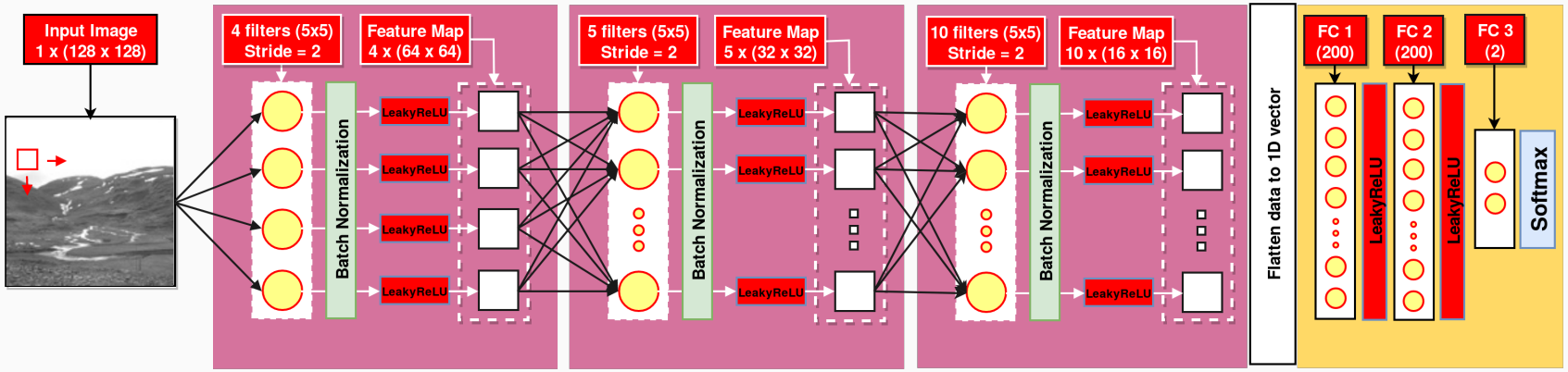


Batch Normalization

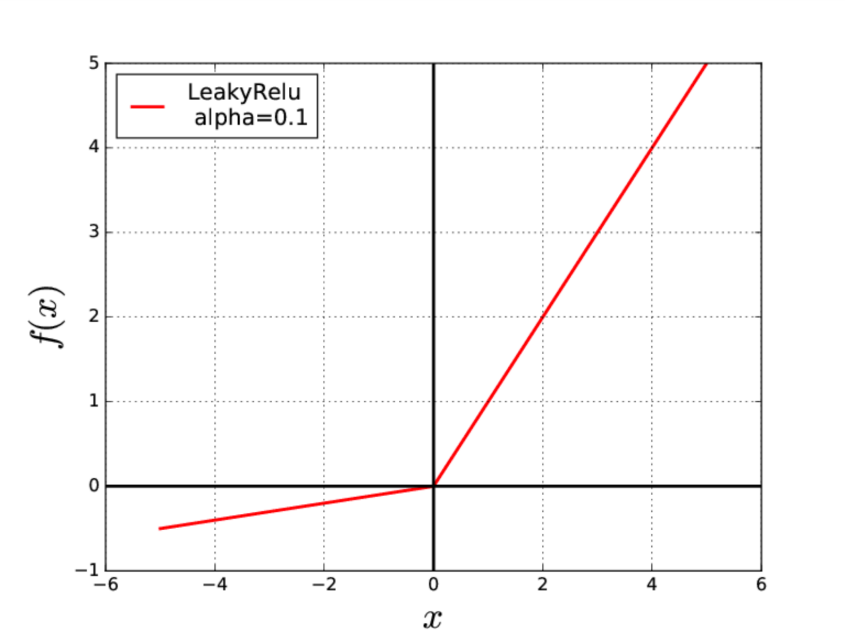


- Normalize the weak stego noise.
- Speed up the learning and improves the detection accuracy

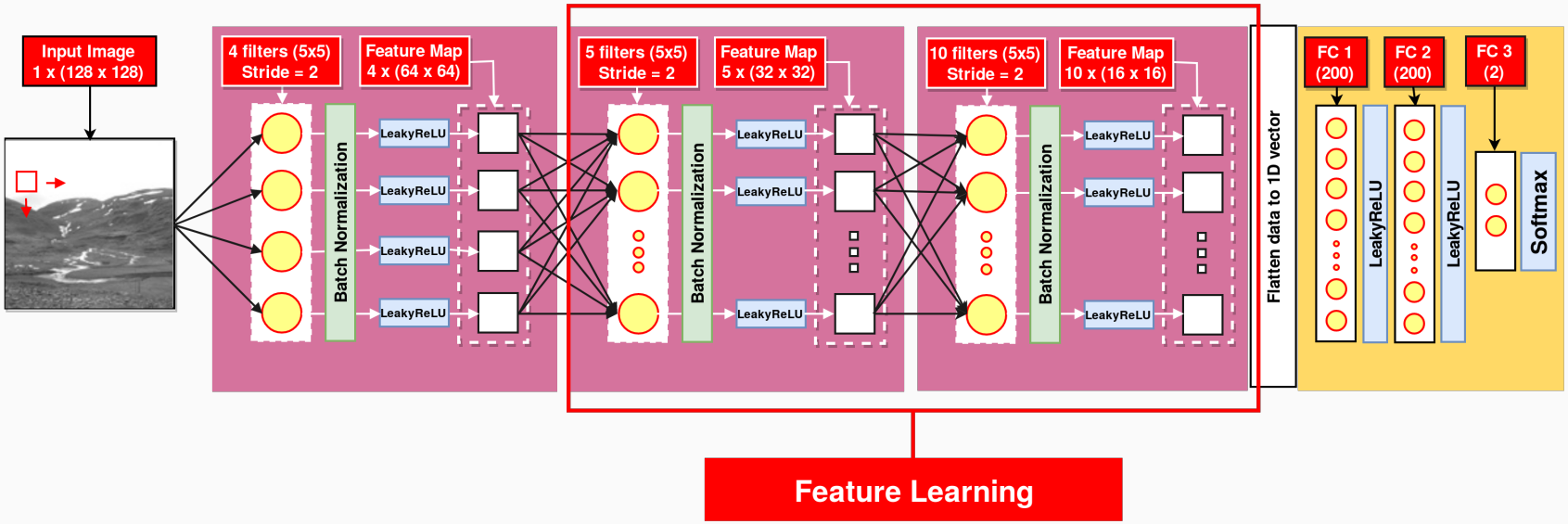
Activation Function (LeakyReLU)



Activation Function: LeakyReLU

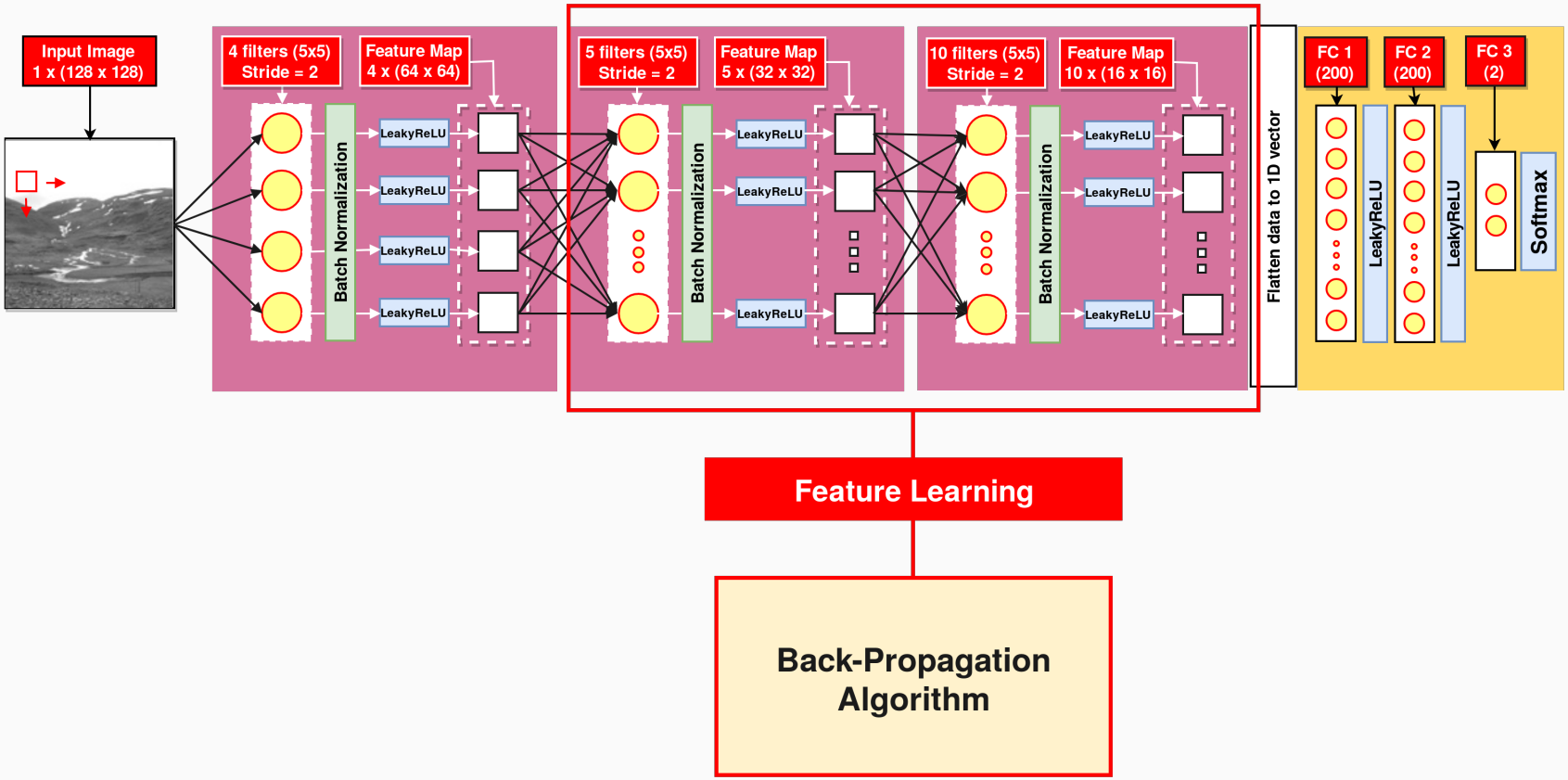


Feature Learning

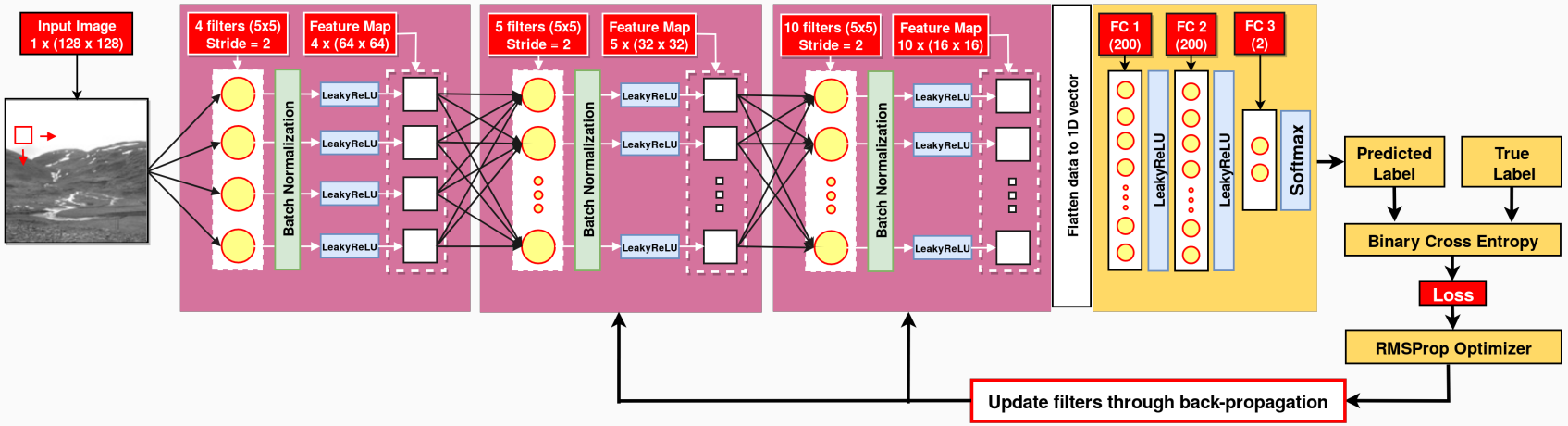


- The values of the filters will be updated dynamically during the learning process
- The update will be done at each iteration for a better separation between the two classes (stego and cover)

Feature Learning

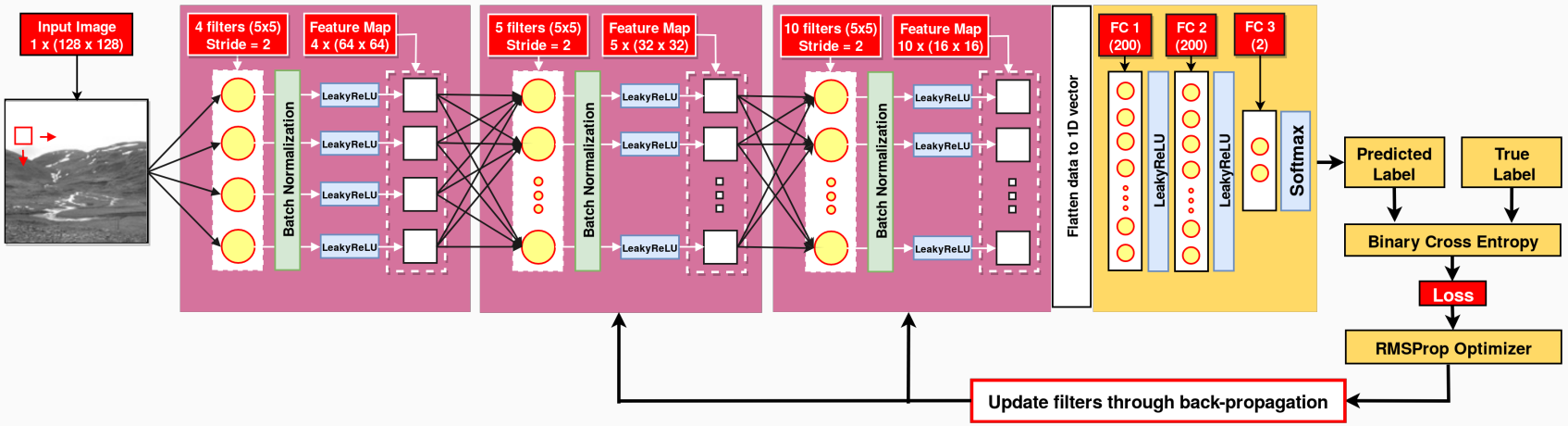


Classification & Back-Propagation Algorithm



- **Binaray Cross Entropy** : Loss function to compute the classification error.

Classification & Back-Propagation Algorithm

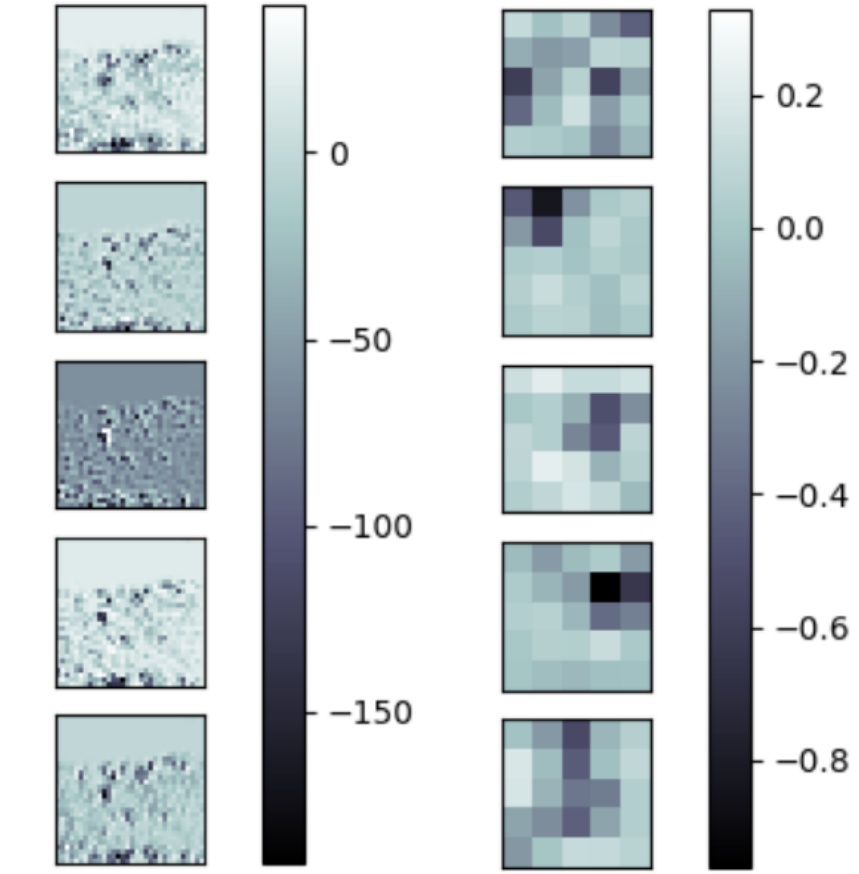


- **Binaray Cross Entropy** : Loss function to compute the classification error.
- **RMSPop Optomizer (for Root Mean Square Propagation)** : Adjust the weight value gradually basing on the back-propagation algorithm

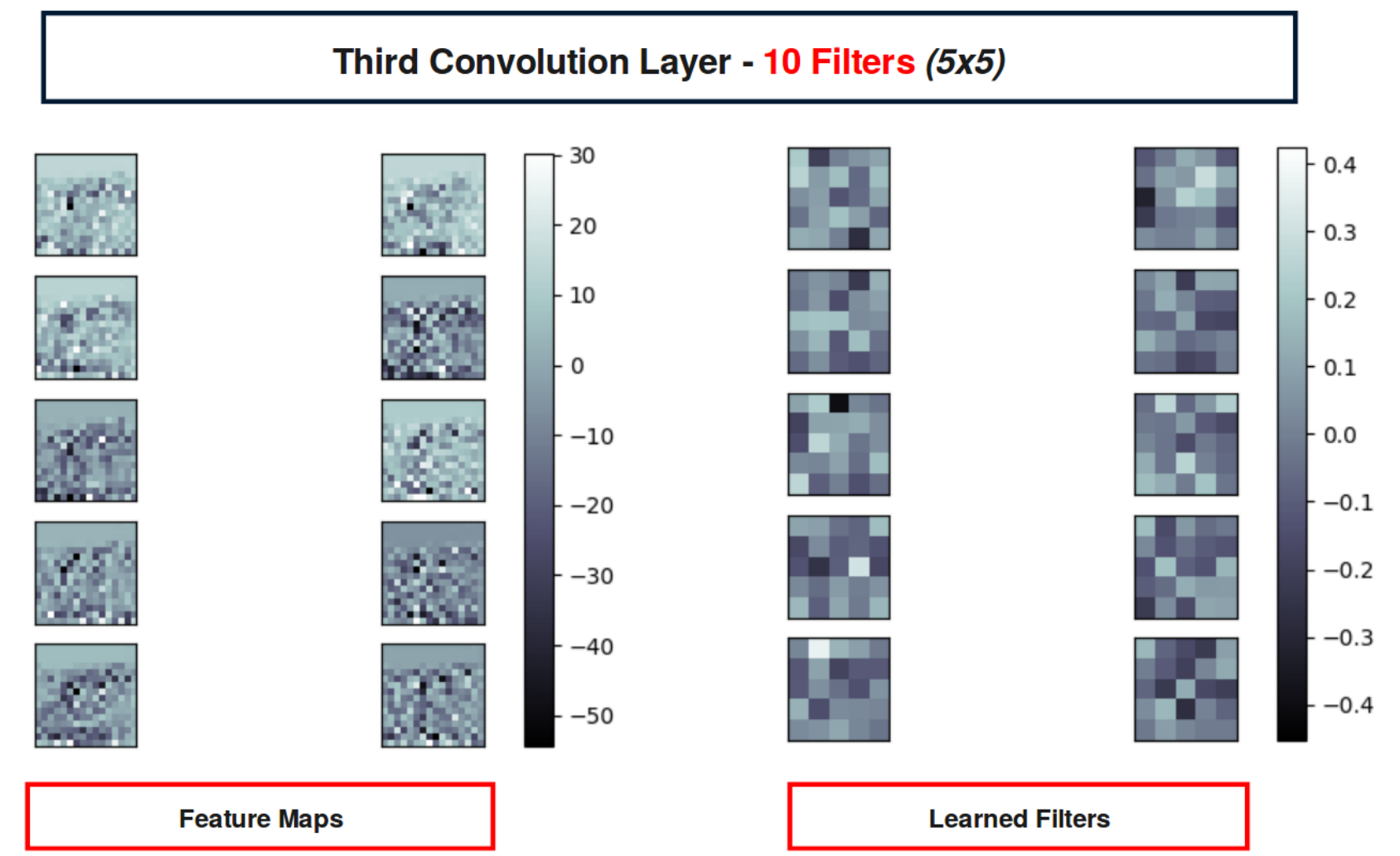
Filters and Feature Maps after learning

Second Convolution Layer

5 Filters *(5x5)*



Filters and Feature Maps after learning

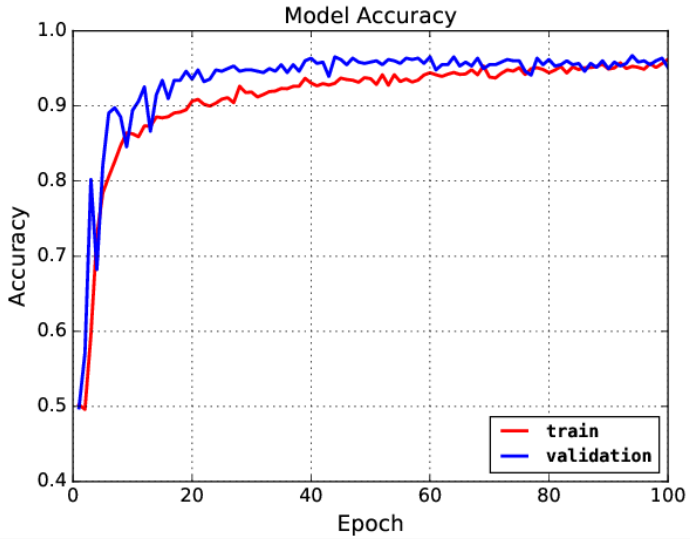


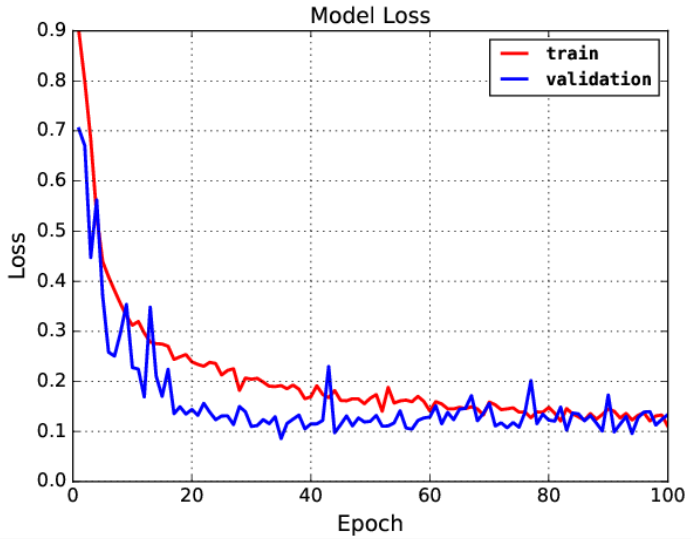
Learning from scratch and Transfer Learning

Learning from scratch

1- For high payloads [1 bpp]

- We trained our network from scratch for 100 epoch.
- Training model accuracy (right) and loss (left) using **WOW** algorithm.

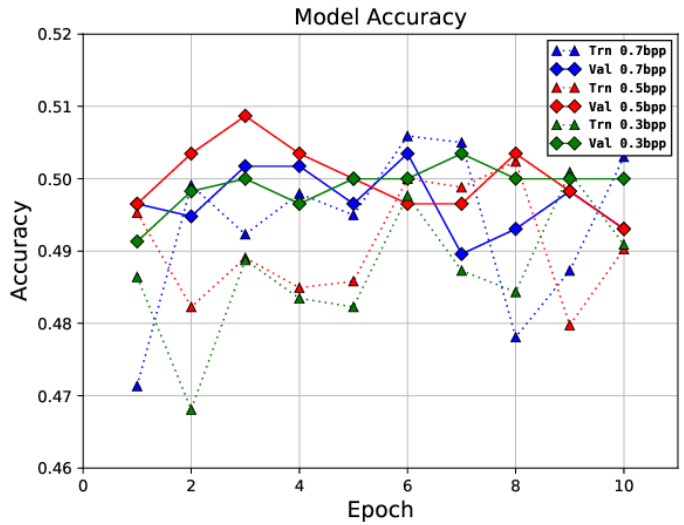


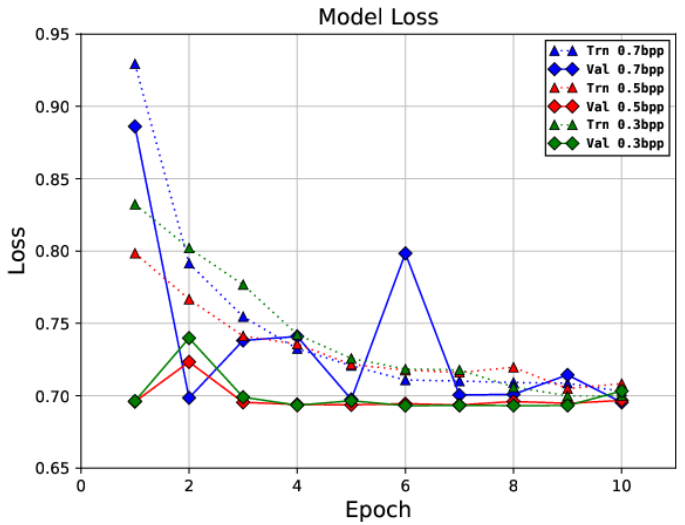


Learning from scratch

2- For low payloads [0.7, 0.5 or 0.3 bpp]

- It's impossible to ensure a convergence with our model for the first 10 epoch at least.

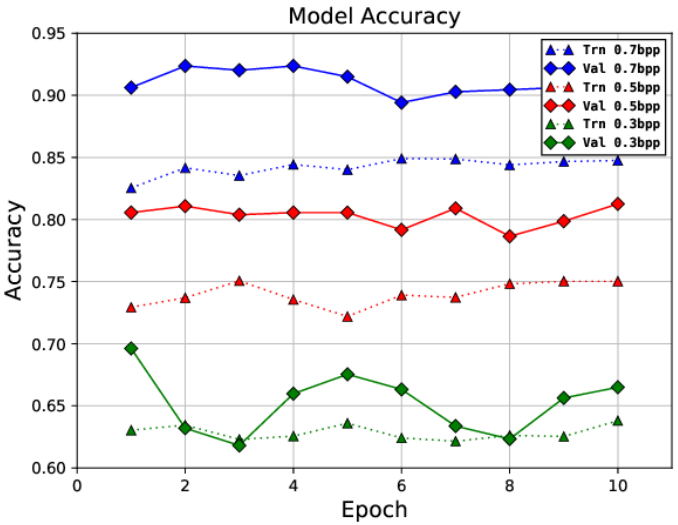


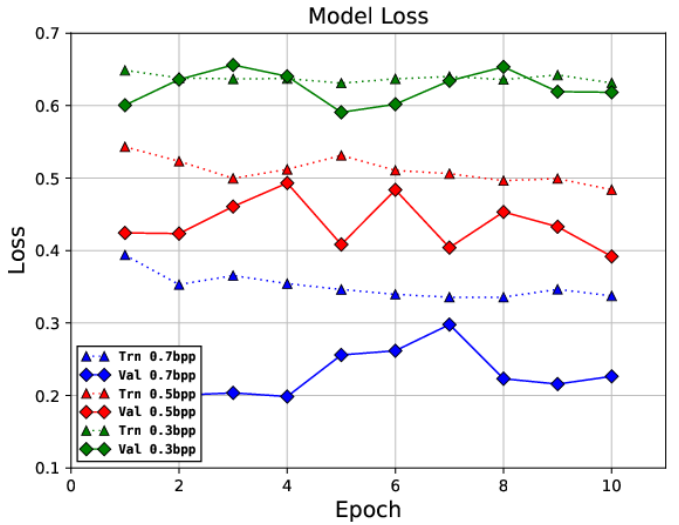


Transfer Learning

Transfer learning for low payloads (0.7, 0.5 or 0.3 bpp)

- The model show convergence from the first epoch.





Experimental setup & Results

Dataset & Implementation Environment

Dataset

- We used a chunk of the public dataset named BossBase v1.01
- We just took the first 2400 images, resized to $(128 \times 128 \times 1)$ pixels
  - 1700 images as training data.
  - 300 images as validation data.
  - 400 images as testing data.

Software platform

- The training of the CNNs is performed on a Keras API using TensorFlow as backend.

Hardware

- The implementation of the algorithms was performed on a computer CPU Intel Core $i3 - 2370M, 2.40GHz \times 4$, with Ubuntu 14.04 LTS.

Results: Model evaluation

- We choose three recent, highly undetectable stenographic algorithms in the spatial domain:
  - ***WOW*** (2012)
  - ***S-UNIWARD*** (2014)
  - ***HUGO*** (2010)
- We prepared for the testing process different datasets with (1*bpp*), (0.7*bpp*), (0.5*bpp*) and (0.3*bpp*) payloads

	S-UNIWARD				**WOW**				**HUGO**			
Payload (bpp)	1.0	0.7	0.5	0.3	1.0	0.7	0.5	0.3	1.0	0.7	0.5	0.3
Accuracy	0.96	0.93	0.88	0.73	0.96	0.92	0.83	0.67	0.96	0.91	0.84	0.69
P_E	0.04	0.07	0.12	0.27	0.04	0.08	0.17	0.33	0.04	0.09	0.16	0.31

Results: Detection errors *vs* payloads

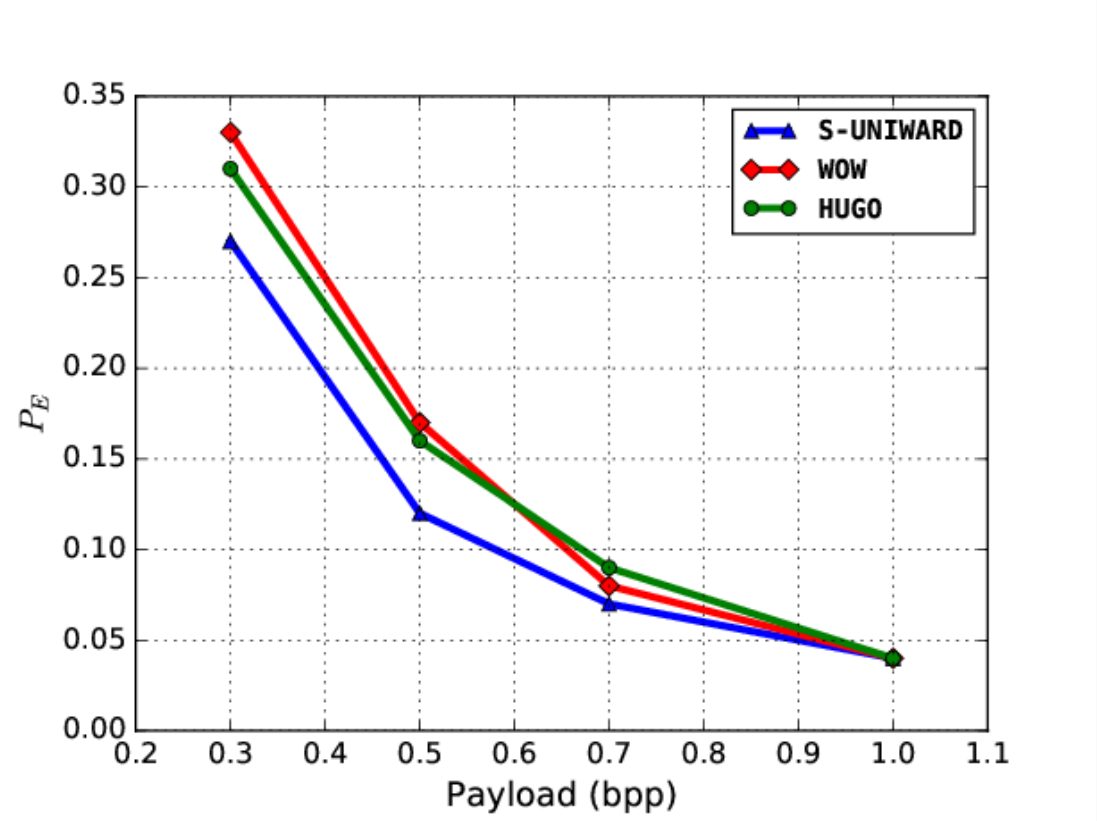
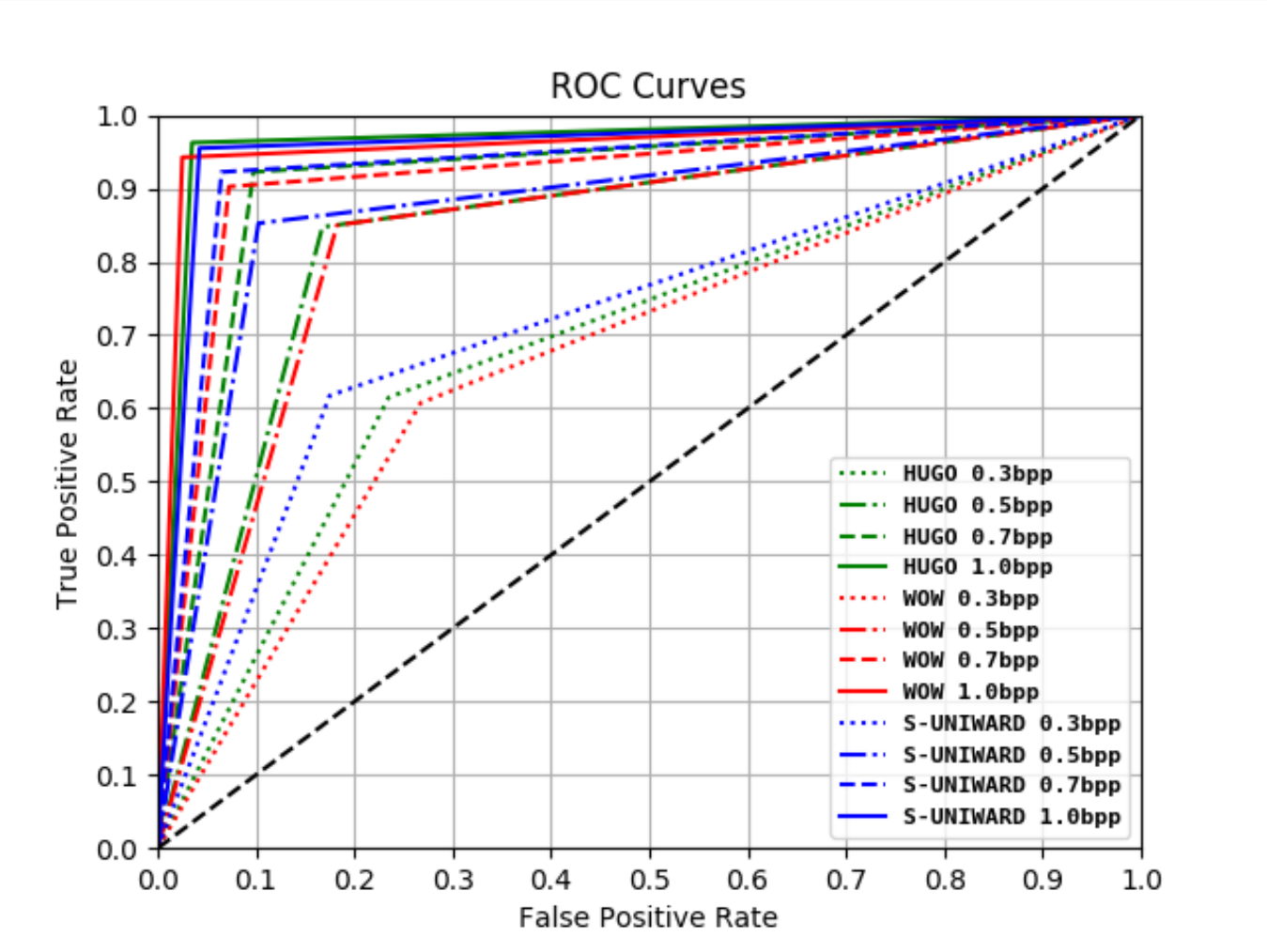


Figure: Detection errors of the proposed classifier for the 3 state-of-the-art stegano- graphic schemes (S-UNIWARD, WOW, HUGO) as a function of the embedded pay- load.

Results: ROC curves



Conclusion & Future work

Conclusion & Future works

- **Conclusion**
  - ⇒ We implemented a new CNN model for Steganalysis with small-scale images and low-cost computing resources.
  - ⇒ The CNN model showed good performance with highly undetectable steganographic algorithms
- **Future works**

⇒ We will focus on the concept of multi-class steganalysis using a system with multiple CNN models for predictions

Thank you for your attention!