Signal Processing for Telecommunications and Economics Lab

ML and DL approaches to identify CTC in IoMT communications

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Mario Cuomo, 569590

AGENDA

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- CYBERATTACK TREND

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- OVERVIEW

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- OVERVIEW
- COVERT CHANNEL

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- PROPOSED APPROACH
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- CONCLUSION

CYBERATTACK TREND

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- HEALTHCARE GETS HIT HARD

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CTC channel attack

OVERVIEW

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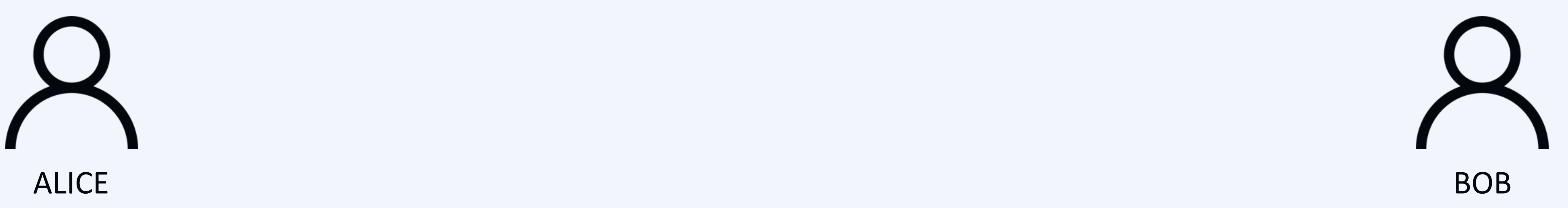
ALICE

BOB

OVERVIEW



ALICE

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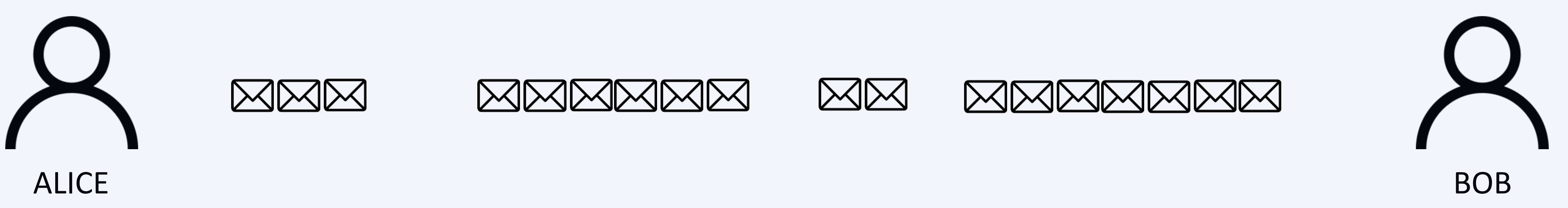

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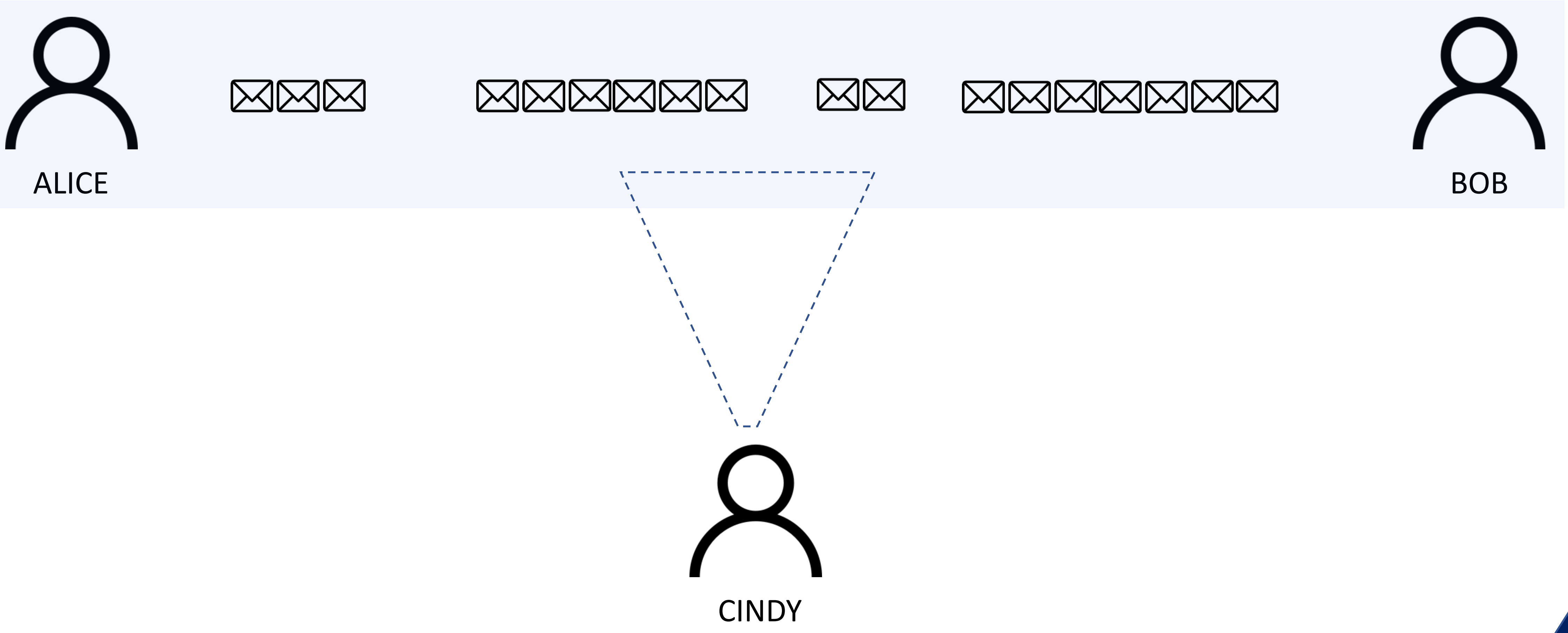

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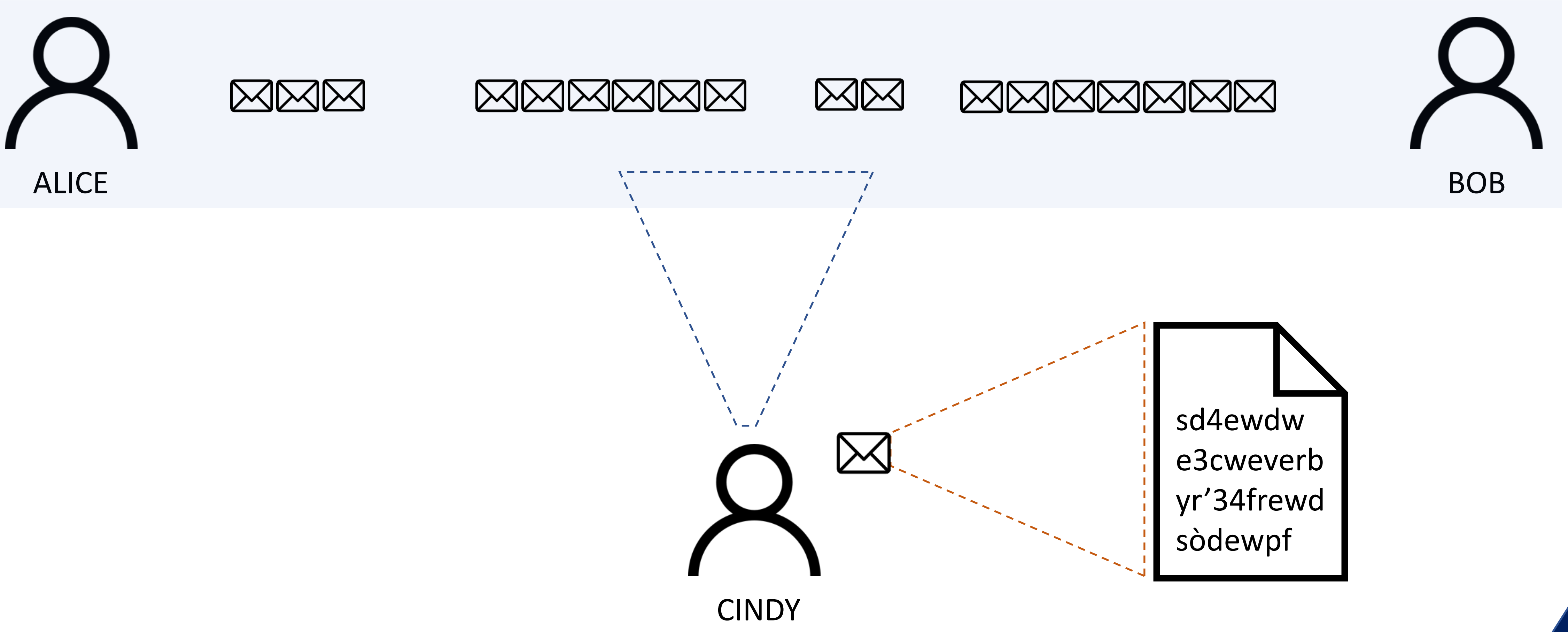

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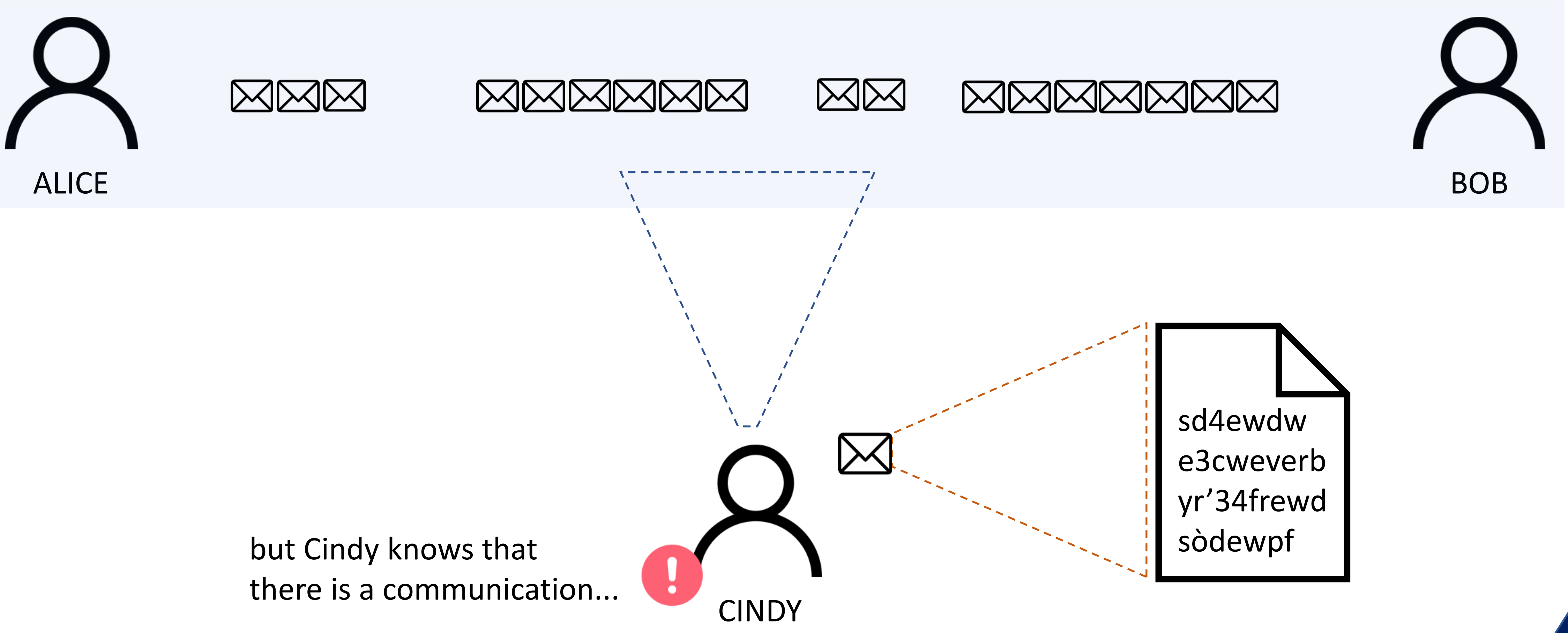

but Cindy knows that there is a communication...

COVERT CHANNEL

COVERT CHANNEL

“channels not intended for information transfer at all, such as the service program's effect on system load”

B. Lampson, 1973

COVERT CHANNEL

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communicate by modifying a "storage location", such as a hard drive

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COVERT TIMING CHANNEL

perform operations that affect the "real response time observed" by the receiver

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CTC TIME-REPLAY - *Serdar Cabuk «Network covert channels: Design, analysis, detection, and elimination»*

COVERT TIMING CHANNEL

perform operations that affect the "real response time observed" by the receiver

ALICE

BOB

COVERT TIMING CHANNEL

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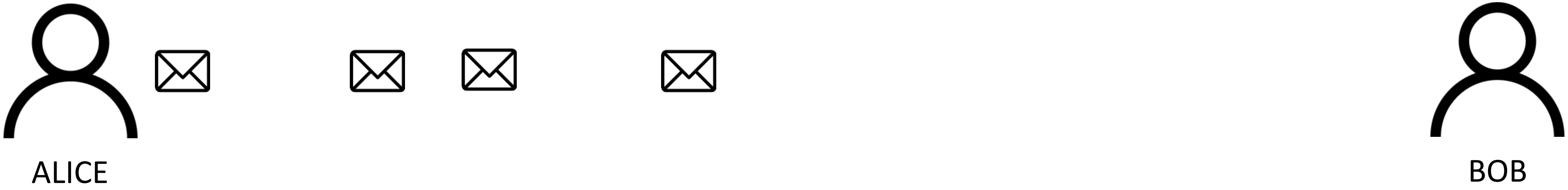

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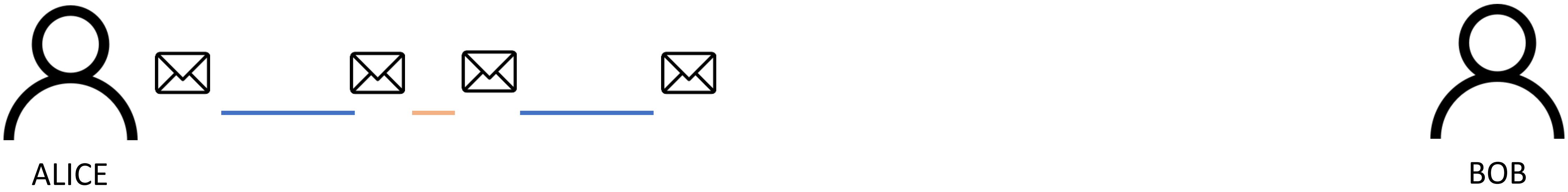

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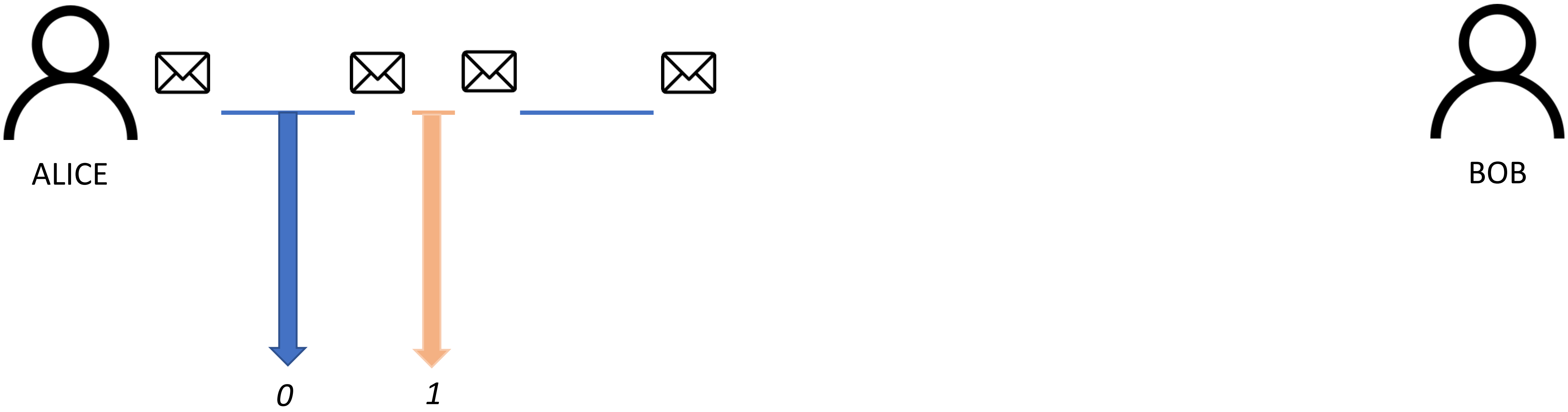

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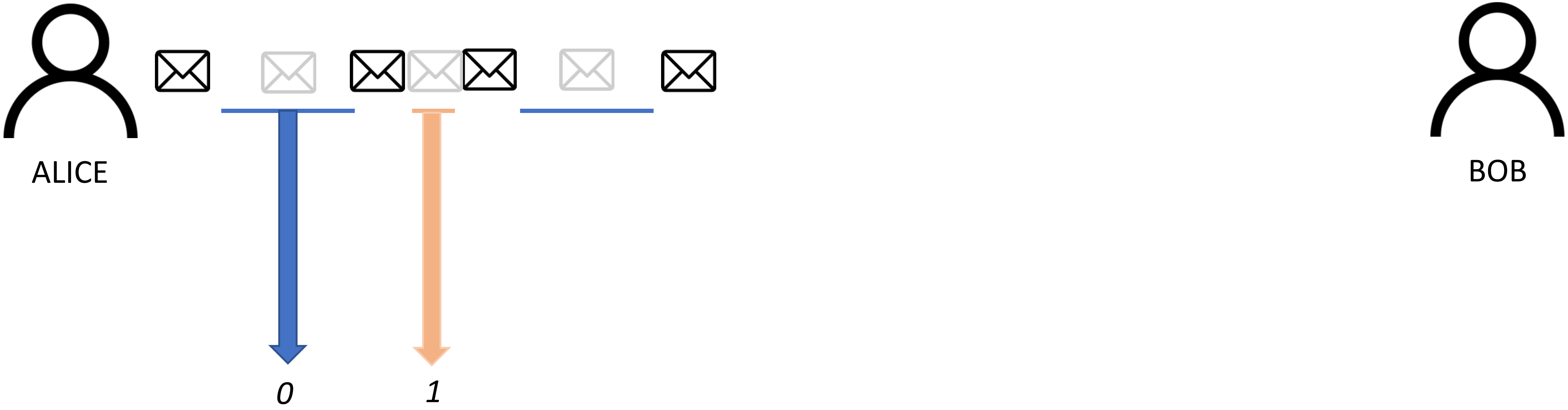

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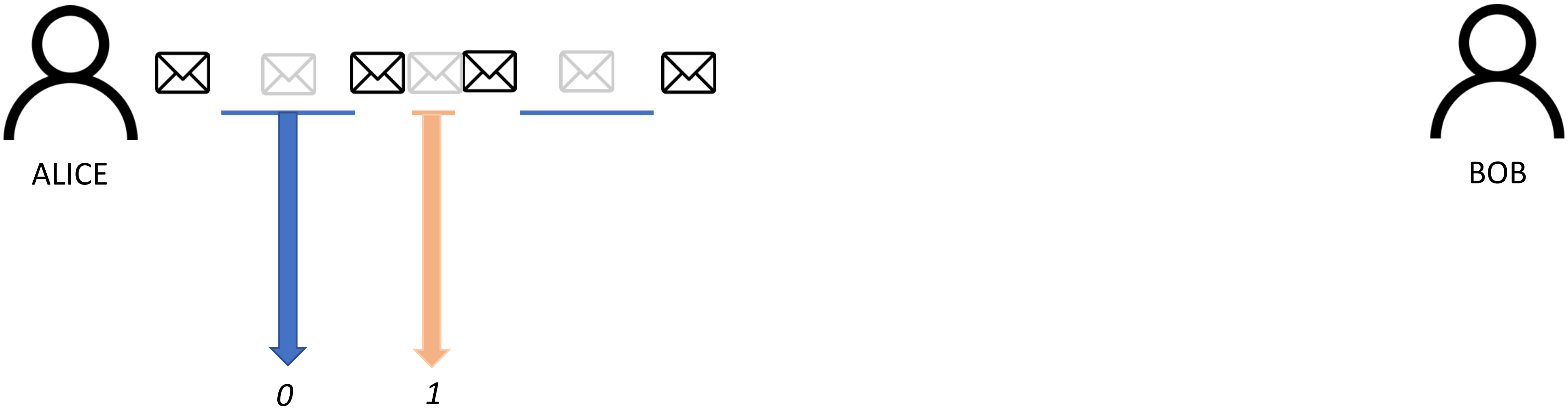

✉ *covering message*

✉ *covert message*

COVERT TIMING CHANNEL

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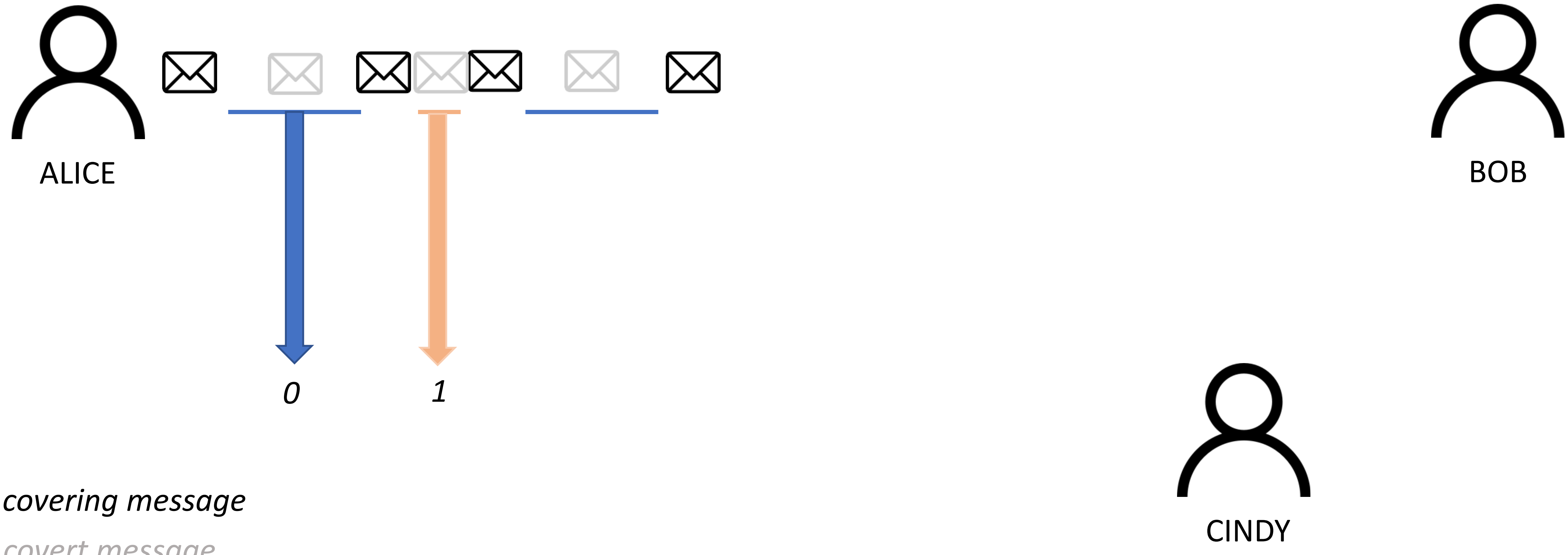

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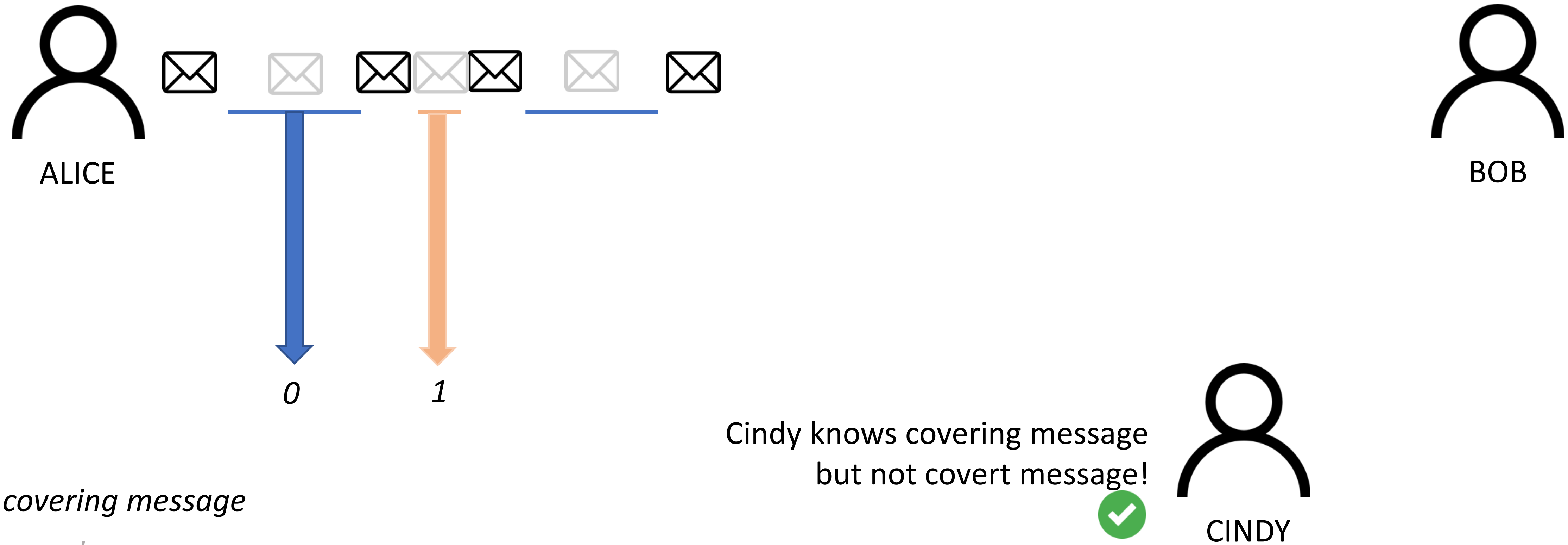


Cindy knows covering message
but not covert message! ✓

✉ *covering message*

✉ *covert message*

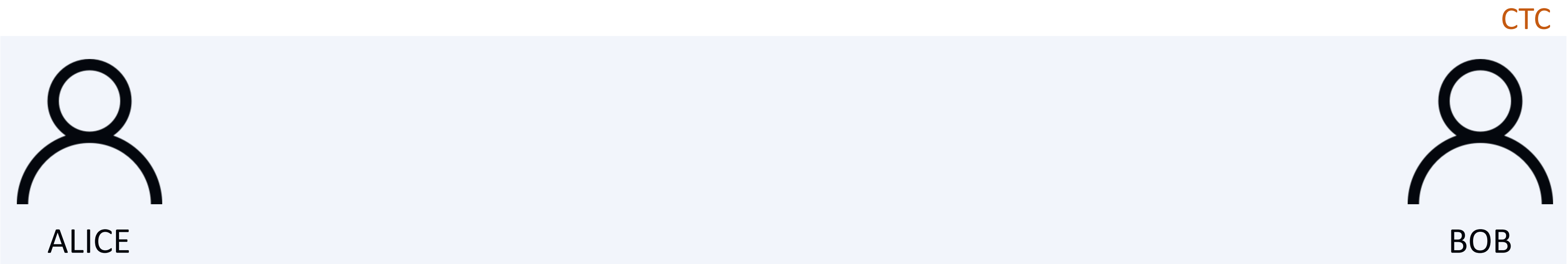
GOAL TO ACHIEVE

GOAL TO ACHIEVE

ALICE

BOB

GOAL TO ACHIEVE



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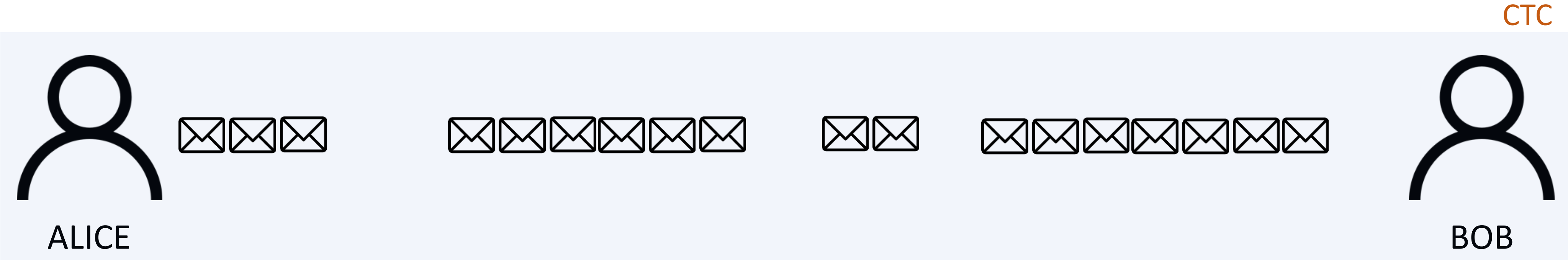

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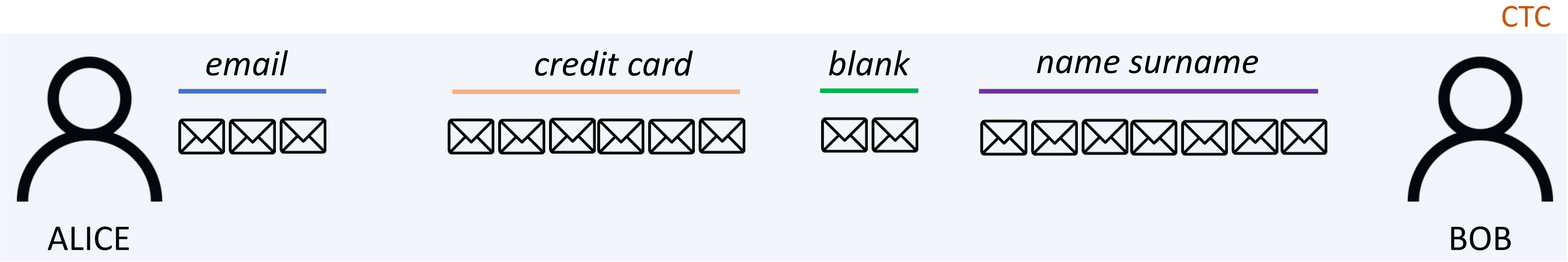

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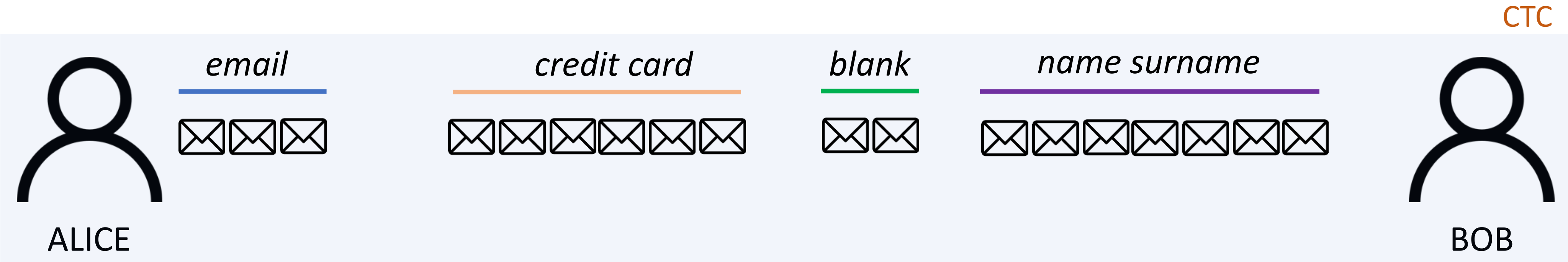


CTC

ALICE

email ✉✉✉

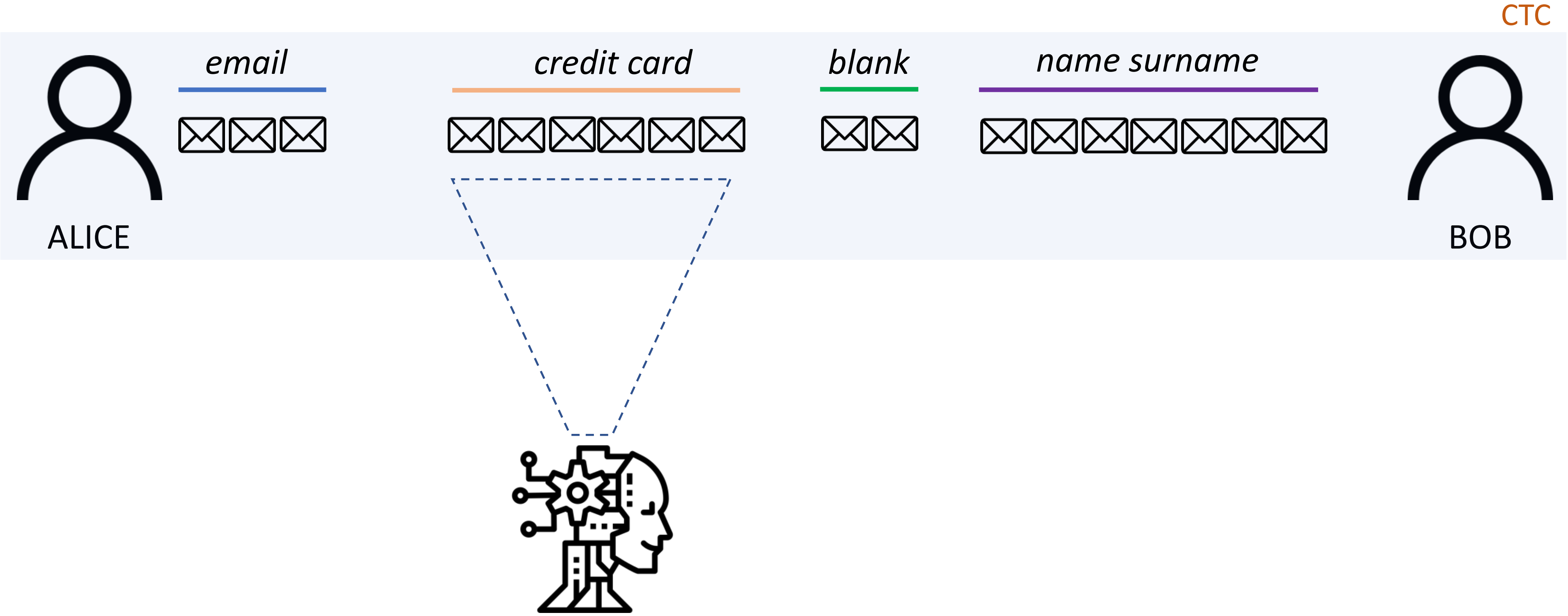
credit card ✉✉✉✉✉✉

blank ✉✉

name surname ✉✉✉✉✉✉✉

BOB

GOAL TO ACHIEVE



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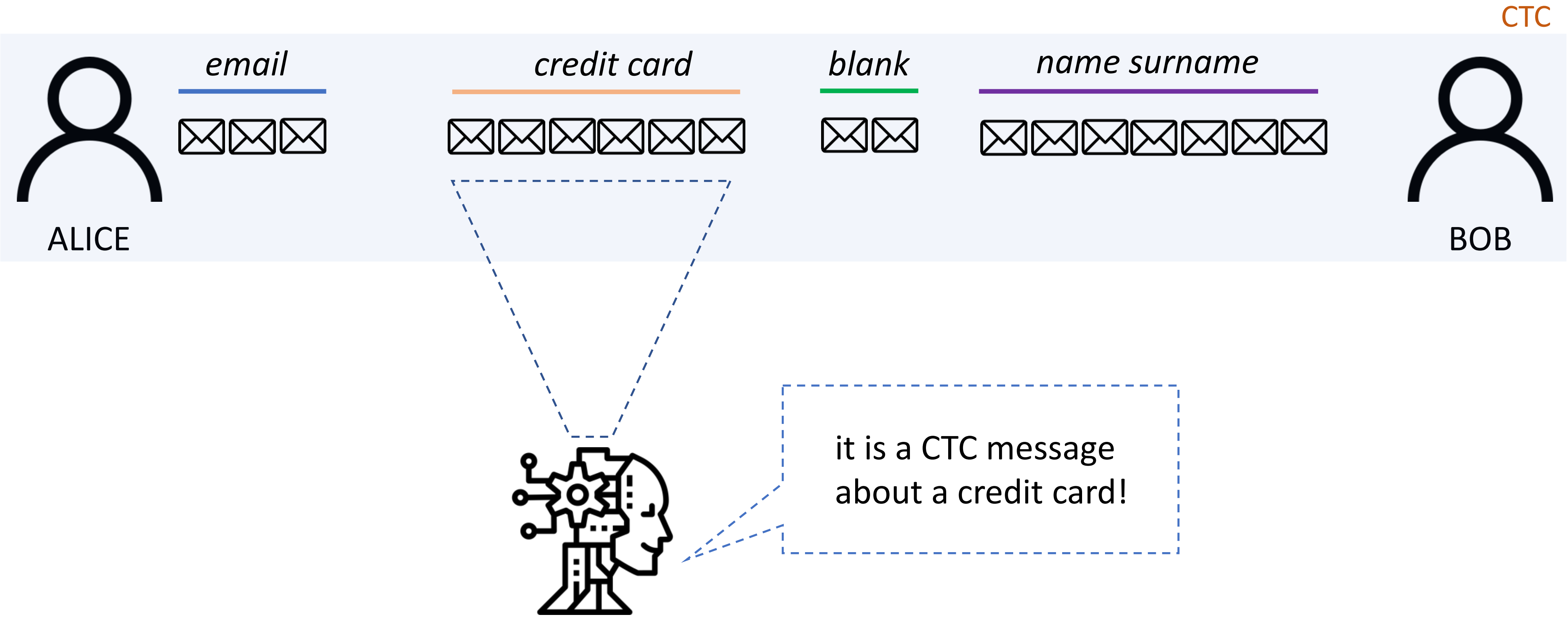

it is a CTC message about a credit card!

PROPOSED APPROACH

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- LAB KATHARÁ - *open source container-based network emulation system* (Roma Tre)

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  - 400 as training set

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python – sklearn and tensorflow, keras

THE BIG PICTURE

STEP ONE

STEP ONE – PACKETS TO SPECTROGRAMS

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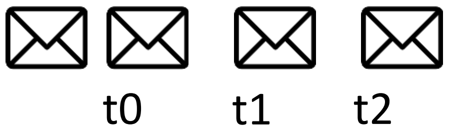
✉ ✉ ✉ ✉

STEP ONE – PACKETS TO SPECTROGRAMS



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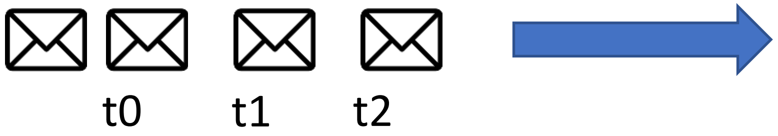
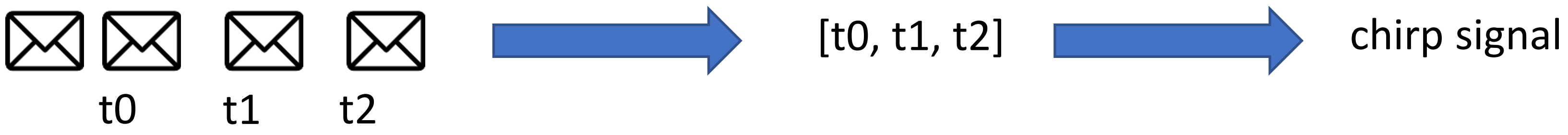


[t0, t1, t2]

STEP ONE – PACKETS TO SPECTROGRAMS

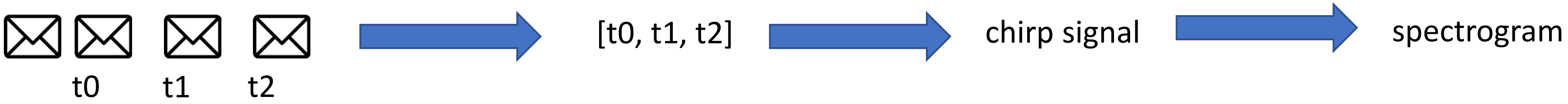


t0 t1 t2

[t0, t1, t2]

chirp signal

STEP ONE – PACKETS TO SPECTROGRAMS



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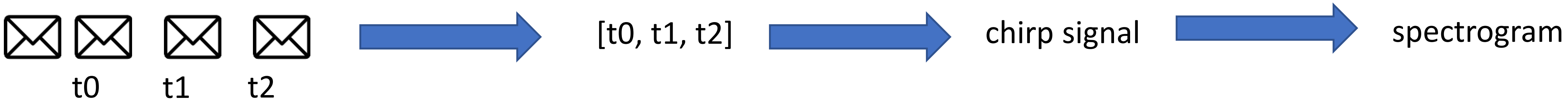

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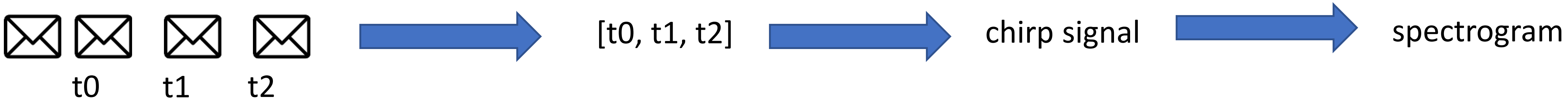
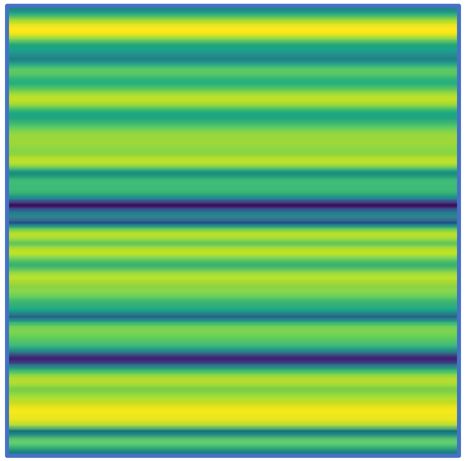
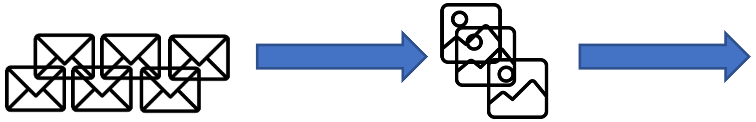


t0 t1 t2 → [t0, t1, t2] → chirp signal → spectrogram



S. Al-Eidi, O. Darwish, Y. Chen and G. Husari, "SnapCatch: Automatic Detection of Covert Timing Channels Using Image Processing and Machine Learning"

THE BIG PICTURE



STEP TWO

STEP TWO – CONVOLUTION NEURAL NETWORK

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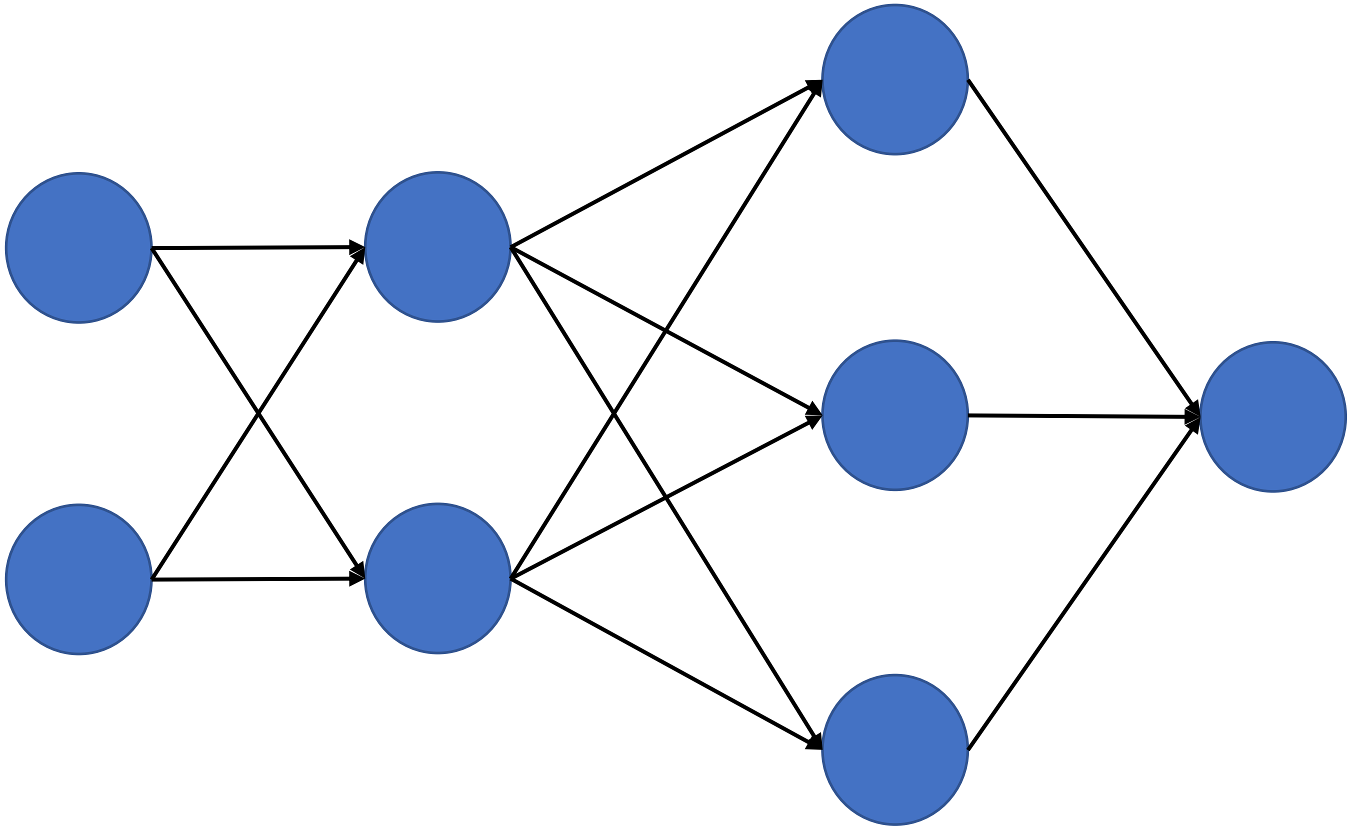

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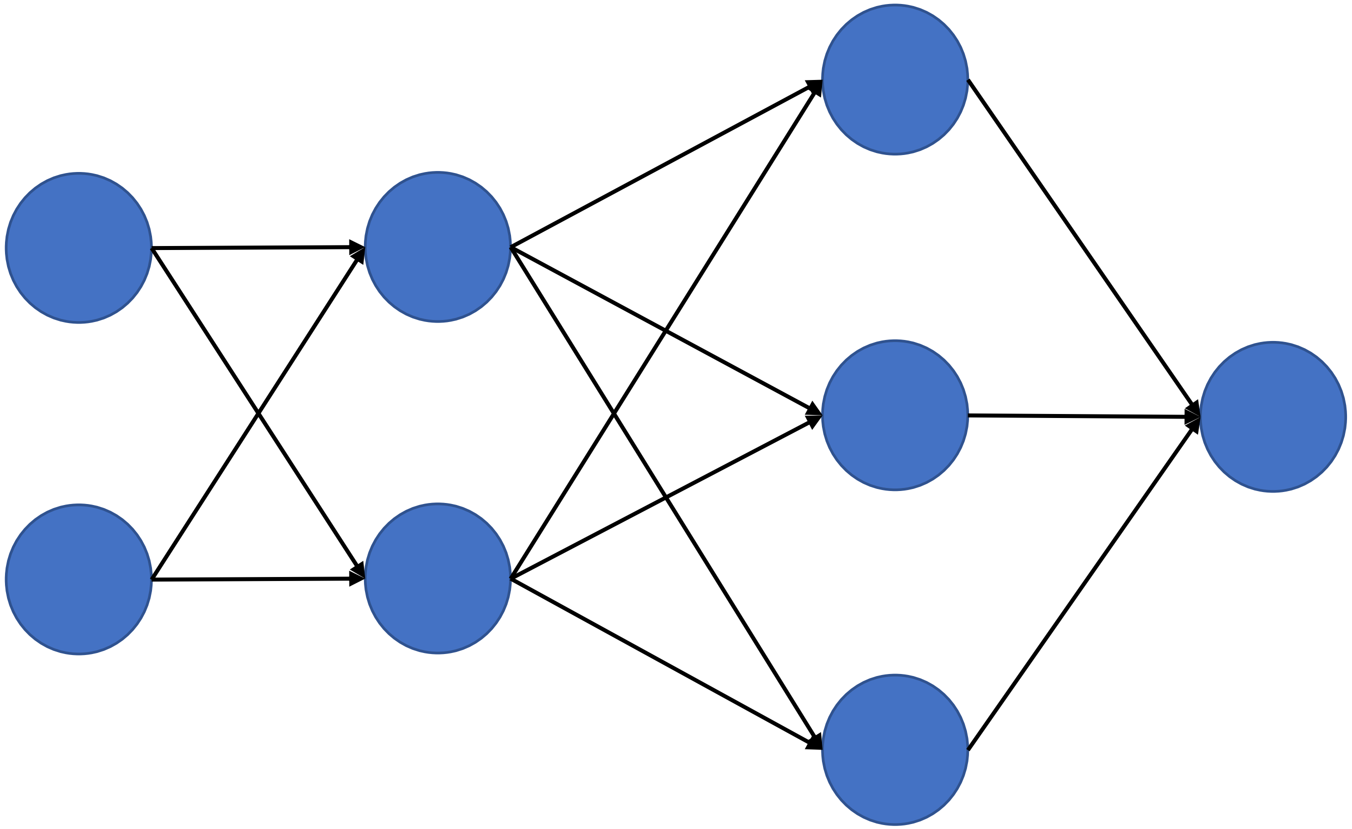

input size 224 × 224 × 3

features map 3 × 3

max pooling 2 × 2

dropout 20 %

fully connected 128 units

output softmax 4 units

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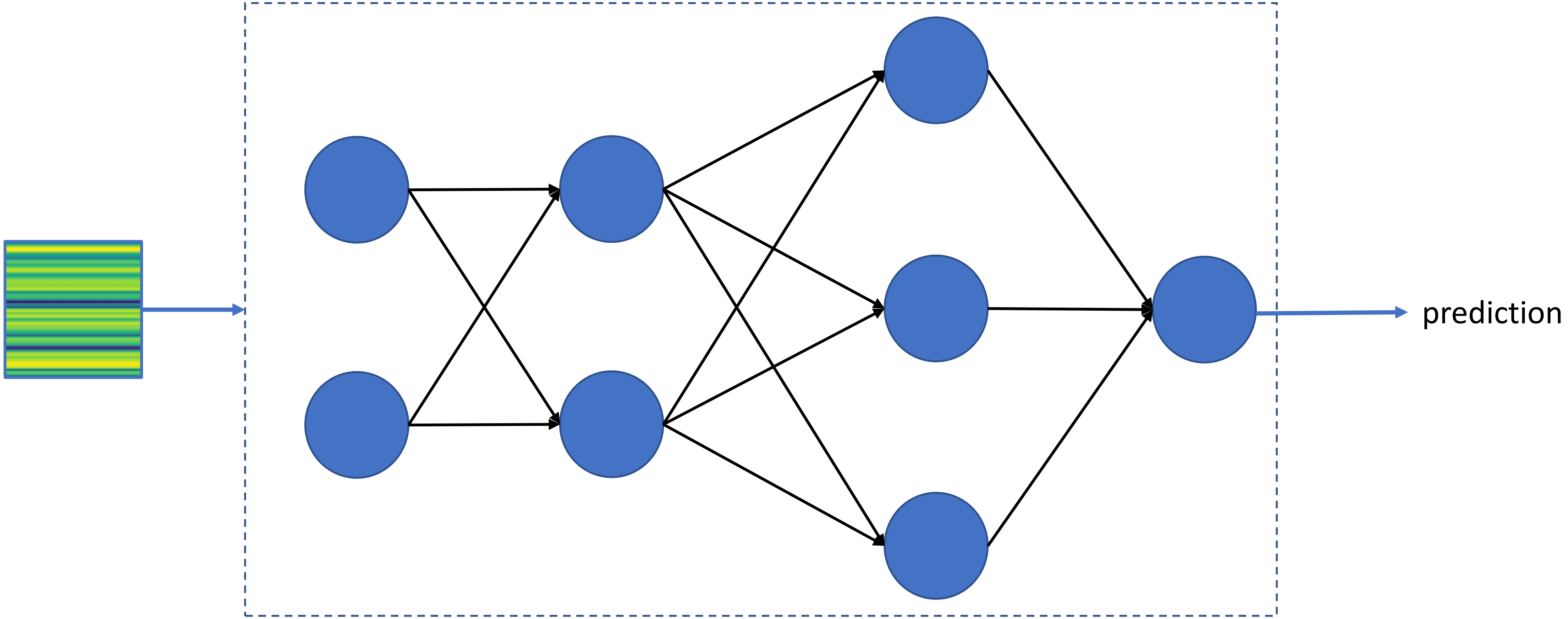

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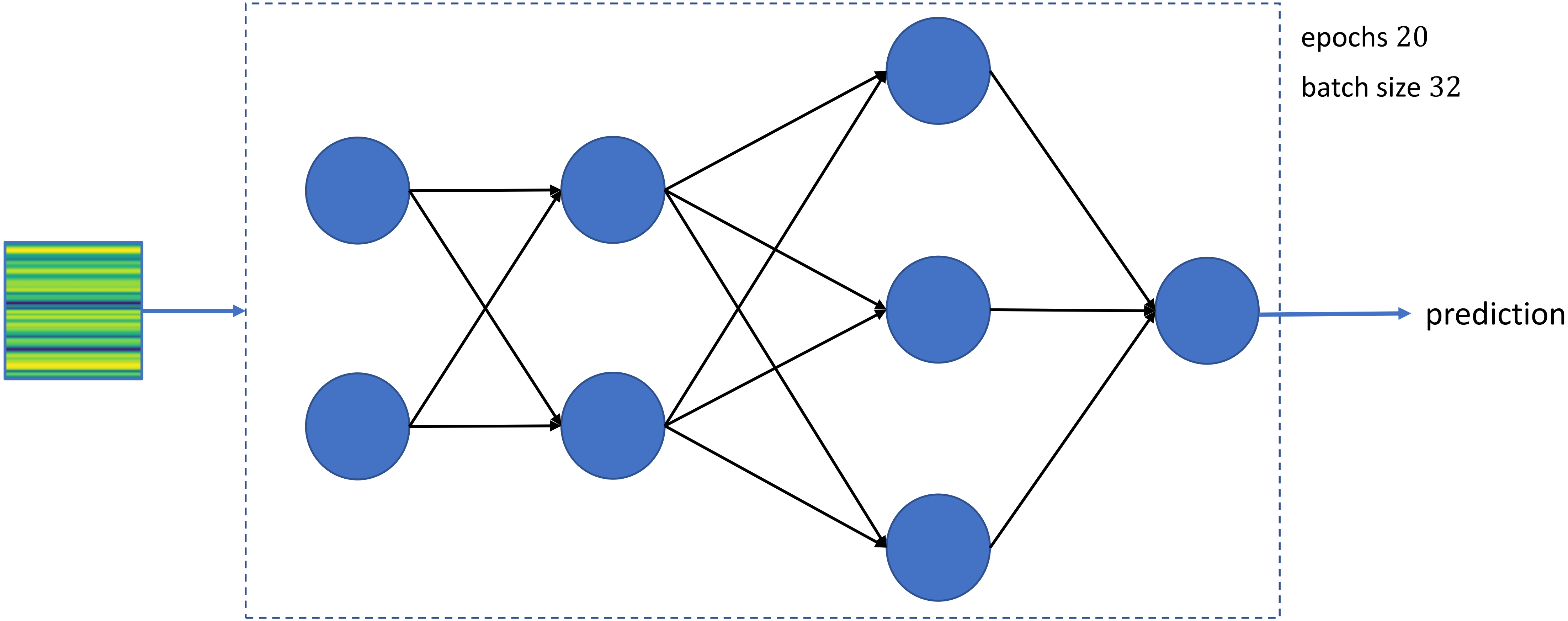


epochs 20

batch size 32

input size 224 × 224 × 3

features map 3 × 3

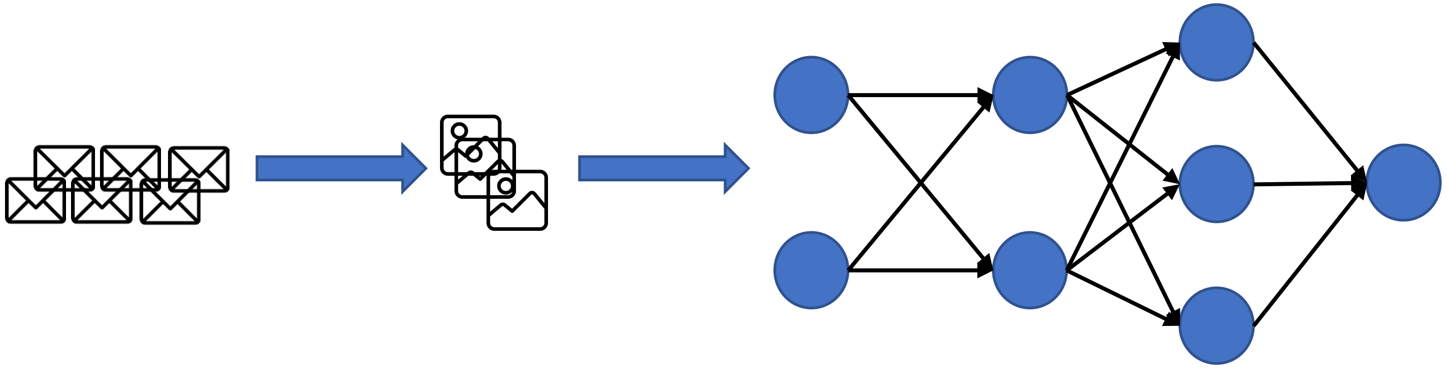
max pooling 2 × 2

dropout 20 %

fully connected 128 units

output softmax 4 units

THE BIG PICTURE



CONFUSION MATRIX CNN

cc	65	9	26	0
email	0	100	0	0
ns	16	5	73	6
blank	0	0	1	99
	cc	*email*	*ns*	*blank*

cc – credit card
ns – name surname

CONFUSION MATRIX CNN

	cc	*email*	*ns*	*blank*
cc	65	9	26	0
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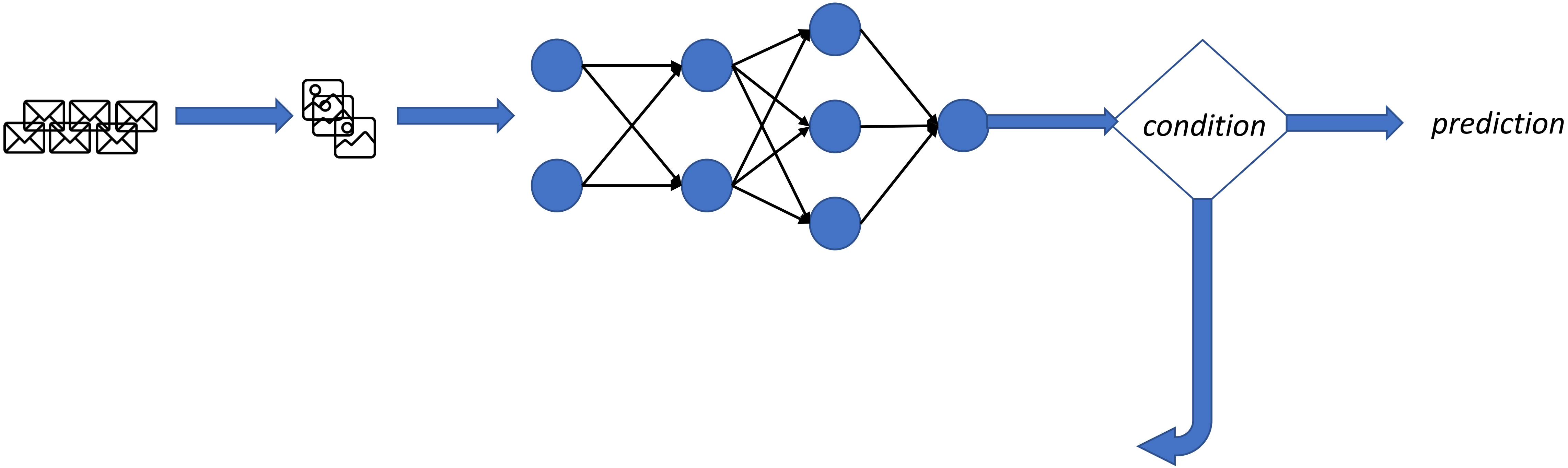

STEP THREE

STEP THREE – SIAMESE NEURAL NETWORK

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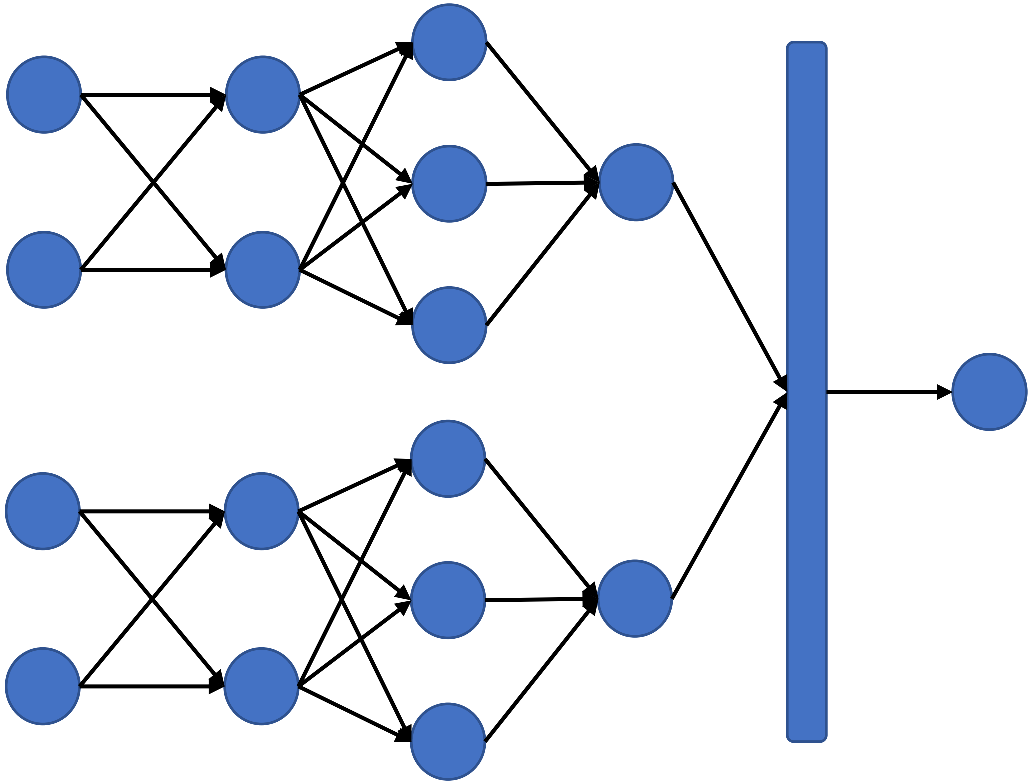

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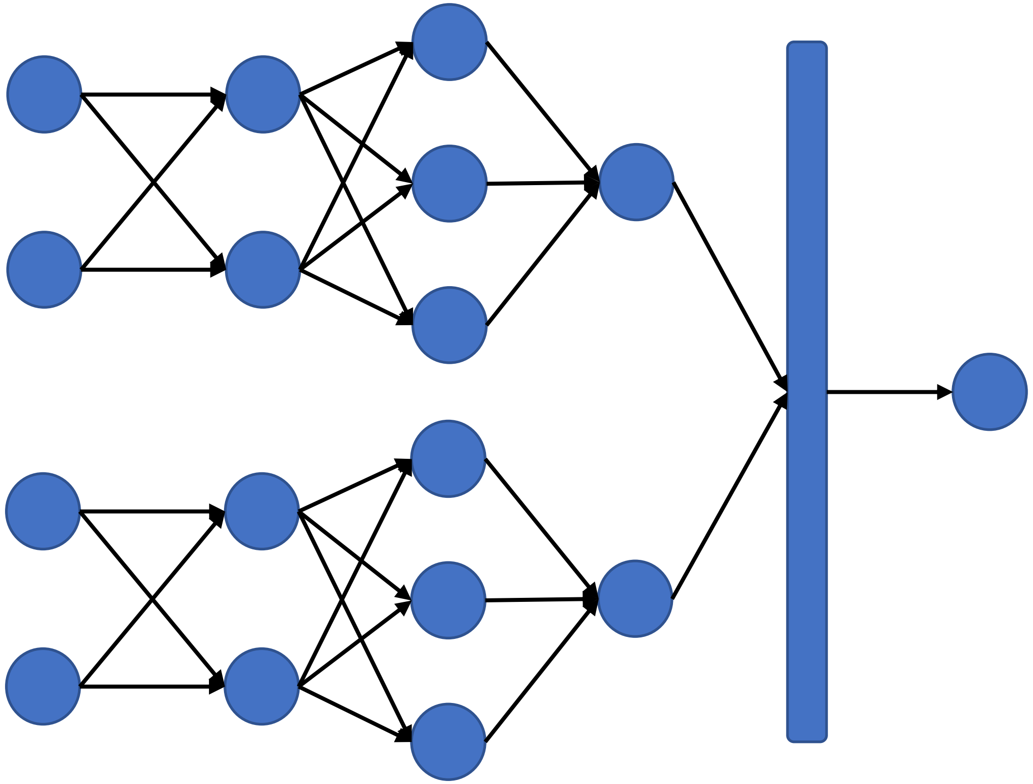


input size $2 \times 224 \times 224 \times 3$

reflection pad 2D

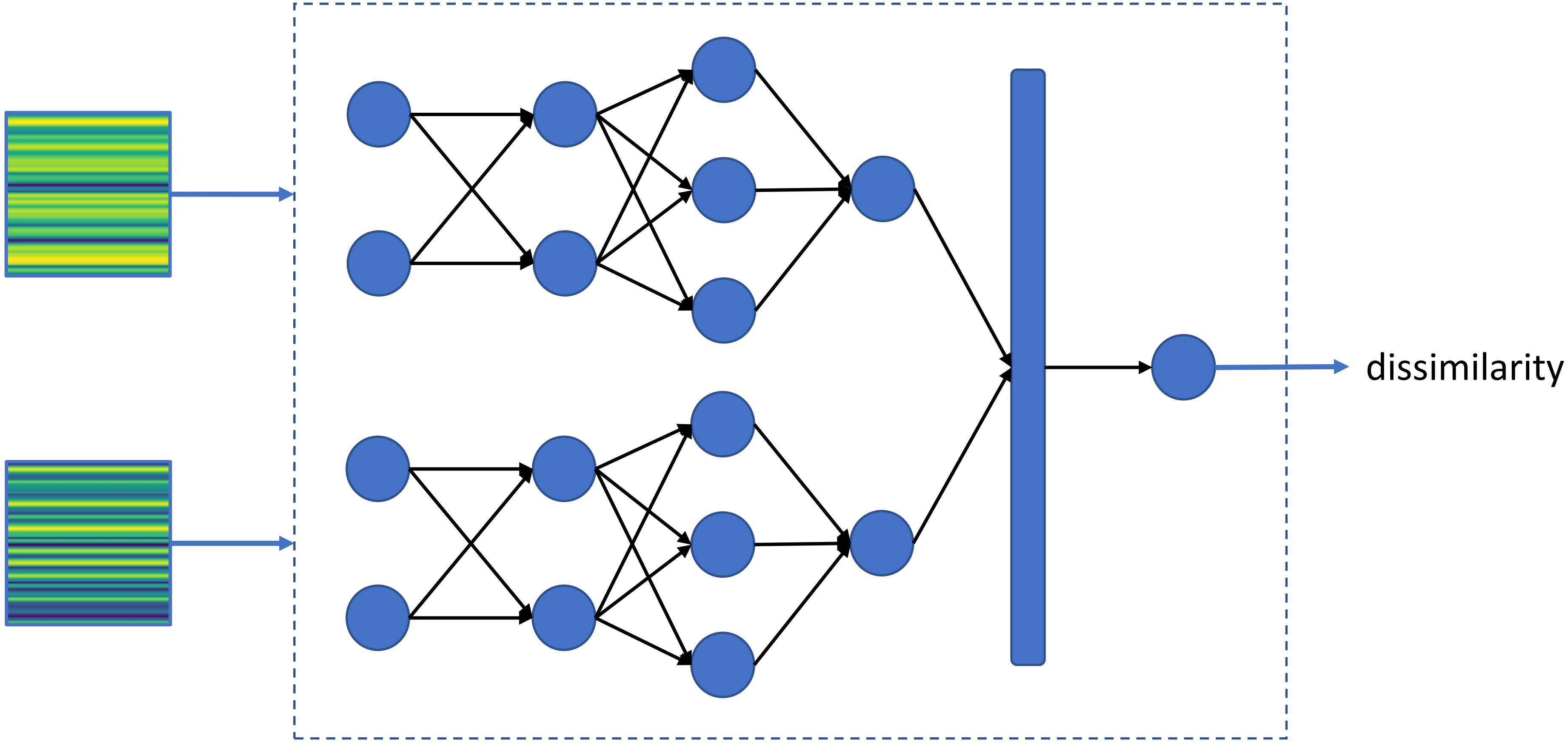
3 convolutional layers

relu as activation

batch normalization

sigmoid 1 unit

STEP THREE – SIAMESE NEURAL NETWORK



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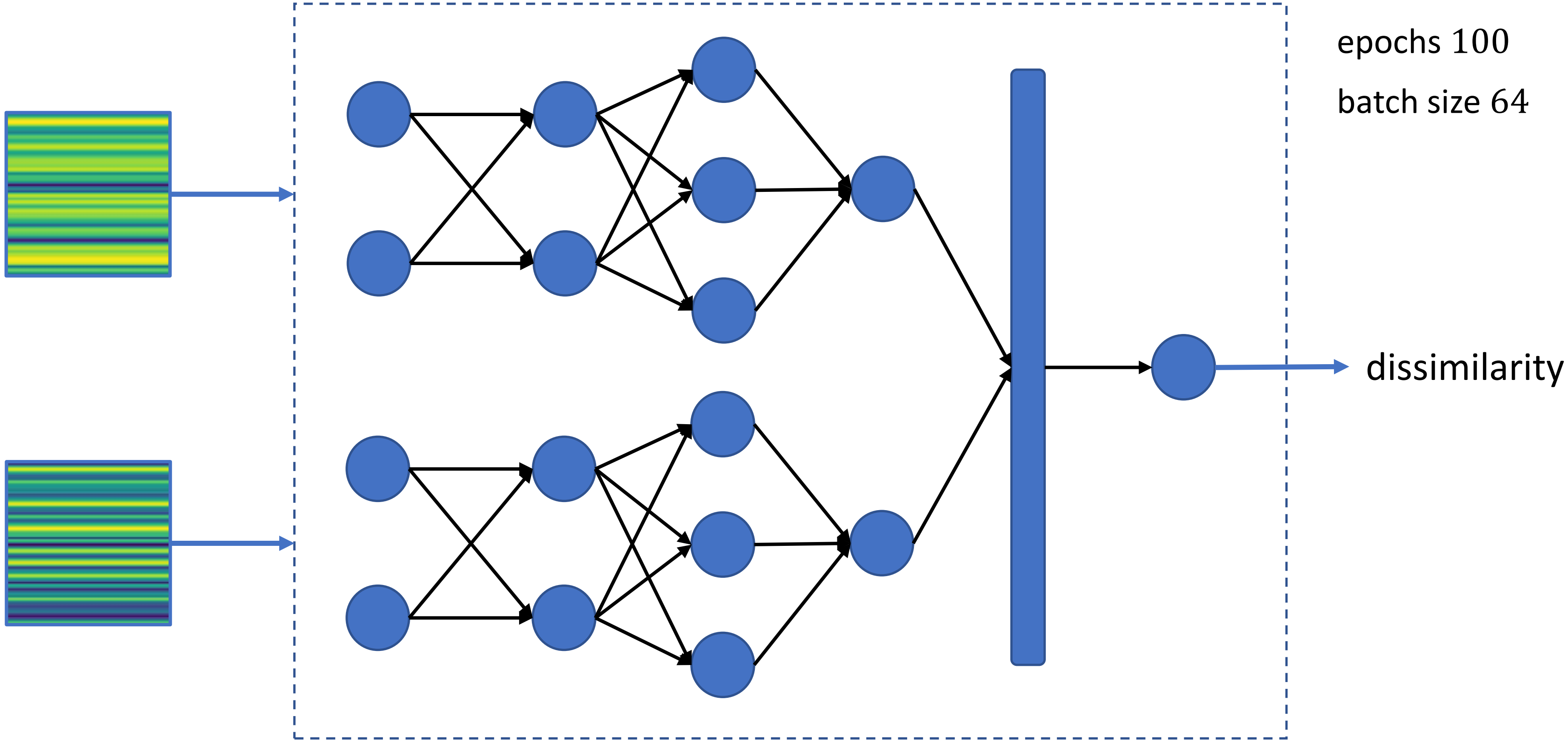

epochs 100

batch size 64

input size 2 × 224 × 224 × 3

reflection pad 2D

3 convolutional layers

relu as activation

batch normalization

sigmoid 1 unit

STEP FOUR

STEP FOUR – PROTOTYPE SELECTION

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prototype selection

→

using k-means

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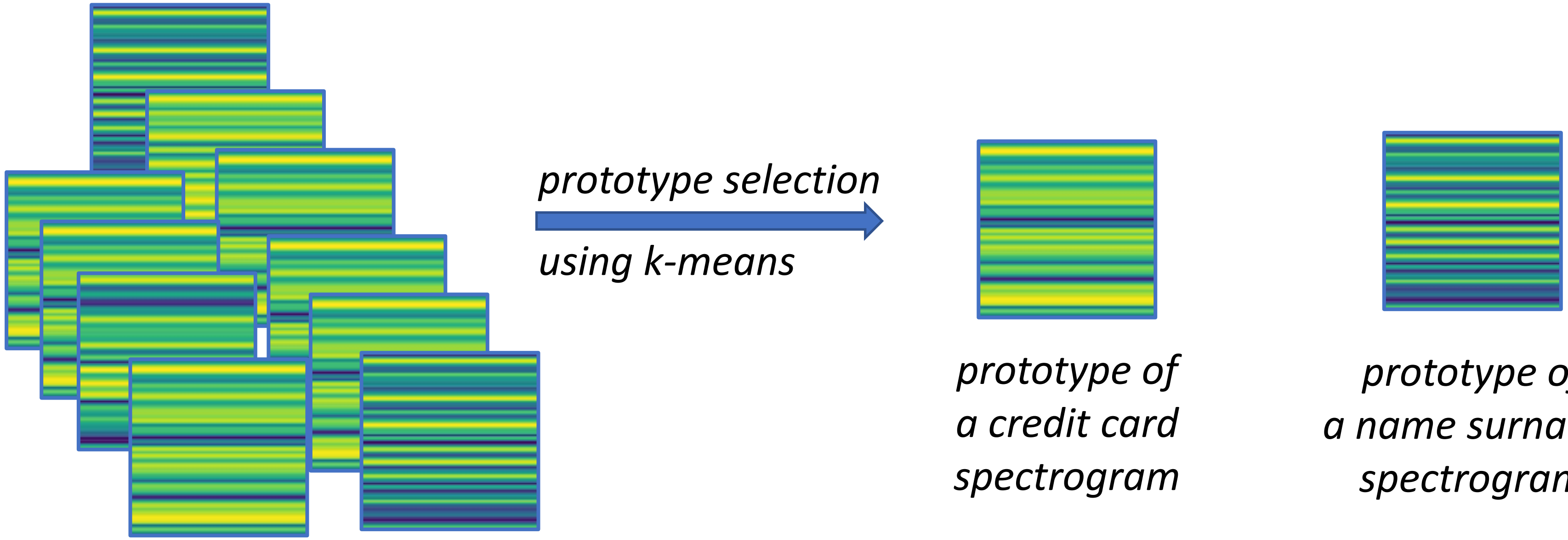


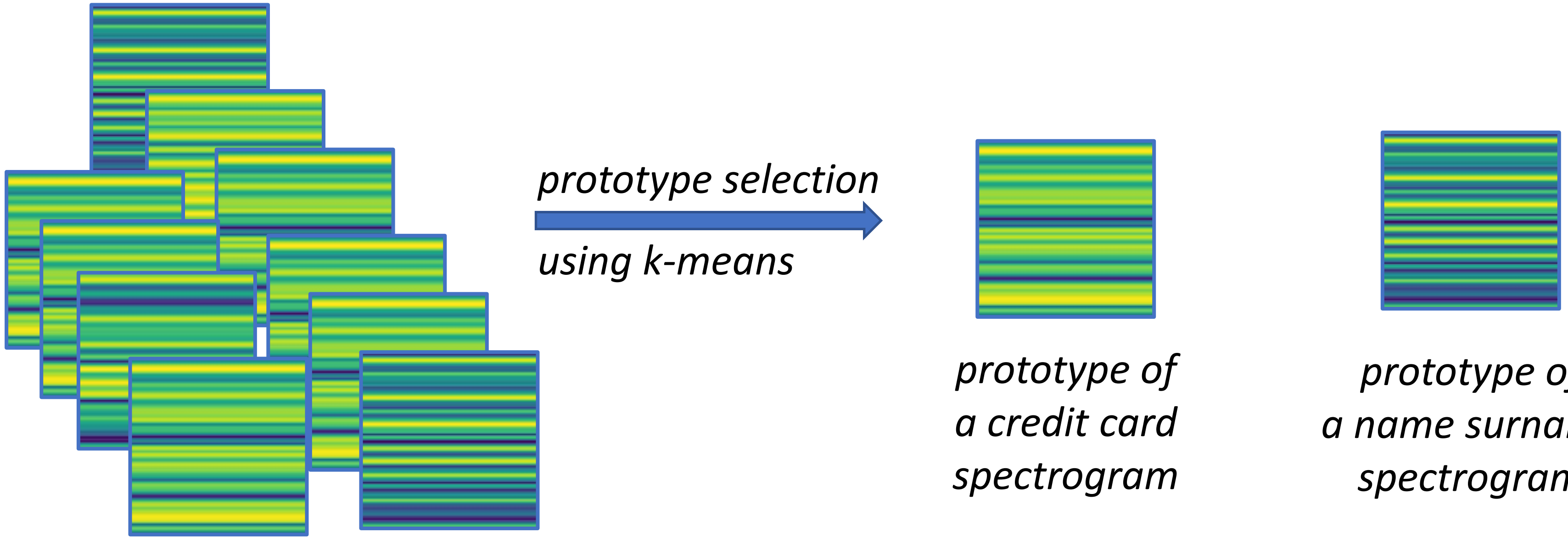
prototype selection

using k-means

prototype of a credit card spectrogram

prototype of a name surname spectrogram

STEP FOUR – PROTOTYPE SELECTION



prototype selection

using k-means

prototype of a credit card spectrogram

prototype of a name surname spectrogram

Loris Nanni et al. «Spectrogram Classification Using Dissimilarity Space».

STEP FIVE

STEP FIVE – DISSIMILARITY SPACE DATASET

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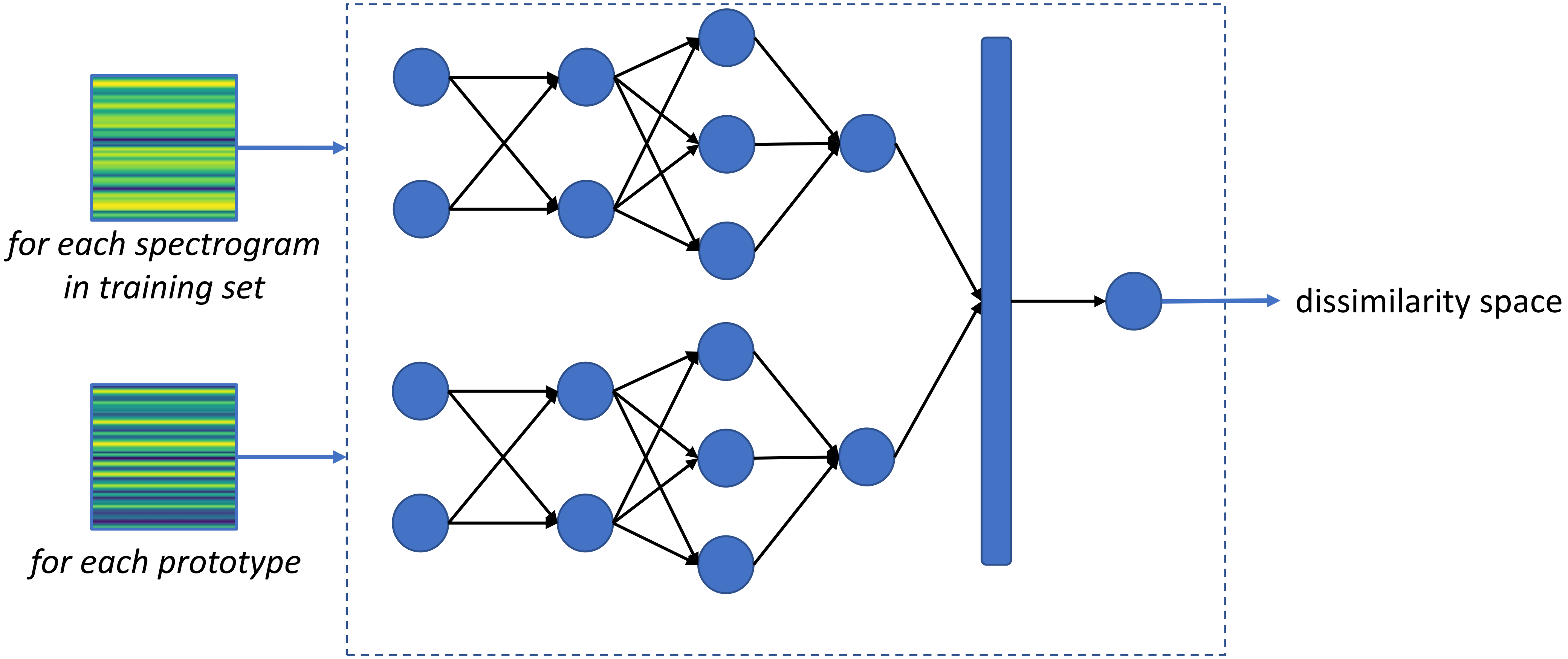
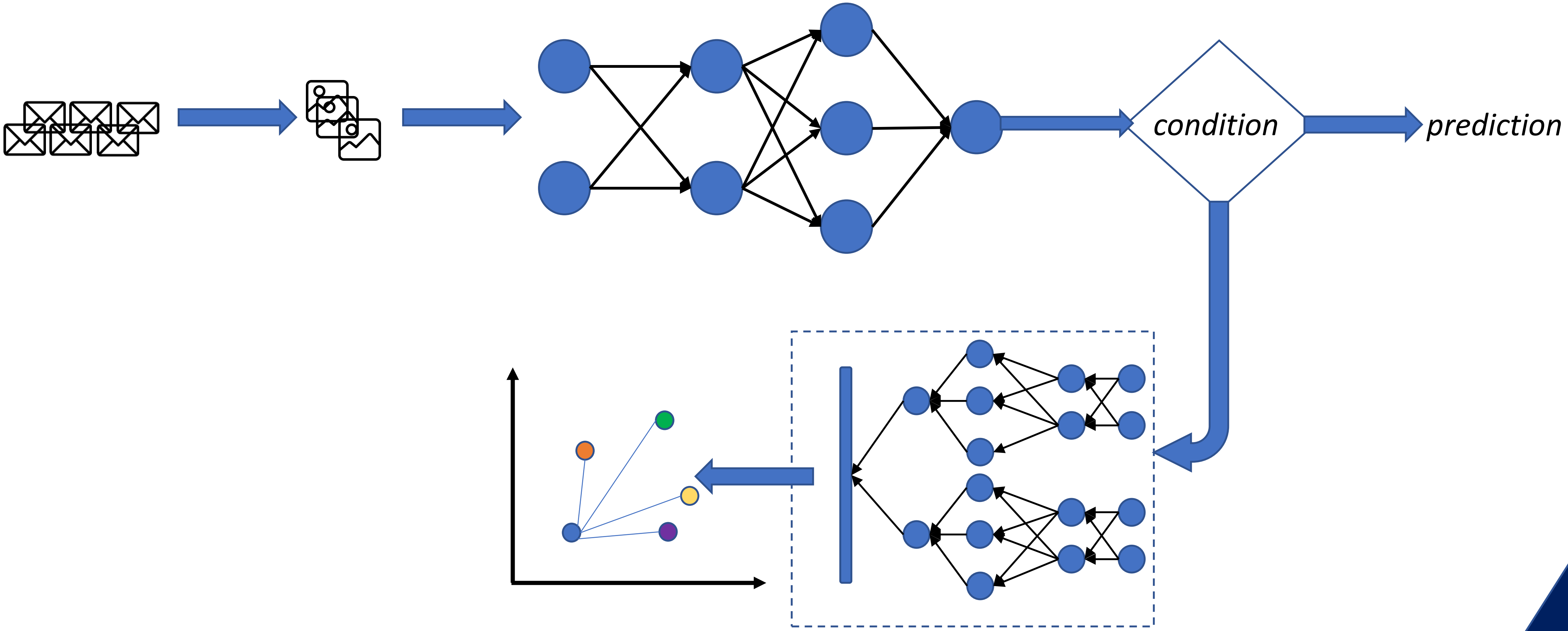


STEP FIVE – DISSIMILARITY SPACE DATASET

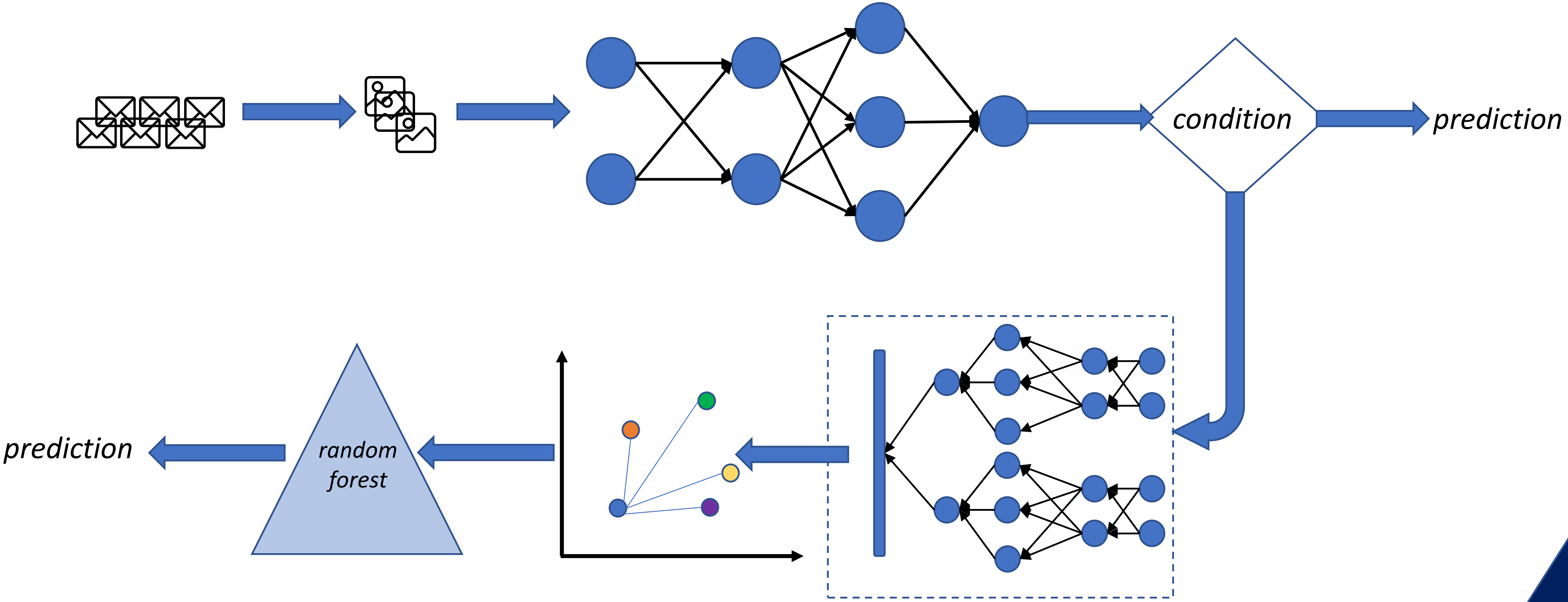
distance to cc	*distance to ns*	*class*
0.22	0.67	*credit card*
0.1	0.97	*name surname*
0.54	0.3	*credit card*
0.44	0.67	*credit card*
…	…	…

cc – credit card
ns – name surname

THE BIG PICTURE

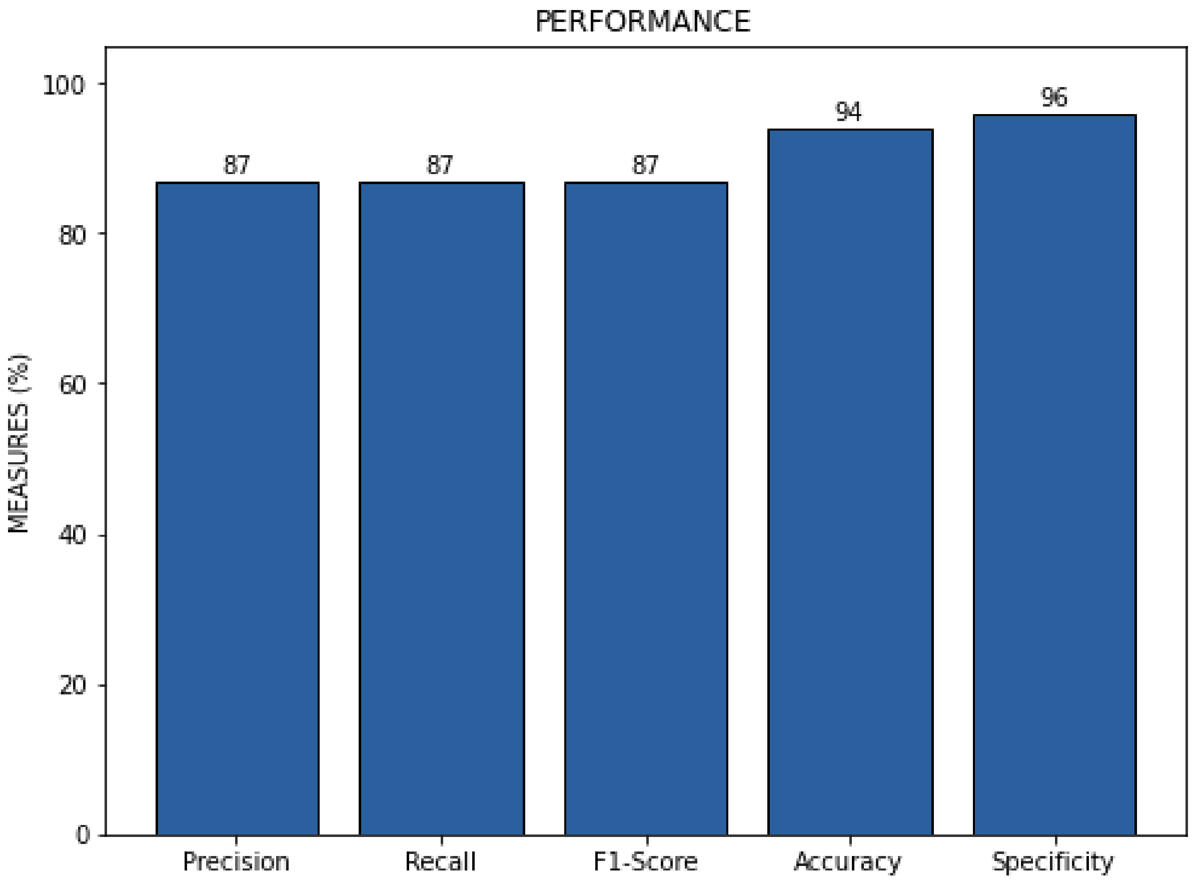


THE BIG PICTURE

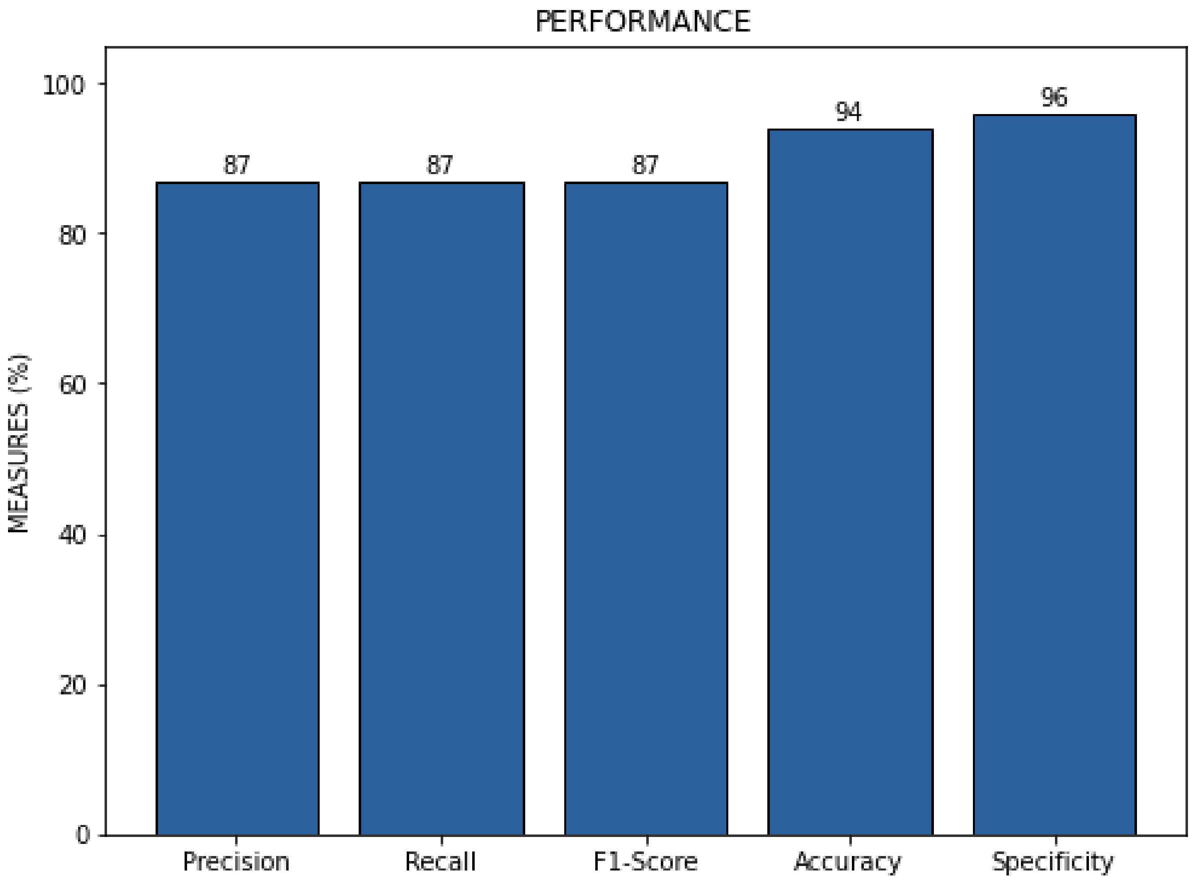


RESULTS

RESULTS

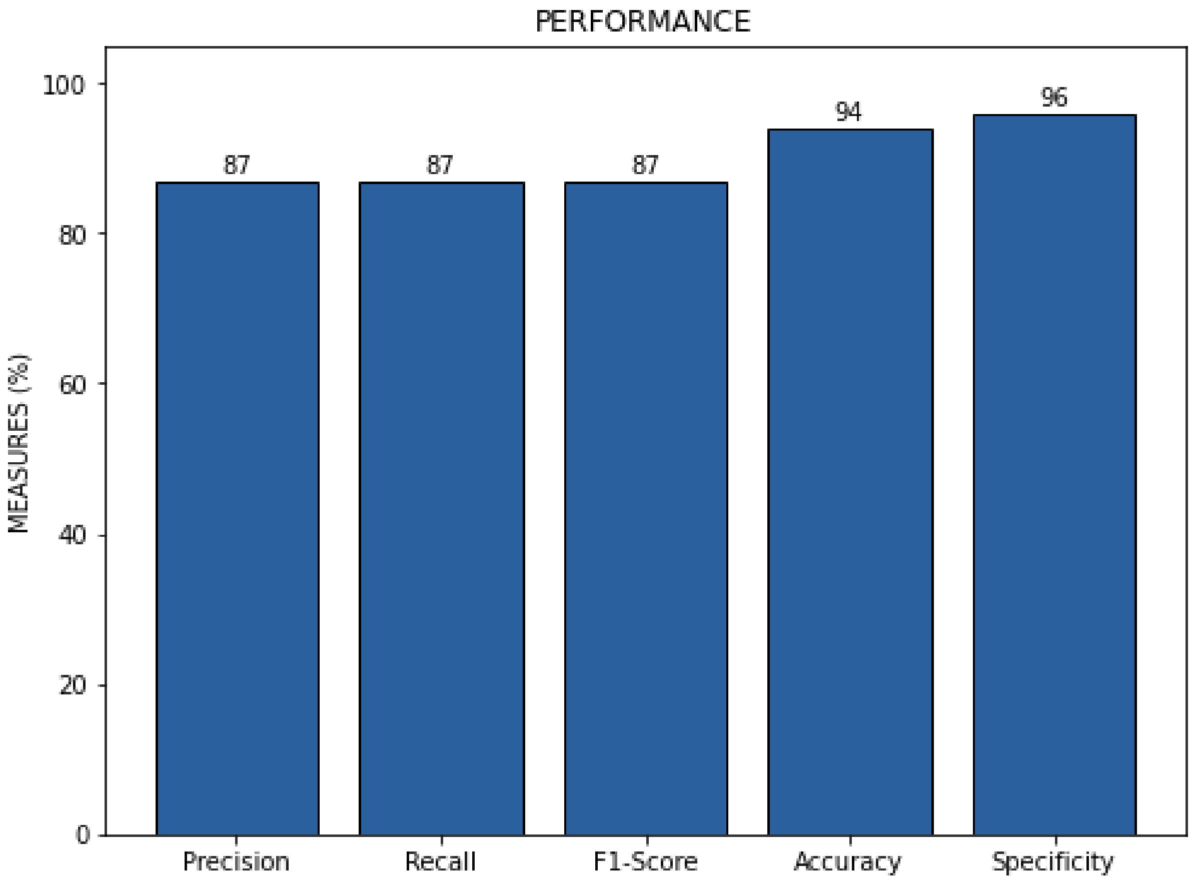

PERFORMANCE
MEASURES (%)
0
20
40
60
80
100
87
87
87
94
96
Precision
Recall
F1-Score
Accuracy
Specificity

RESULTS



SOME STATE OF ART ACCURACY RESULTS

RESULTS



SOME STATE OF ART ACCURACY RESULTS

- image preprocessing, feature extraction

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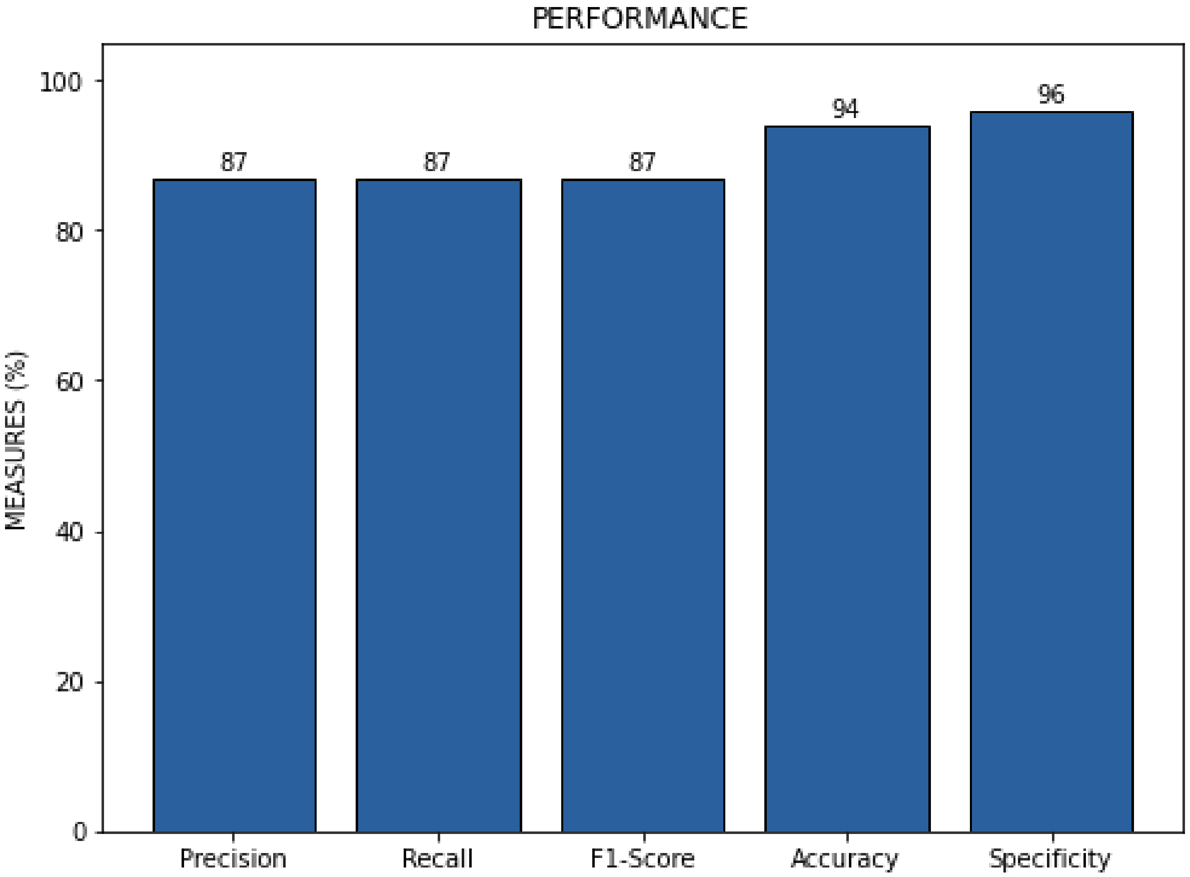
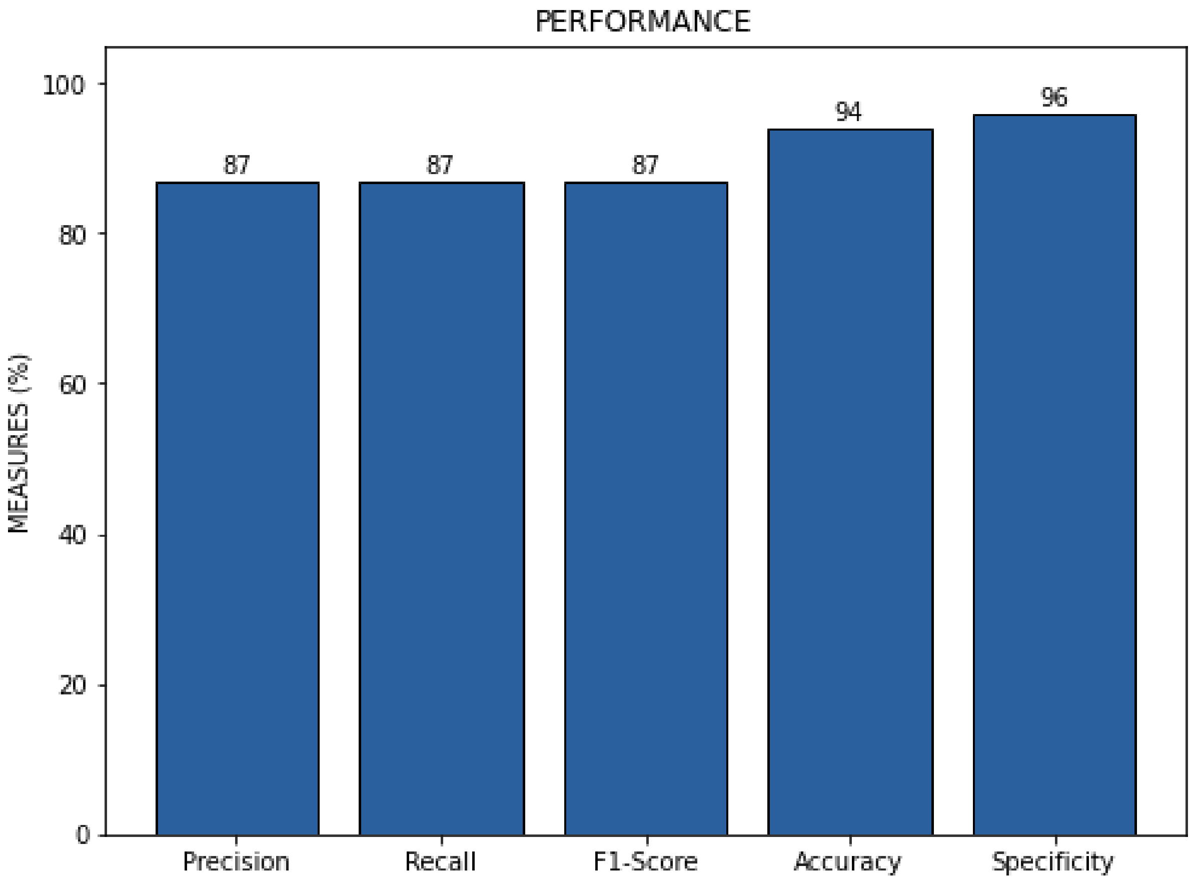


SOME STATE OF ART ACCURACY RESULTS

- image preprocessing, feature extraction
  - SVM, DT, NB 95%

RESULTS



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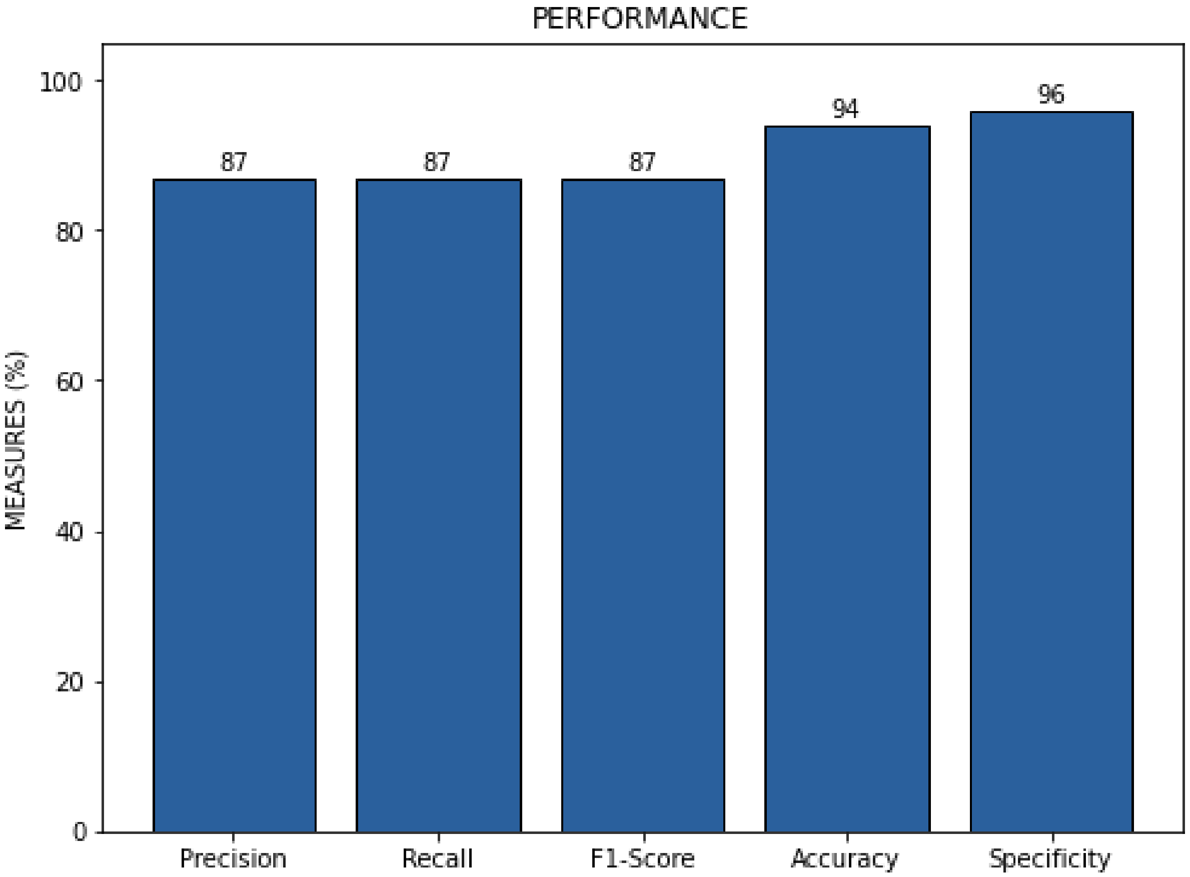
- statistical approach

RESULTS



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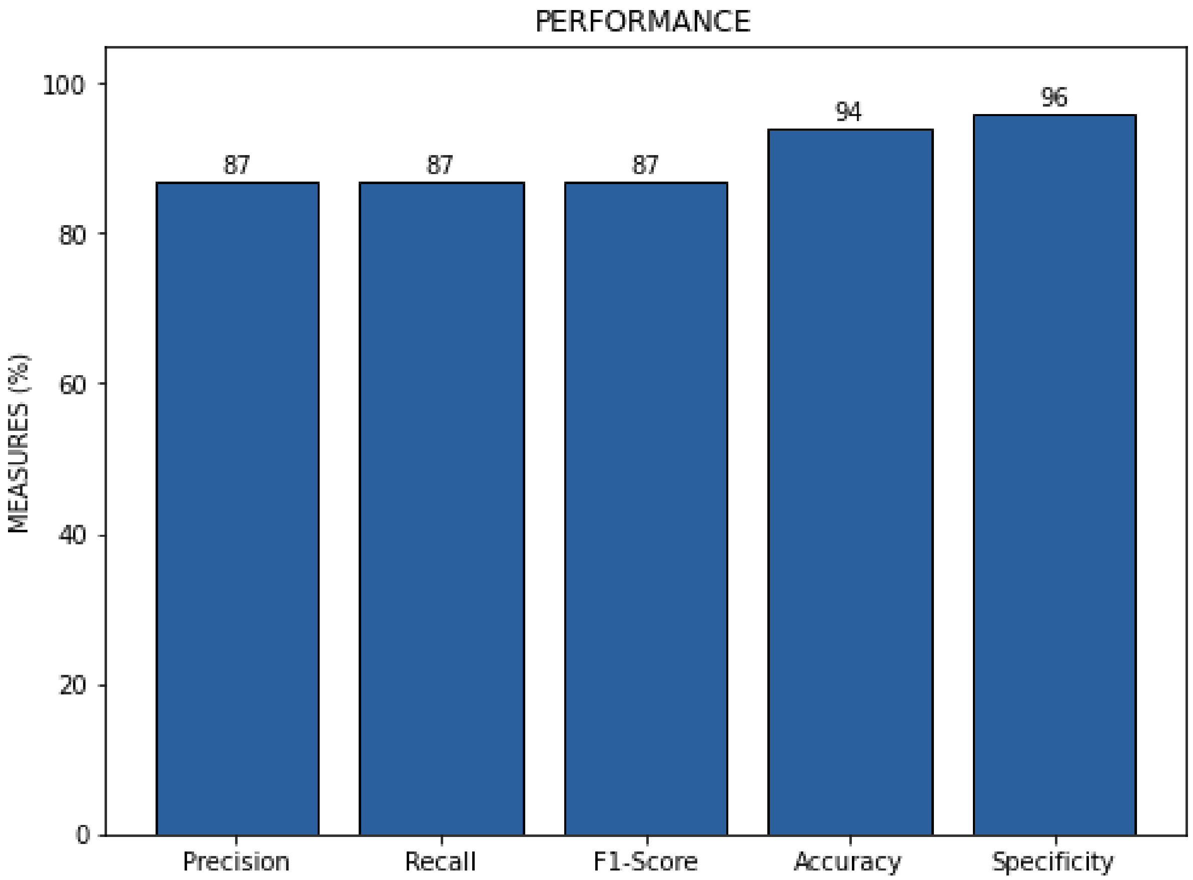
  - KNN 96%

RESULTS



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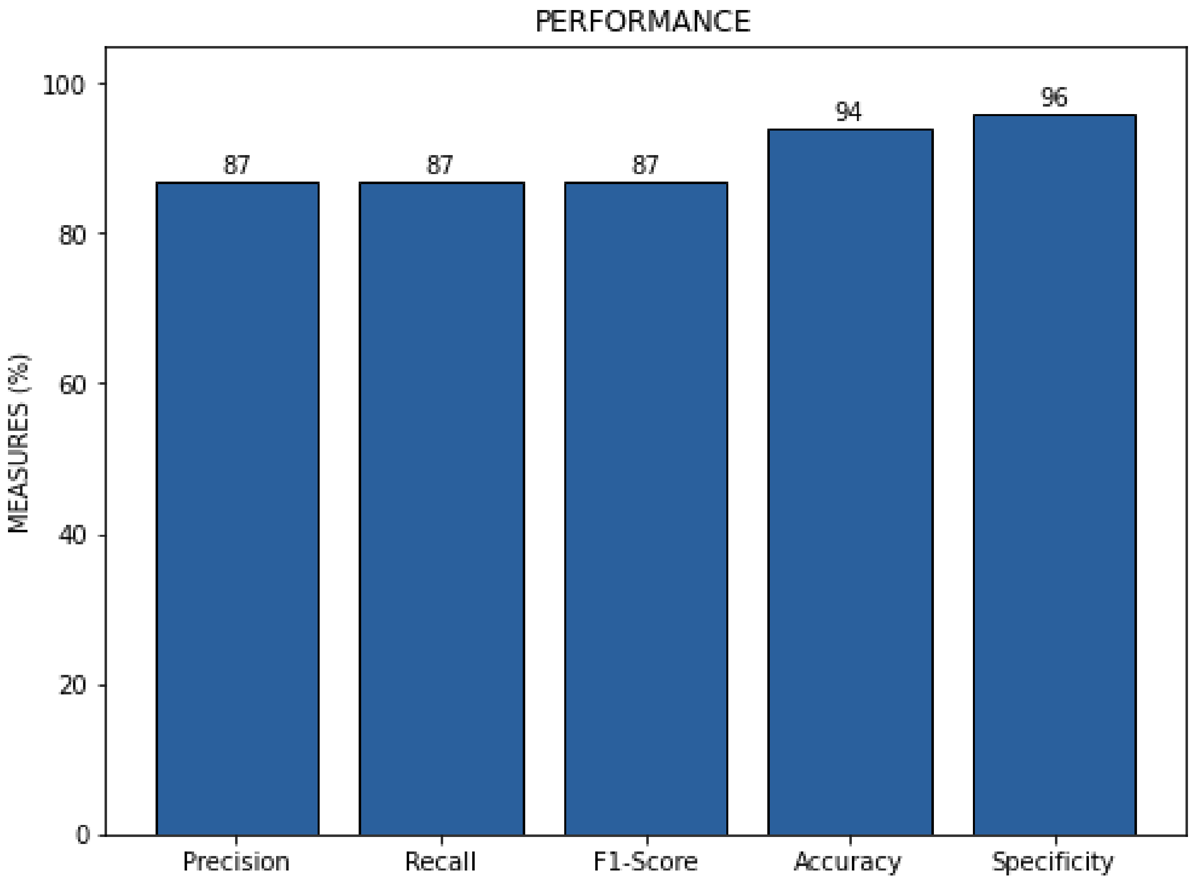
COMMON ISSUES

RESULTS



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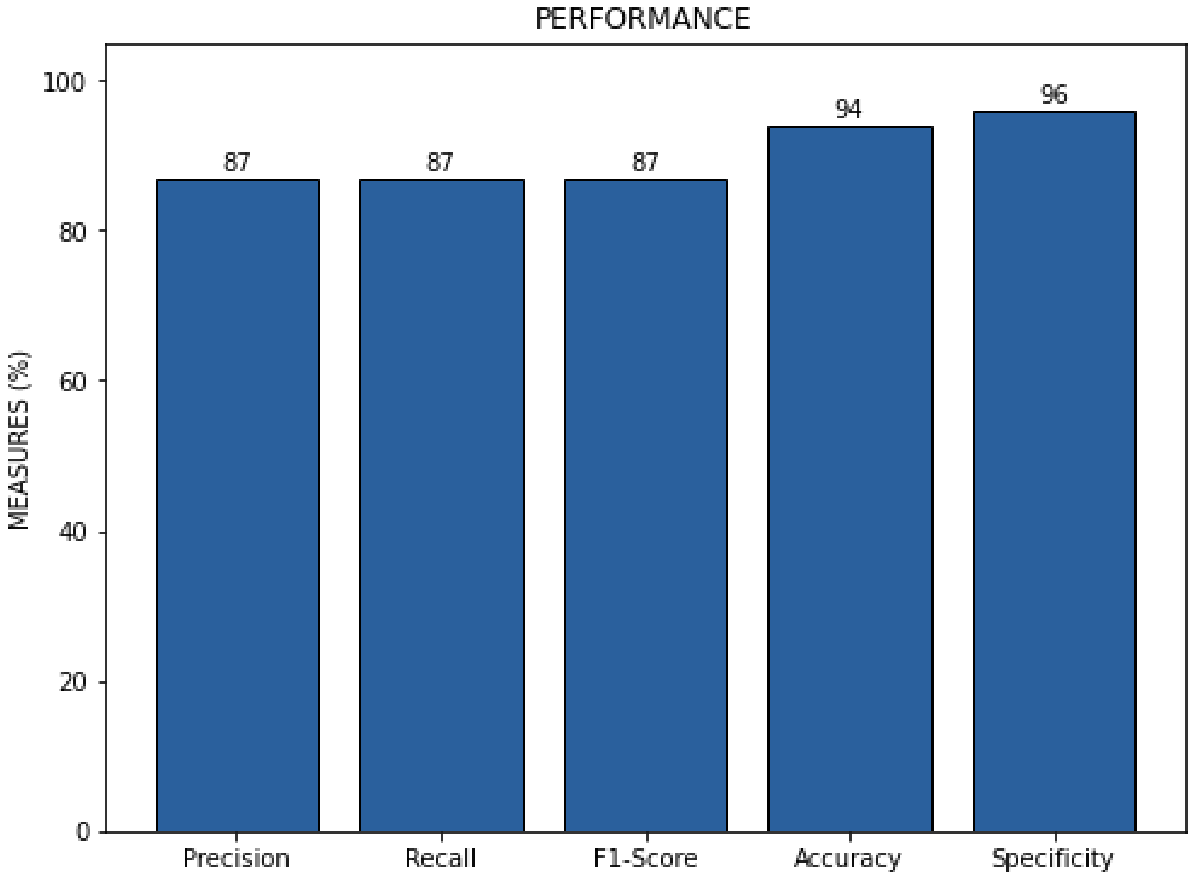
- high false-negative rate

RESULTS



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- high false-negative rate
- detect only a few type of CTC

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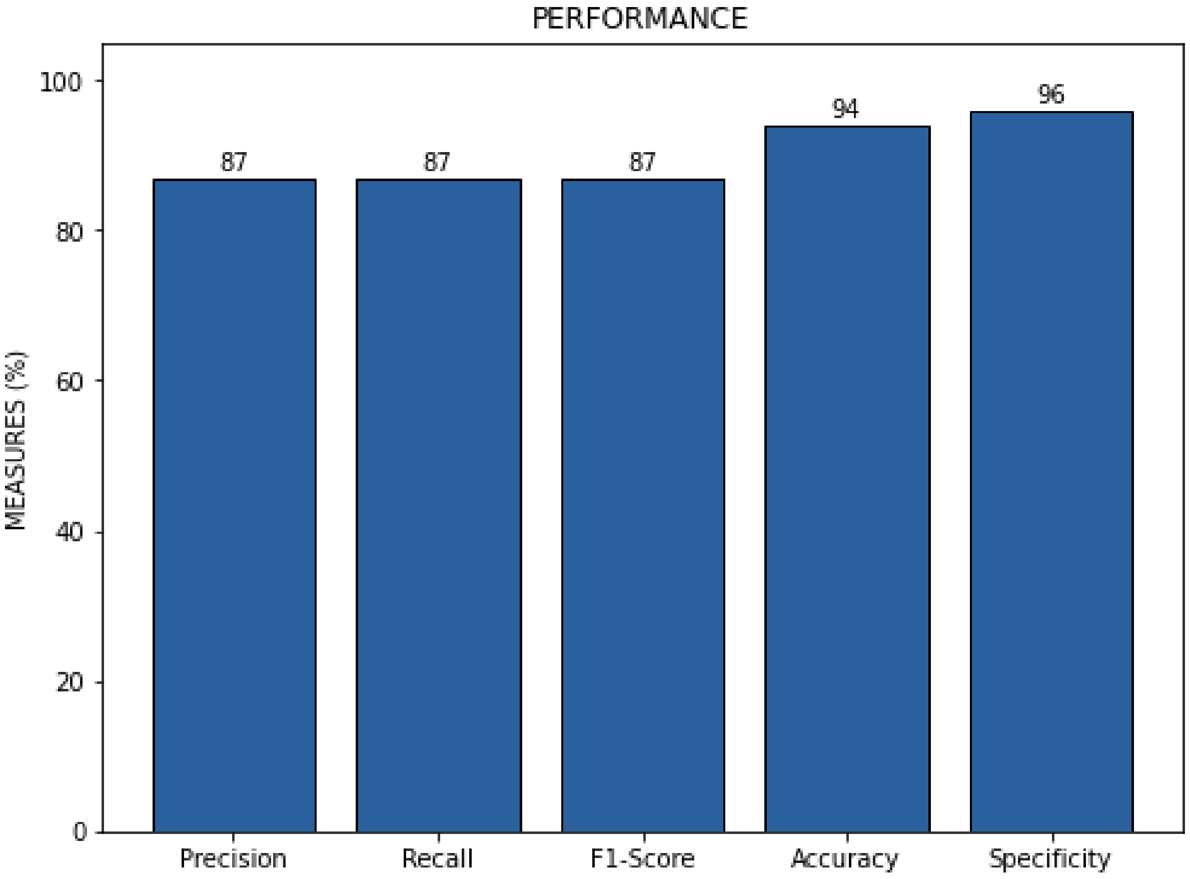

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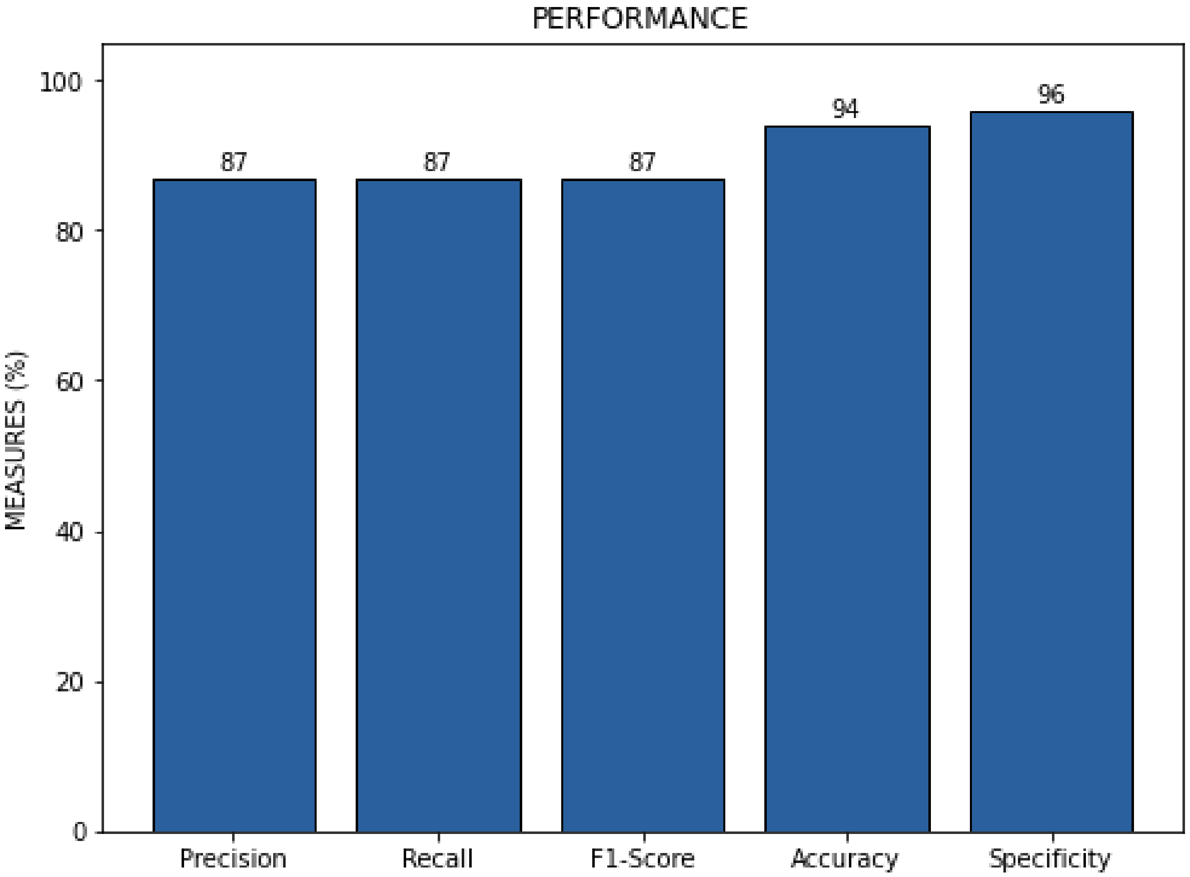

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M. A. Elsadig and A. Gafar, "Covert Channel Detection: Machine Learning Approaches," in IEEE Access, vol. 10, pp. 38391-38405, 2022

RESULTS – GAUSSIAN NOISE

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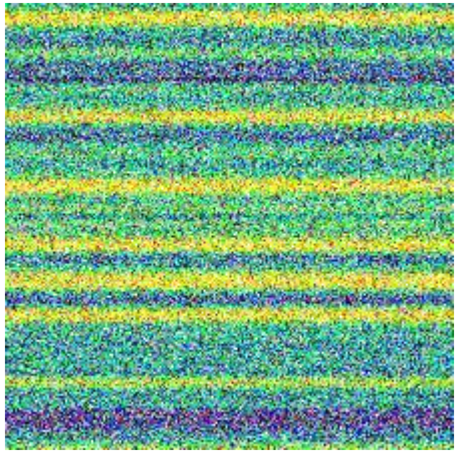
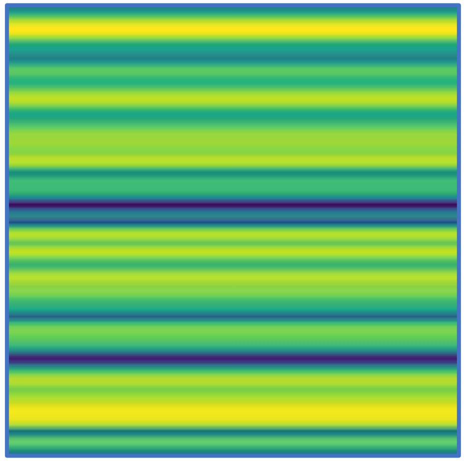
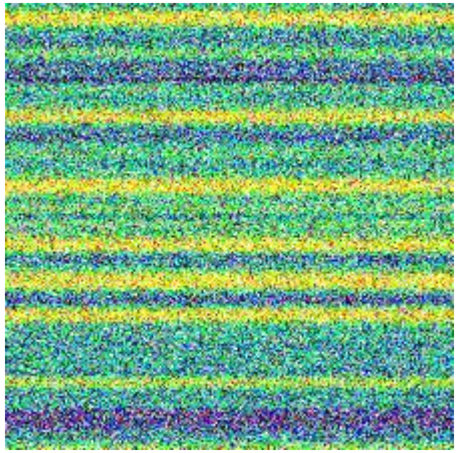
RESULTS – GAUSSIAN NOISE



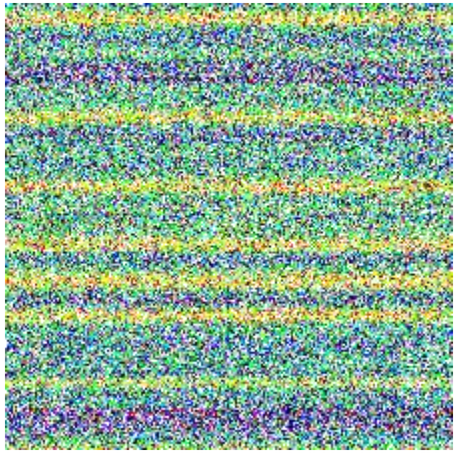
standard deviation 0.05

RESULTS – GAUSSIAN NOISE





standard deviation 0.05



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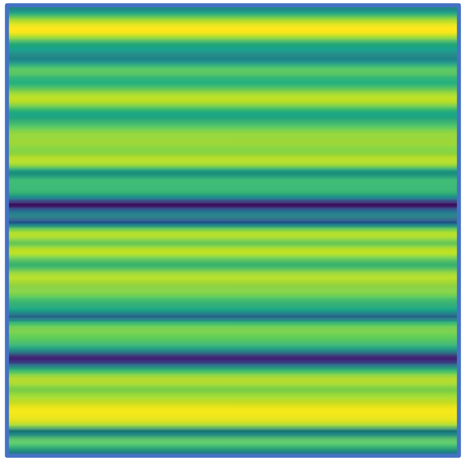

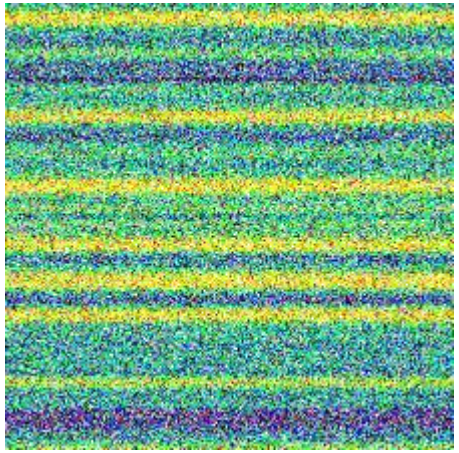

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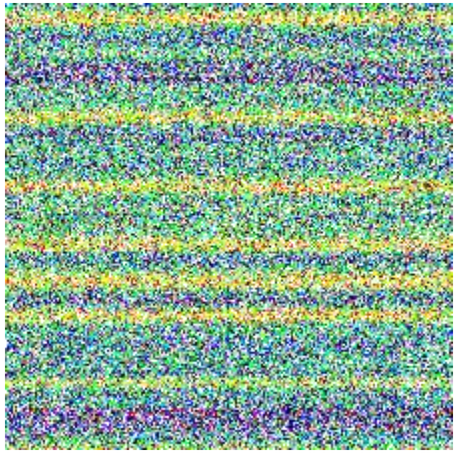
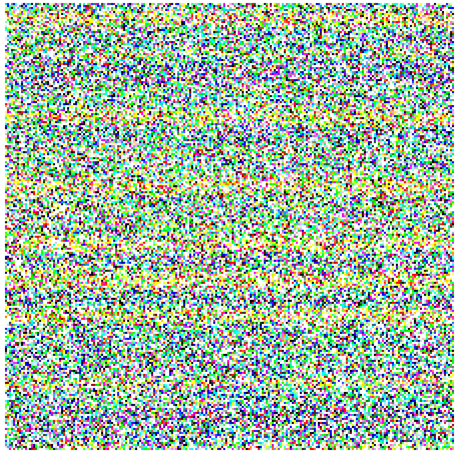
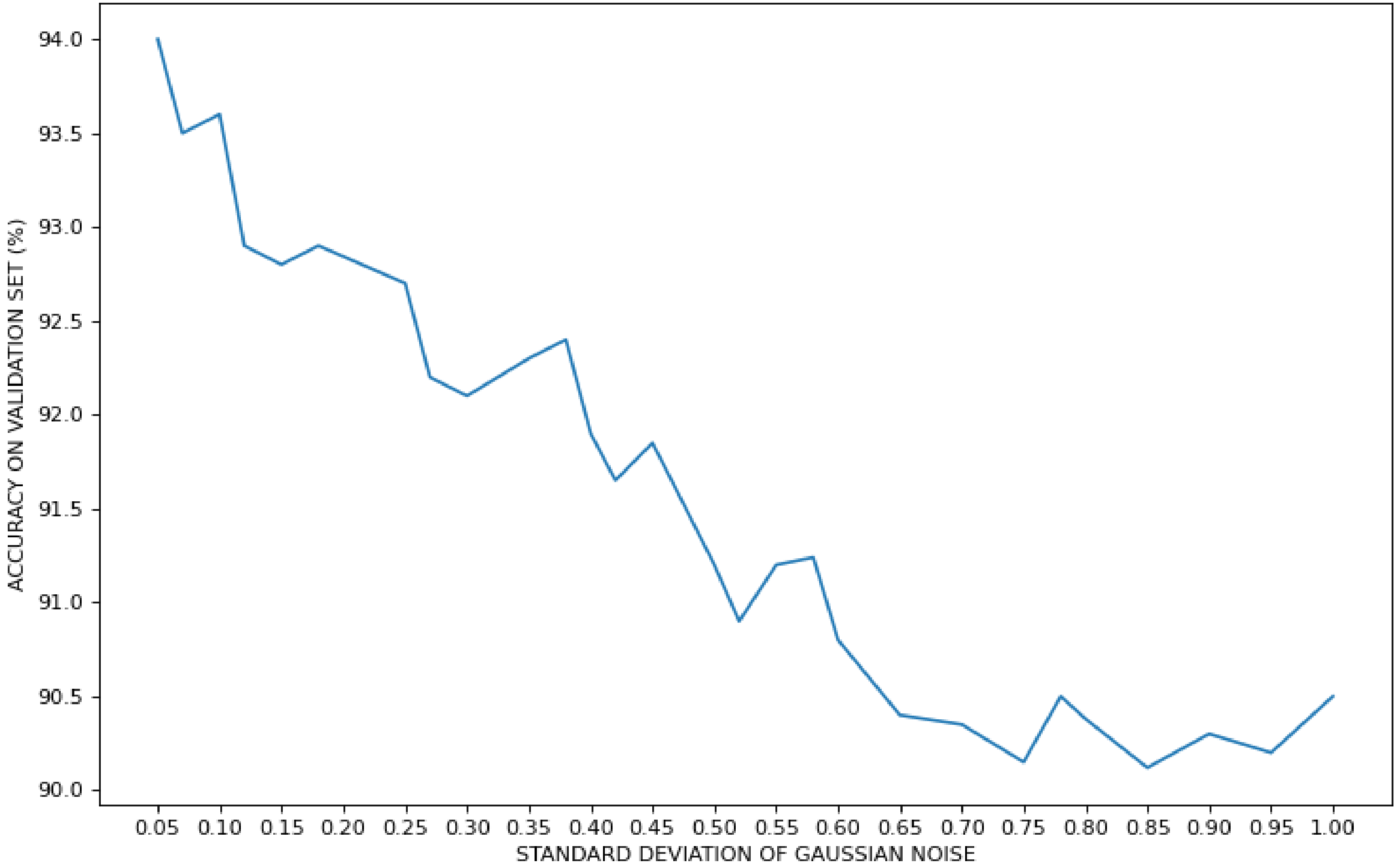


standard deviation 0.5

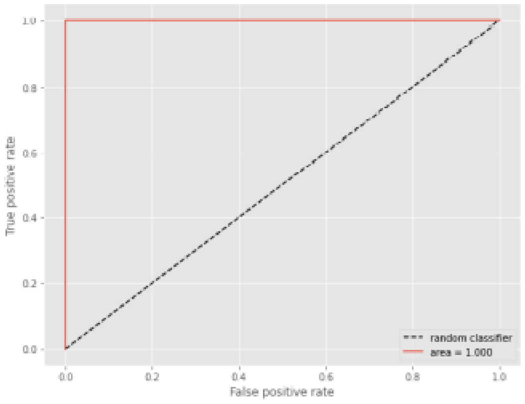


standard deviation 1.0

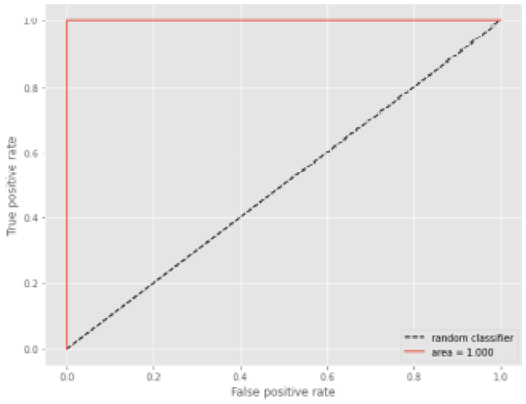
RESULTS – GAUSSIAN NOISE



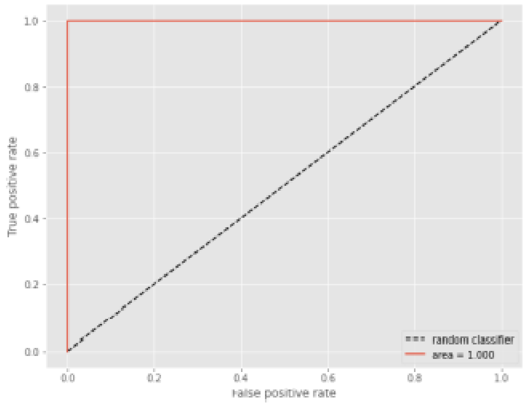
RESULTS – RECEIVER OPERATOR CHARACTERISTIC



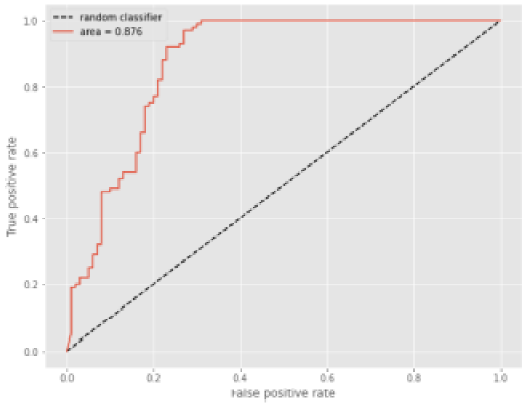
(a) ROC credit-card e email



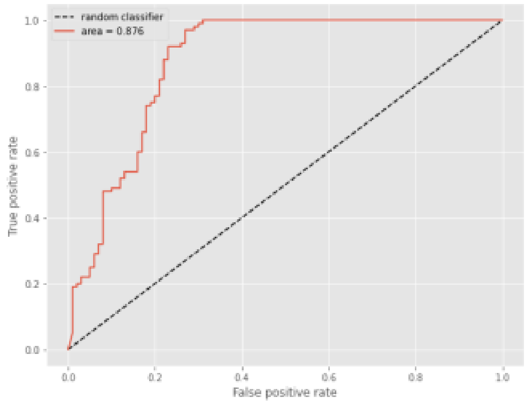
(b) ROC credit-card e vuota



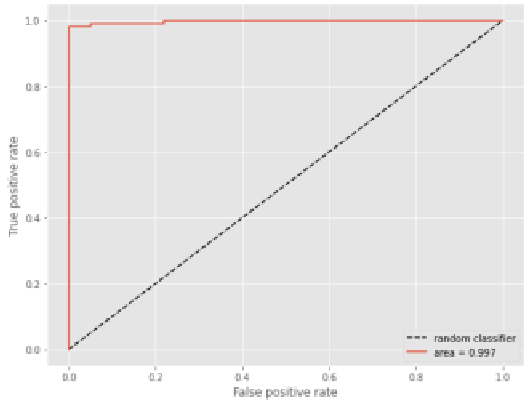
(e) ROC email e vuota



(f) ROC nome-cognome e credit-card



(c) ROC credit-card e nome-cognome



(d) ROC email e nome-cognome

CONCLUSION AND FUTURE DEVELOPMENTS

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- each CTC type spectrogram has a *prototype*

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- deep packet inspection
- other CTC types

THANKS *(english)*

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谢谢 *(chinese)*

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धन्यवाद *(hindi)*

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