UNIVERSITÀ DEGLI STUDI DI PADOVA

DIPARTIMENTO DI INGEGNERIA DELL'INFORMAZIONE

Network anomaly detection

Digital forensics

Master Degree in Cybersecurity, Master Degree in ICT for Internet and Multimedia

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Network anomaly

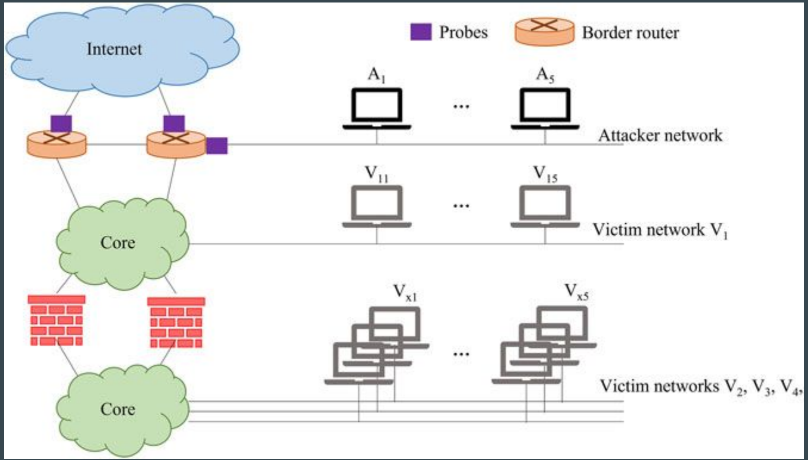
- Given a set of data: ”nominal” samples and “anomalous” samples, assume that anomalies are created by a different generation process with respect with the nominal samples.
- **Well-Defined Anomaly Distribution (WDAD)** assumption: anomalies are drawn from a known distribution

Anomaly can be caused by different factors:

1. *Non-human error*
2. *Human error*
3. *Malicious human activity*
    - Network attack (anomalous traffic)
    - Image tampering or deepfake detection
    - Fraud detection
    - OS attacks

Dataset

- UGR'16 dataset has been selected
  - It's composed by two parts:
    - clean subset: includes real background traffic → training
    - test subset: combination of real background and controlled attack traffic → testing

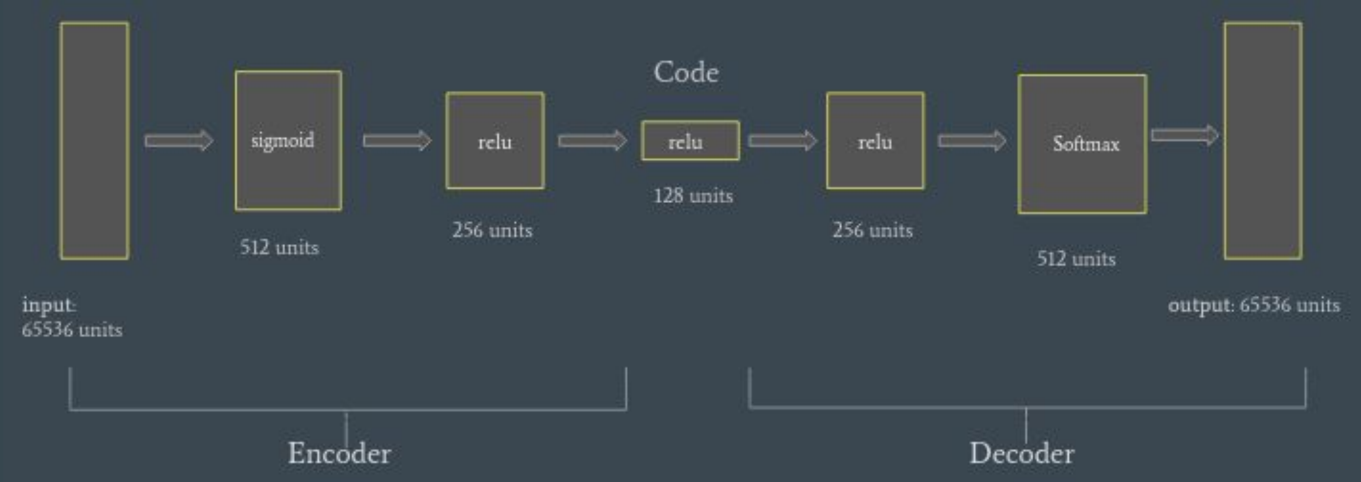


- Types of attack considered:
  - DoS11: one-to-one DoS where attacker A1 attacks the victim V21;
  - DoS53: the five attackers (A1 – A5) attack three victims.
  - Scan11: one-to-one scan attack where attacker A1 scans the victim V41;
  - Scan44: four-to-four scan attack where the attackers A1, A2, A3 and A4 scan the victims V21, V11, V31 and V41, respectively.

Goal and implementation

Develop and design an *anomaly detection system* which is able to detect anomalous conditions in form of attacks:

1. Clean
2. Dos 11
3. Dos 53
4. Scan 11
5. Scan 14



Method used:

- We opted for a deep learning approach to detect anomalies → Autoencoder
- Classification of the type of attack by using unsupervised segmentation
  → K-means clustering
  → Agglomerative Clustering

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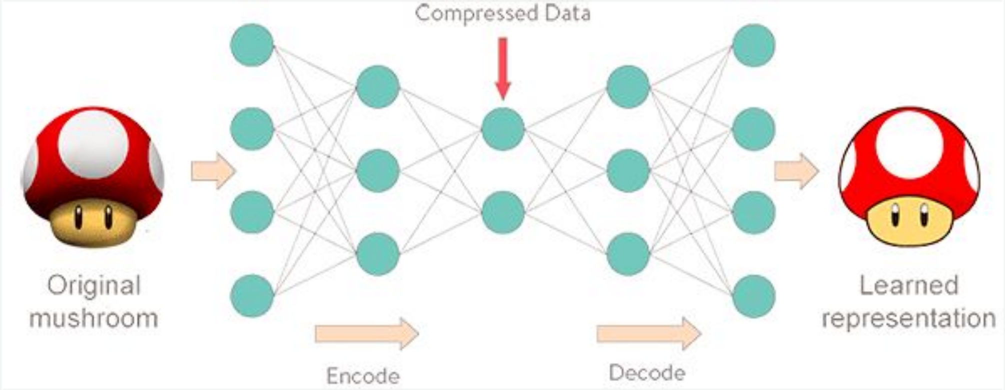
Autoencoder

- What is an autoencoder?
  - Is a type of **artificial neural network** used to learn efficient codings of unlabeled data.
  - The autoencoder learns a hidden representation (through encoding) by learning the main features of the data and then reconstructing in based to the hidden representation.



- Basic architecture
  encoder → the input layer
  decoder → the output layer

- Fields of application
  - facial recognition
  - feature detection
  - anomaly detection

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How do we detect an anomaly with autoencoders?

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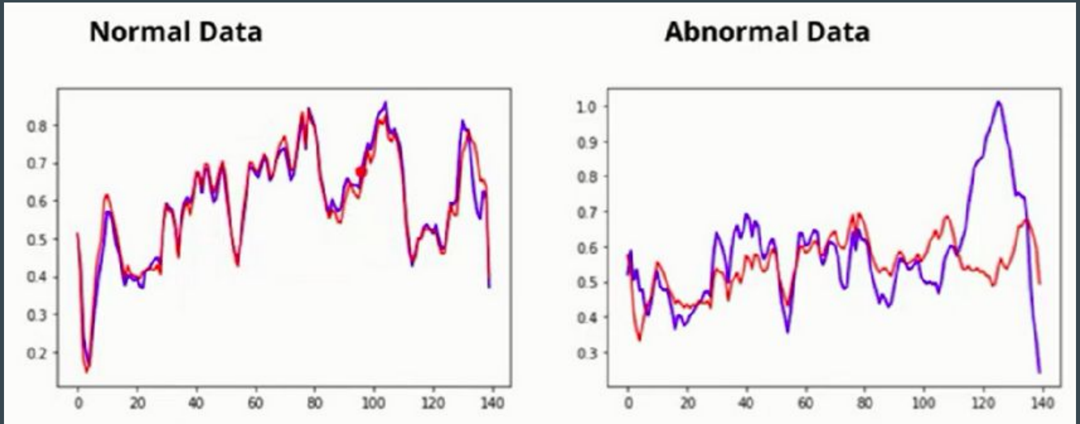
Autoencoders are naturally lossy due the compression of information. This loss is known as reconstruction error.

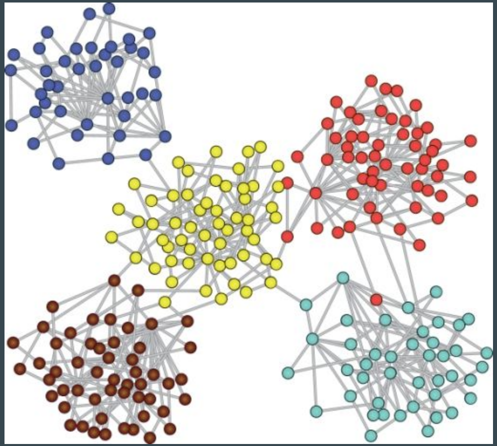
- We train the autoencoder in normal data (without) anomalies and get the nominal error
- In the test data, if the error is greater than a threshold value, then we have anomaly data.



Clustering

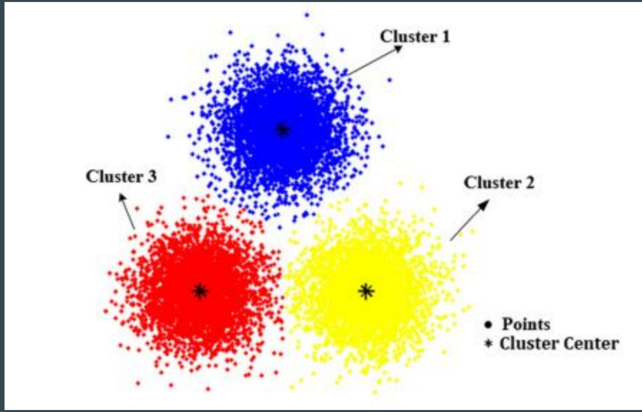
Agglomerative Clustering

Each object is initially a single-element cluster and combine the most similar elements until the target.



K means

Starts with a randomly selected centroids, which are used as the beginning points for every cluster, and then iteratively optimize the positions of the centroids



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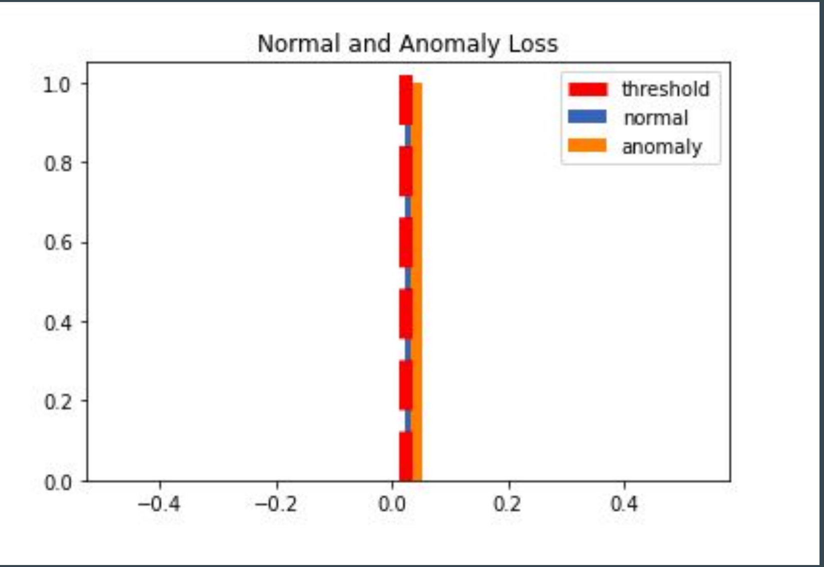
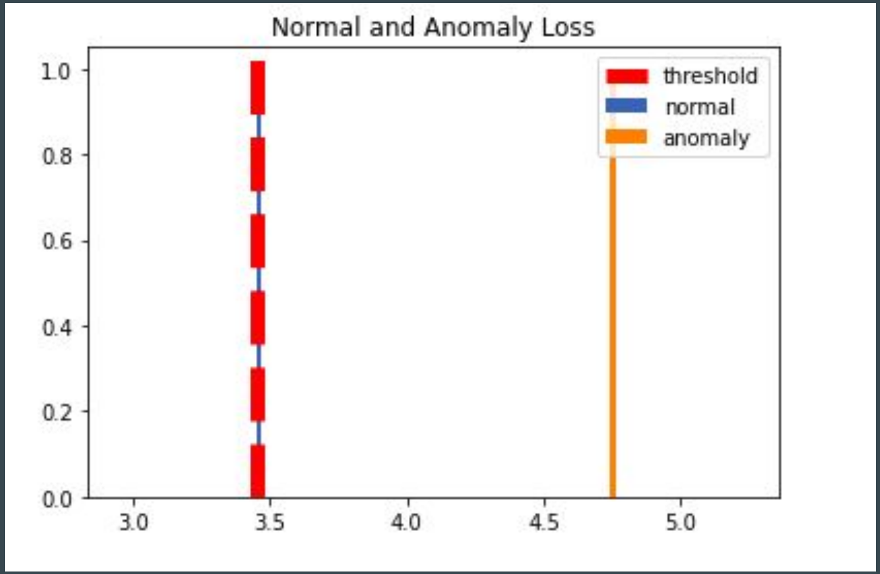
Experimental results

MSLE



MSE



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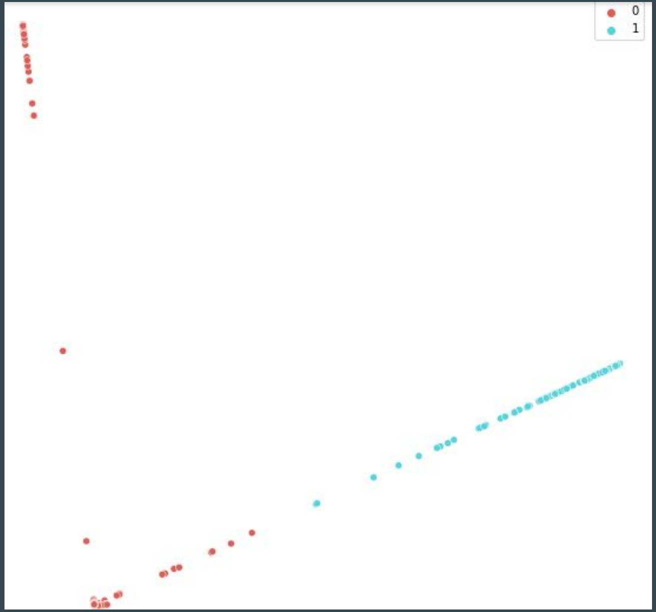
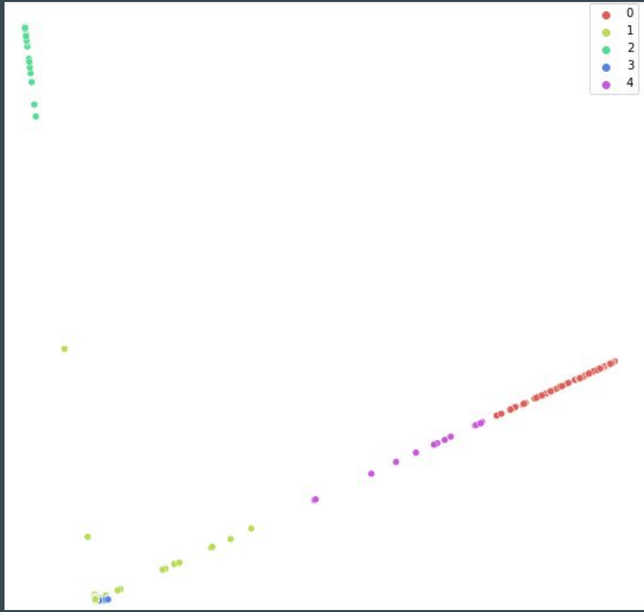
Experimental results II

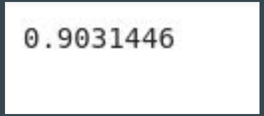


Silhouette Coefficient

PCA
Agglomerative clustering

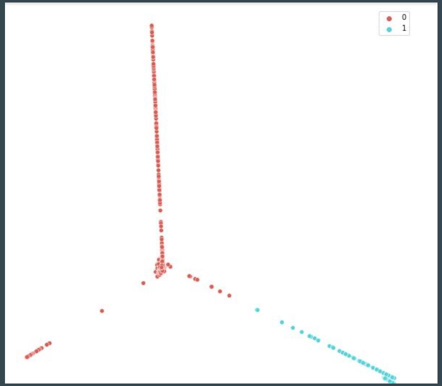


Silhouette Coefficient



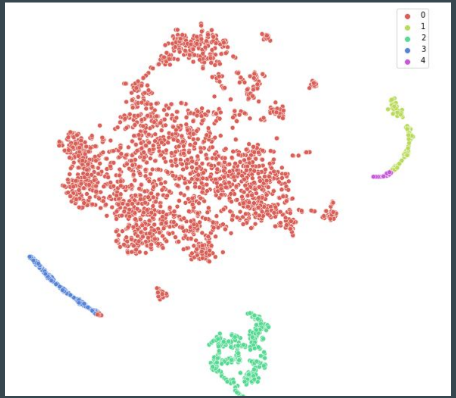
Experimental results II

0.85686904

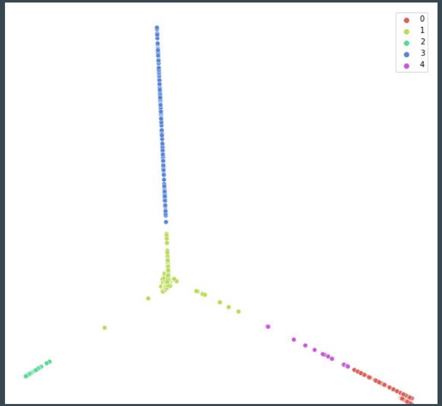


TSNE
K means

Isomap
Agglomerative clustering



0.90360093



Conclusions

- Key point of the project: adequate hidden representations inside the autoencoder.
  - No too simple, no too complex: reaching the best model is an empirical process.
- The greater the distance between anomalies and nominal data, the better.
- In this case no linear dimensionality reduction helped us to get the best model but linear reduction performed good as well.
- With good hidden representations, independently the method of clustering, the result is good enough.
- Resources limitations can limit the improvement.

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