IT DAYS

#Programming
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An innovative machine learning model for short term weather prediction based on radar data

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Research part of the WeaMyL project

- Collaboration between:
  - Babeș-Bolyai University (BBU)
  - Romanian National Meteorological Administration (ANM)
  - Norwegian Meteorological Institute (MET)

- Major goal: provide an efficient, seamless nowcasting platform which will be integrated with national warning systems

Norway grants

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WeaMyL

METEO ROMANIA

Norwegian Meteorological Institute

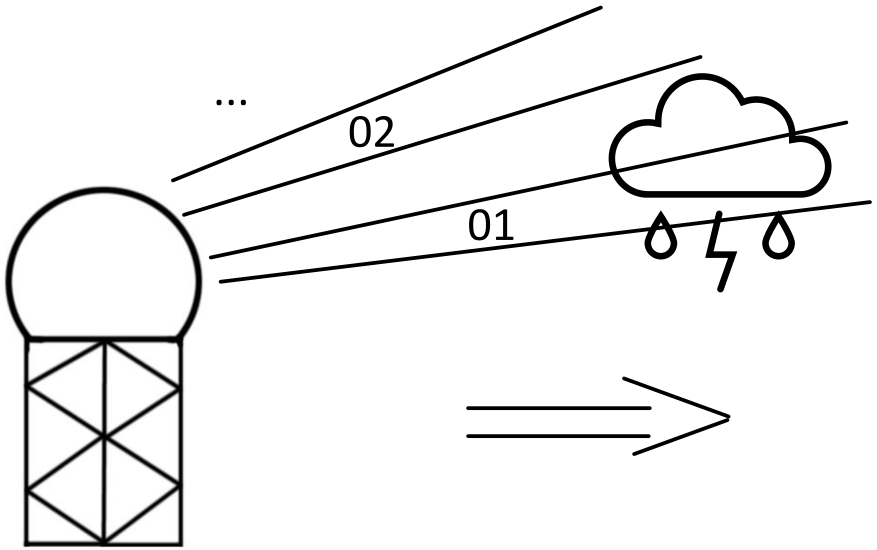
Weather nowcasting

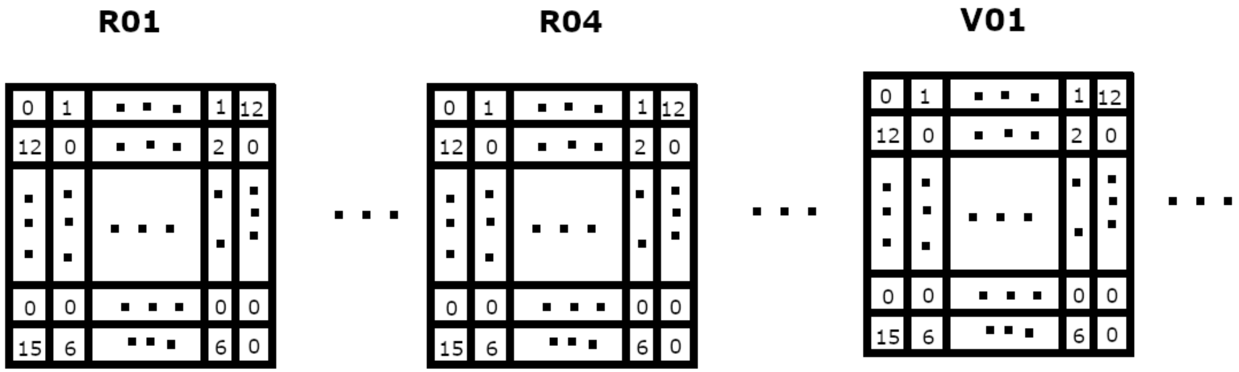
- **Weather Nowcasting:** short-term weather prediction.
- Usually defined as forecasts for the next **0 to 6 hours.**

- Weather nowcasting:
  - especially useful for *severe weather* and *storm tracking*
  - needed for relevant early warnings
  - a *difficult* task for meteorologists

Radar Data

- **Radar output:**
  - *Base products*: Reflectivity, Velocity
  - *Derived products*: vertically integrated liquid, one-hour precipitation etc.
  - One full scan every **6 minutes**





Reflectivity:

- estimates the size of water droplets
- expressed in decibels relative to the reflectivity factor Z (dBZ)
- can be used to derive the rainfall rate

Current research goal:

Predict radar data for the purpose of weather nowcasting.

- Predict reflectivity data - most helpful for meteorologists for estimating the severity of a storm.
- Reflectivity at **the lowest elevation angle** is the most relevant.
- From the data at the **current step** predict the data at **next step.**

Prediction as classification:

For a specific location, it is predicted if the radar value at that location will be higher or lower than a certain threshold τ

Autoencoders

- Are a type of Deep Neural Networks
- Learn *low dimensional representations* that capture the relevant characteristics of the input data

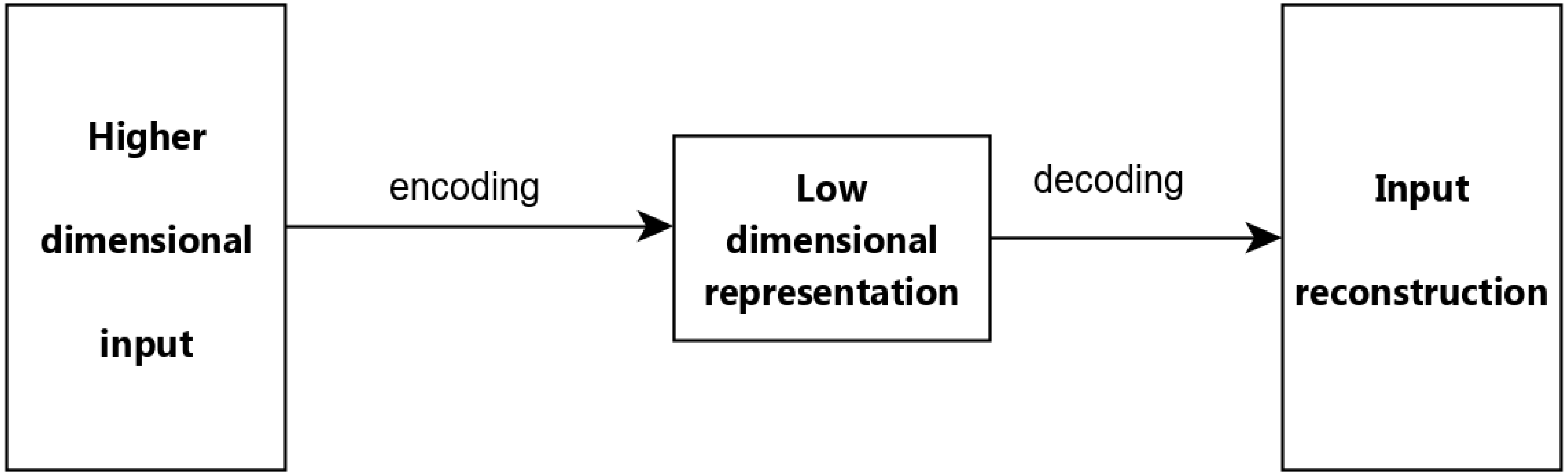


Figure: Abstract representation of an Autoencoder

AutoNowP - Architecture

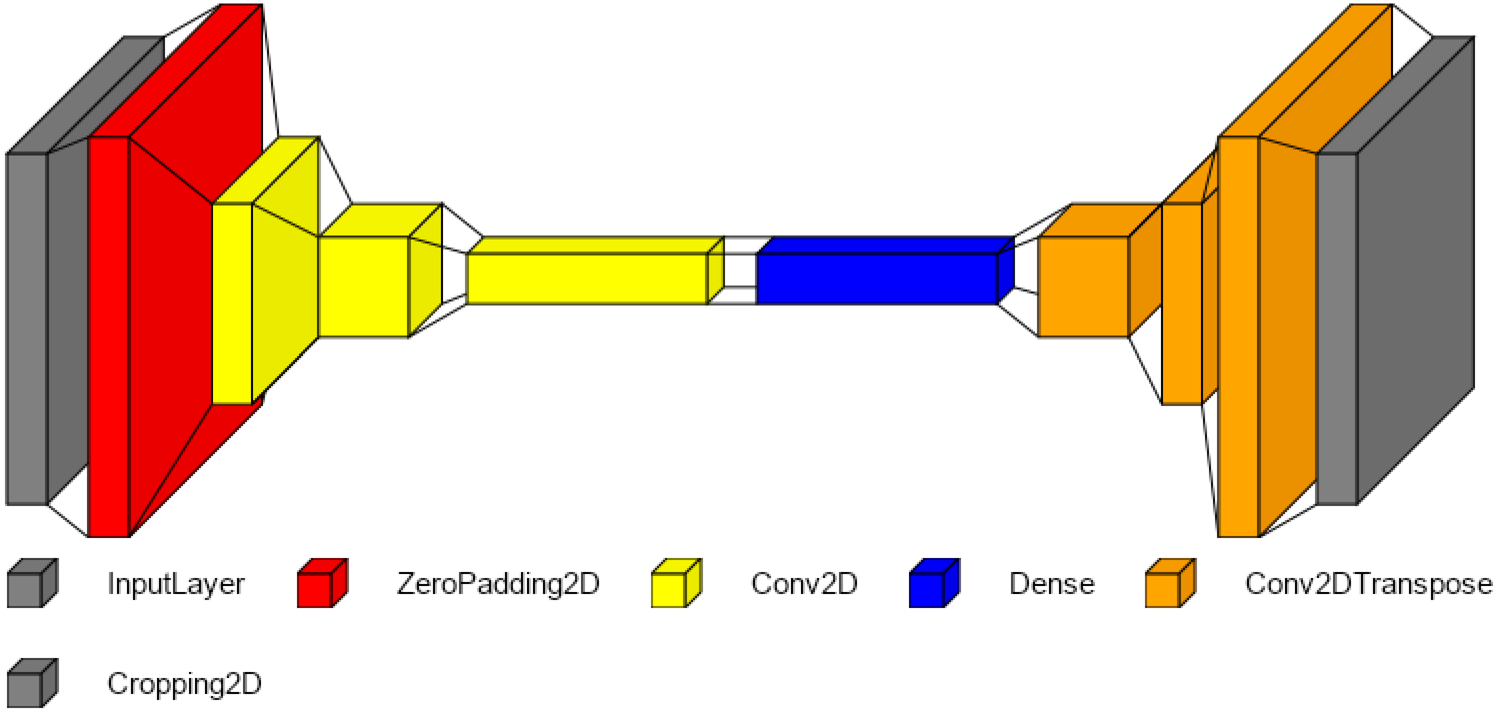


Figure: Architecture of one AutoNowP convolutional autoencoder.

AutoNowP- Data Model

- In example on the right:
  - Highlighted instance at time *t* with location (3,3)
  - In blue: the corresponding data grid
  - In red: the corresponding label

20	30	10	15	10
15	15	10	20	5
20	10	**15**	20	25
10	5	10	10	20
15	5	10	15	20

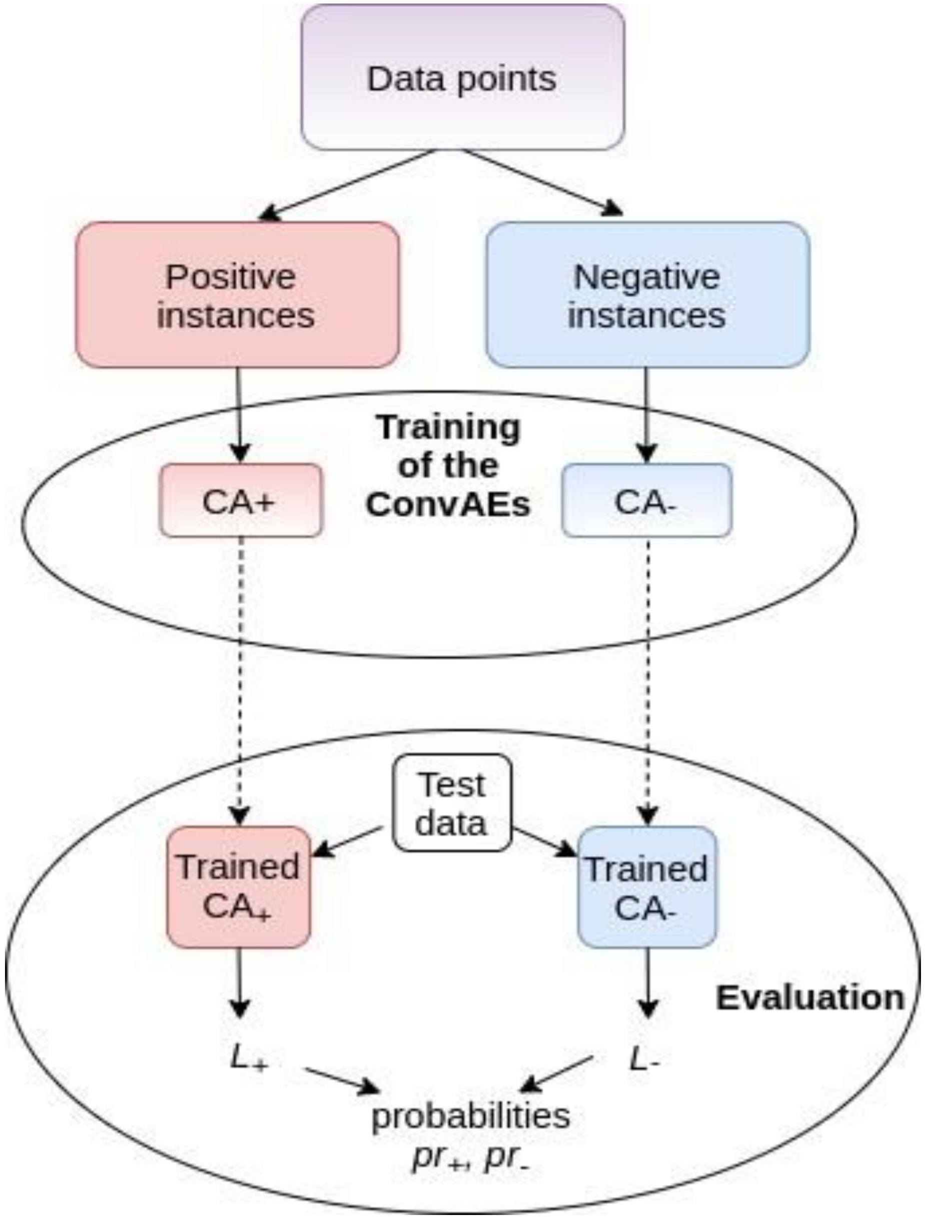
Figure: The data grid at time stamp *t*-1. In blue is the neighbourhood of the location *l* = (3, 3) of diameter *d* = 3.

15	5	10	10	15
10	25	15	5	10
20	0	**10**	10	10
15	10	25	15	5
15	0	15	5	0

Figure: The data matrix at time stamp *t*. In red is the value of R at location *l* = (3, 3).

AutoNowP - Overview

- $CA_{+/-}$: Convolutional autoencoder for positive/negative values
- $L_{+/-}$: reconstruction loss for the test sample by the $CA_{+/-}$
  (loss is Mean Squared Error - MSE)
- $p_{+/-}$: probability that the test sample is in the positive/negative class



Computing Probabilities

$$p_+(q) = 0.5 + \frac{MSE_-(\hat{q},q) - MSE_+(\hat{q},q)}{2 \cdot (MSE_-(\hat{q},q) + MSE_+(\hat{q},q))}$$

$$p_- = 1 - p_+(q)$$

where:

- q : query sample
- $p_{+/-}$: probability that the query sample is in the positive/negative class
- $MSE_{+/-}(\hat{q},q)$: MSE between q and $\hat{q}$ - the reconstruction of q by the autoencoder $CA_{+/-}$

Case study

- Dataset:
  - Data collected over central Romania
  - Single polarization 458 S-band Weather Surveillance Radar - 98 Doppler (WSR-98D)
    - Full volume scan every 6 minutes
  - radar data gathered from **20** days from June 2010, 2017, 2018

- Properties:
  - 9,003,688 instances
  - 3.44% in the positive ("+") class
  - 96.56% in the negative ("-") class

Methodology - preprocessing

- Split into positive/negative class depending on threshold τ
  - We tested with τ values 10, 20 and 30

- Normalize dataset:

$$R'(l,t) = \frac{R(l,t) - R_{min}}{R_{max} - R_{min}}$$

where:

- $R(l,t)$: the value of Reflectivity (R) at time t and location l
- $R'(l,t)$: is the normalized value of R at time t and location l
- R_{min} : is the minimum value in the domain of R
- R_{max} : is the maximum value in the domain of R

Methodology - 3-Fold Cross Validation

1. Split into training, validation datasets
   - Training and validation datasets are used while training the network models (CA_+, CA_-)
   - Testing is used for evaluating the model
   - 47% used for training, 20% used for validation, 33% used for testing

2. Used multiple folds:
   - From the entire set select testing dataset multiple times
   - Use the rest for training/validation

Testing Fold 1
Testing Fold 2
Testing Fold 3

Evaluation

- **Metrics used:**
  - Based on Confusion Matrix (True positives, True negatives, False positives, False Negatives)
  - Critical success index (CSI), True skill statistic (TSS), Probability of detection (POD), PPV, NPV, Specificity, AUC, AUPRC

- **Using folds results:**
  - Computing the mean and standard deviation for the results.
  - Compute the 95% Confidence intervals (multiply standard deviation with critical value 1.96)
  - Confidence intervals shows us the reliability of the results

Results per threshold

T	CSI	TSS	POD	PPV	NPV	Spec	AUC	AUPRC
10	**0.615** ± 0.018	**0.861** ± 0.012	**0.876** ± 0.012	**0.674** ± 0.017	**0.996** ± 0.001	**0.985** ± 0.002	**0.931** ± 0.006	**0.775** ± 0.013
20	0.425 ± 0.072	0.471 ± 0.091	0.474 ± 0.092	0.810 ± 0.015	0.989 ± 0.001	0.997 ± 0.001	0.736 ± 0.046	0.642 ± 0.039
30	0.151 ± 0.046	0.157 ± 0.051	0.157 ± 0.028	0.812 ± 0.031	0.993 ± 0.001	1.000 ± 0.000	0.579 ± 0.014	0.485 ± 0.007

Table: Experimental results for different thresholds, with 95% CI

Comparison to other classifiers

- **Table:** Comparative results between *AutoNowP* and other classifiers.

95% CIs are used for the results.

Model	CSI	TSS	POD	PPV	NPV	Spec	AUC	AUPRC
AutoNowP	**0.615** ± 0.018	**0.861** ± 0.012	**0.876** ± 0.012	**0.674** ± 0.017	**0.996** ± 0.001	**0.985** ± 0.002	**0.931** ± 0.006	**0.775** ± 0.013
Logistic Regression	0.672 ± 0.012	0.752 ± 0.013	0.757 ± 0.013	0.857 ± 0.005	0.992 ± 0.001	0.996 ± 0.000	0.876 ± 0.007	0.807 ± 0.008
Linear Support Vector Classifier (SVC)	0.685 ± 0.012	0.778 ± 0.007	0.783 ± 0.007	0.845 ± 0.015	0.992 ± 0.000	0.995 ± 0.000	0.889 ± 0.003	0.814 ± 0.009
Decision Trees	0.574 ± 0.007	0.725 ± 0.004	0.734 ± 0.006	0.724 ± 0.012	0.991 ± 0.001	0.990 ± 0.002	0.862 ± 0.002	0.729 ± 0.006
Nearest Centroid Classification	0.571 ± 0.006	0.793 ± 0.013	0.807 ± 0.013	0.662 ± 0.015	0.993 ± 0.001	0.986 ± 0.001	0.896 ± 0.006	0.735 ± 0.003

Conclusions & Future Work

We presented the idea of using machine learning methods in the field of short term weather forecasting - weather nowcasting.

We presented a novel machine learning technique - the AutoNowP model, which uses two autoencoders to make radar data predictions.

Future Work:

- Multi class classification
- Using multiple products
- Considering other weather data beyond radar data

Thank you!

Questions?