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Forecasting Trends in Technological Innovations with Distortion-Aware Convolutional Neural Networks

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Introduction

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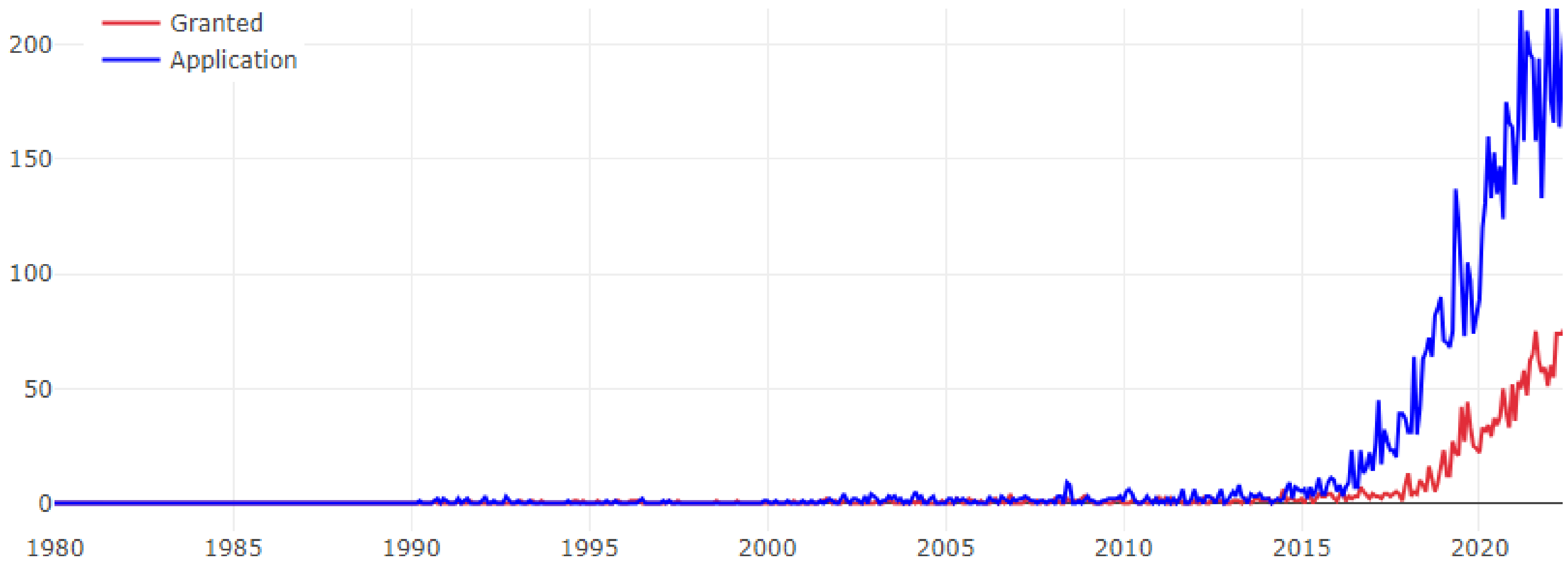
Example: Number of Patents Related to “Neural Networks”



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Background

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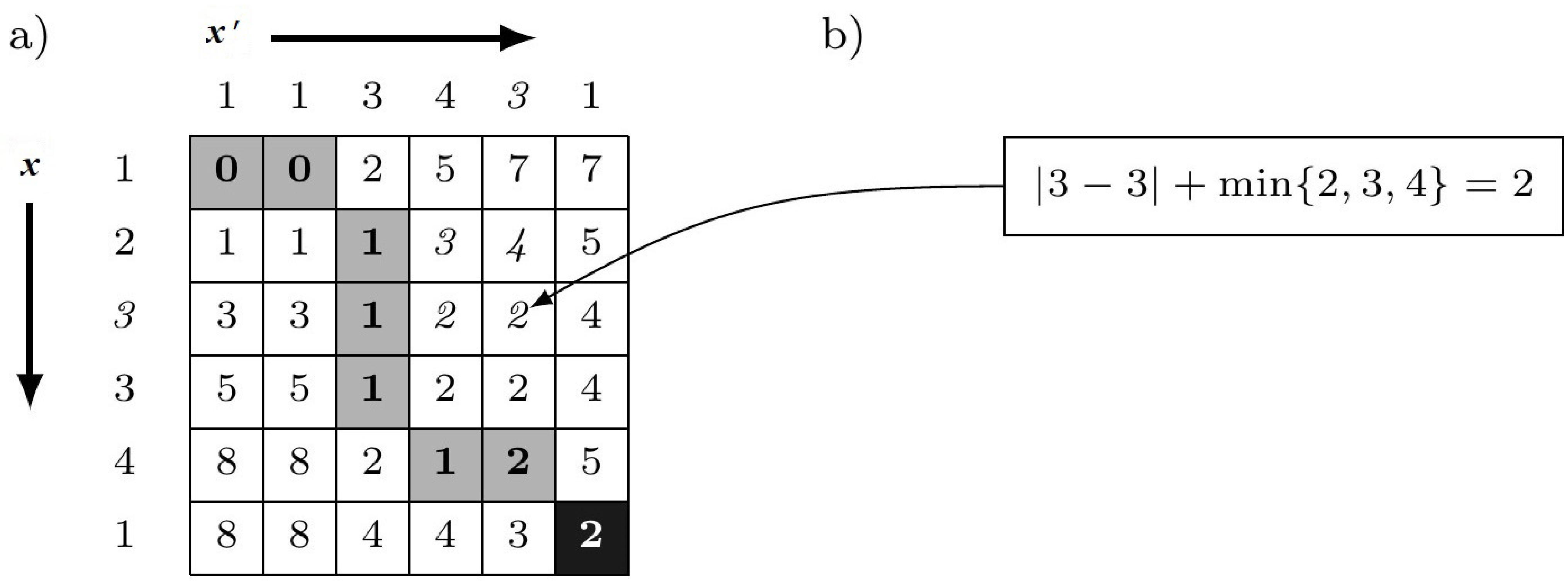
Dynamic Time Warping



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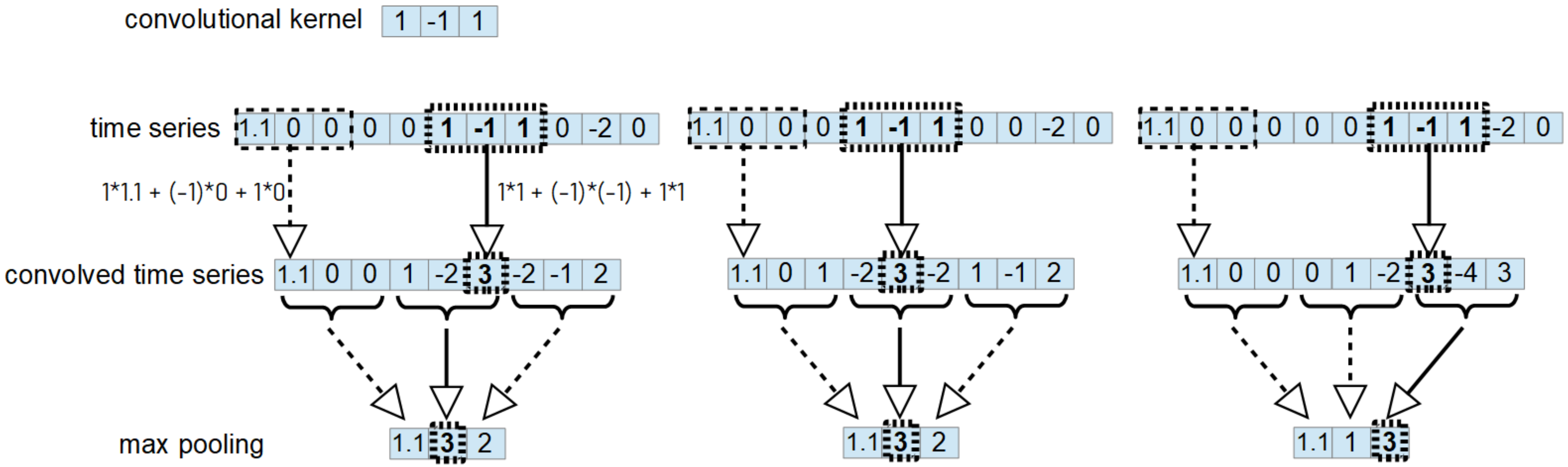
Curse of Convolution



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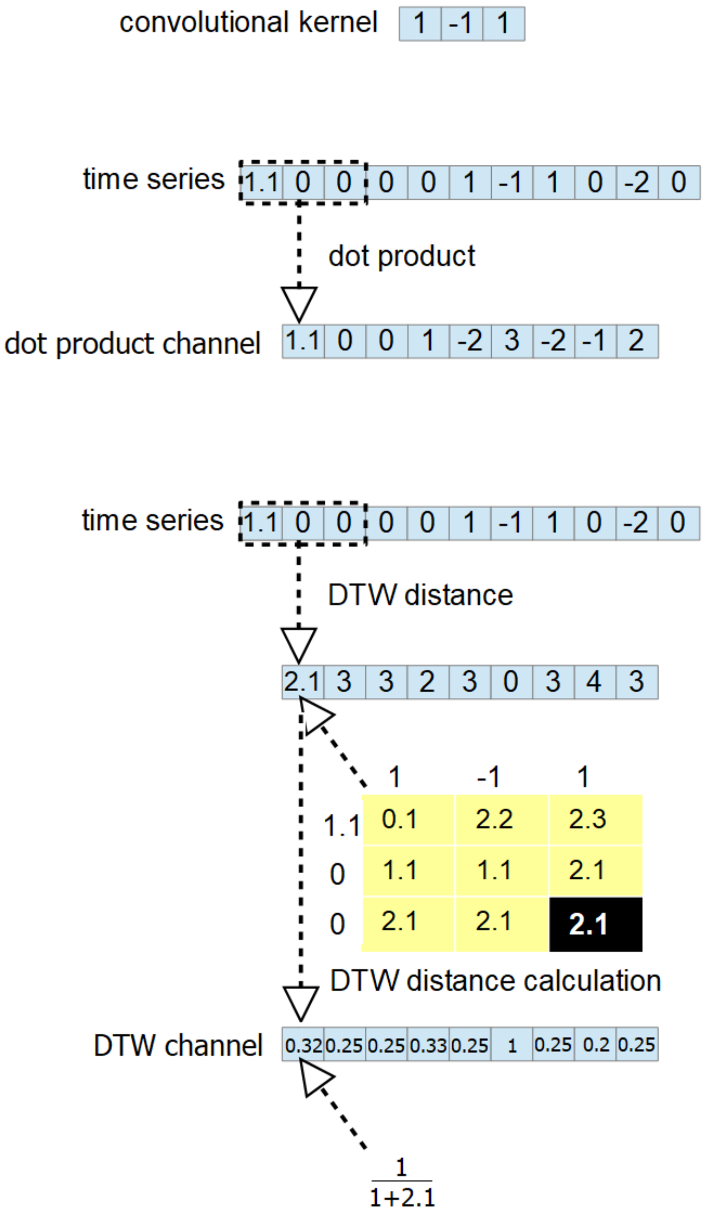
Distortion-aware Convolution



Krisztian Buza. 2023. Time Series Forecasting with Distortion-Aware Convolutional Neural Networks. In *9th SIGKDD International Workshop on Mining and Learning from Time Series*.

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Problem Formulation

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Problem Formulation

Given an observed time series $x = (x_1, \ldots, x_l)$ of length l, we aim at predicting its subsequent h values $y = (x_{l+1}, \ldots, x_{l+h})$. We say that h is the forecast horizon and y is the target. Furthermore, we assume that a dataset D is given which contains n time series with the corresponding target:

$$D = \{(x^{(i)}, y^{(i)})_{i=1}^{n}\}. \quad (1)$$

We use D to train neural networks for the aforementioned prediction task. We say that $x^{(i)}$ is the input of the neural network.

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Our Approach

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Our Approach

- DCNN: Convolutional Neural Network with Distortion-aware convolution

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Experiments

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Data

- Time series: number of (a) granted patents and (b) patent applications per month between January 1980 and December 2022.
- Selected topics:
  - Image or video recognition
  - Neural networks
  - Natural Language Processing
  - Artificial Intelligence
- We considered the patents separately for the most significant jurisdictions: (a) United States of America, (b) China, (c) Korea, (d) Japan and (e) Europe, (f) all jurisdictions.

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Experimental Settings

- Forecast horizon: h = 6 months, input: previous 36 month
- Training data: 1980…2018
- Test data: 2019…2022
- Baseline: Convolutional network with "usual" convolution (CNN)
- Training loss: MSE, Adam optimizer, learning rate of 10^{-5}, batch size: 16
- Implementation: https://github.com/kr7/dcnn-forecast
  (using publicly available datasets)
- Evaluation metrics:
  - mean squared error (MSE)
  - mean absolute error (MAE)

Table 1: Mean absolute error (MAE) and root mean squared error (RMSE) for forecasting the time series of granted patents in case of our approach (DCNN) and the baseline (CNN). Lower values indicate better performance.

topic	juris-diction	RMSE CNN	RMSE DCNN	MAE CNN	MAE DCNN
image or video recognition	US	165.9	106.0	131.2	92.7
	China	405.8	320.9	323.87	217.6
	Korea	13.9	27.7	12.4	19.9
	Japan	55.9	49.8	39.9	37.8
	Europe	34.5	34.7	32.3	32.9
	ALL	494.7	399.6	416.8	341.3
neural networks	US	10.7	9.1	9.4	7.9
	China	5.6	5.5	3.8	3.7
	Korea	6.3	2.3	5.4	2.1
	Japan	3.5	2.9	2.5	2.0
	Europe	2.7	1.6	2.2	1.2
	ALL	7.6	8.3	6.3	6.7
natural language processing	US	19.7	15.1	14.8	12.0
	China	57.1	47.0	41.6	41.7
	Korea	14.2	8.5	13.1	7.3
	Japan	11.8	10.7	9.5	7.3
	Europe	4.8	3.0	3.5	2.7
	ALL	67.0	45.7	59.5	35.5
ALL	US	270.2	216.9	224.1	196.4
	China	870.2	1108.8	763.2	998.1
	Korea	56.6	138.3	53.8	129.4
	Japan	124.8	132.0	81.4	89.9
	Europe	85.8	69.2	82.1	65.9
	ALL	1045.1	1129.1	929.2	964.6

Table 2: Mean absolute error (MAE) and root mean squared error (RMSE) for forecasting the time series of patent applications in case of our approach (DCNN) and the baseline (CNN). Lower values indicate better performance.

topic	juris-diction	RMSE CNN	RMSE DCNN	MAE CNN	MAE DCNN
image or video recognition	US	188.2	177.1	170.2	163.3
	China	3405.0	1061.7	3375.4	1042.3
	Korea	128.9	70.8	99.7	69.4
	Japan	103.8	106.4	87.1	66.1
	Europe	51.9	55.5	45.0	49.4
	ALL	3641.9	2110.5	3627.3	2027.8
neural networks	xUS	79.8	15.3	76.9	12.7
	China	21.2	20.8	16.8	19.0
	Korea	44.6	6.8	43.7	6.2
	Japan	13.9	7.1	13.5	4.8
	Europe	15.8	5.9	14.9	4.4
	ALL	267.7	45.6	262.7	38.6
natural language processing	US	64.1	68.7	55.5	64.6
	China	418.9	318.2	363.6	289.3
	Korea	35.1	23.4	29.7	21.0
	Japan	16.7	18.7	10.5	10.8
	Europe	11.2	14.3	9.7	11.2
	ALL	298.1	543.0	226.9	489.3
ALL	US	532.3	329.1	458.9	311.3
	China	6443.7	2784.2	6239.0	2386.5
	Korea	405.4	216.8	340.2	180.8
	Japan	224.8	228.1	159.1	128.6
	Europe	130.0	163.5	97.5	121.3
	ALL	5445.1	3355.8	5009.0	2547.0

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Conclusions

- Overall, DCNN performs better than CNN
- Combination of CNN and DCNN may be a promising direction of future work
- The presented approach may be simply generalized to multivariate time series using multivariate DTW

Krisztian Antal Buza. 2011. Fusion methods for time-series classification. *PhD thesis at the University of Hildesheim* (2011).

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