Precipitation Nowcasting Based on Convolutional Neural Networks

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I. Objective

Short-term prediction of precipitation based on latest precipitation observations is called "nowcasting," and widely used for various purposes such as disaster prevention. The aim of this project is to predict precipitation amounts within 10--30 minutes by taking advantage of dense and frequent observations of Phased-Array Weather Radar (PAWR). Among various techniques, we compared a classical convolutional neural network (CNN) model with a modified version of InceptionV3 [1].

II. Data

We used a dataset of 3D PAWR images of Kobe area with a frequency of one image every 30 seconds. The image size is $321 \times 321 \times 57$ pixels. The grid spacing is 250 m. We used three months of data from 01/05/2018 to 31/07/2018. The prediction is based on the last hour images. For computation reasons, we aggregated data frequency from 30 seconds to 10 minutes.

III. Challenges

1. High dimensionality:

The output is a predicted image having the same size as the input images. The high dimensionality of the output leads to a large number of local minima in the objective function during the optimization process. The model is more likely to converge to a local minimum rather than the global one. To address this issue, we use stacked CNNs, each contributing to the prediction of a portion of the output image. 2. Sparsity:

The images are sparse (2% on average contain rain). The sparsity of data leads to two issues: space complexity and time complexity. Space complexity refers to the incapacity to fit data into the memory during processing due to its large size.

Time complexity denotes the processing time growth induced by the data size. To deal with these issues, we introduce a compressed data structure that contains only significant information (rain pixels). 3. Border Effect:

We have limited information about pixels in the image border. So, the prediction accuracy is lower than the pixels in the image center. As the image size is large, images are split into patches for the learning phase. To prevent the accuracy loss due to border effect at the border of each patch, we use a sliding patch and predict only the central part at each step.

4. Resolution:

The prediction accuracy in the case of high resolution (HR) images is higher compared to low resolution (LR) images. However, for HR images, the accuracy drops quickly after about 10-minute prediction unlike LR where the accuracy is relatively stable. Consequently, we use HR images for short-range prediction up to 10 minutes and LR for longer-range prediction.

IV. Results and future work

The results given by CNN are promising in terms of precision and recall. The next step of our work is to extend our study to Convolutional Long Short-Term Memory (LSTM) and to Reservoir computing. Our goal is to compare the performance of different algorithms to select the most suitable solution for 3D precipitation nowcasting.

[1]C. Szegedy, V. Vanhoucke, S. loffe, J. Shlens, Z. Wojna, "Rethinking the Inception Architecture for Computer Vision," Computer Vision and Pattern Recognition, 2016.

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