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Week-Ahead Electrical Load Forecasting Based on Convolutional Neural Network with Two-Dimensional Image Mapping of Time Series Load and Weather Data

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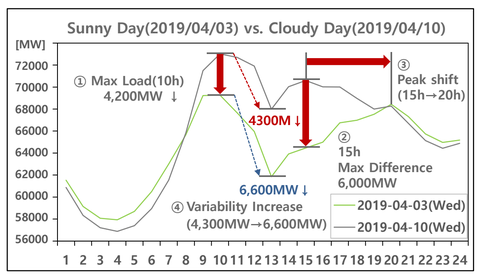
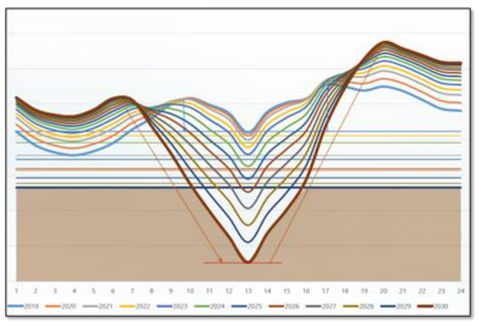
1. Introduction

- Week-ahead load forecasting : 168 hours for 7 days electrical load forecast after the forecasting point
- Before 2015 : not much photovoltaic penetration in South Korea
- Rapid photovoltaic penetration rising since 2016 → different daily load pattern and the change of maximum load occurrence hour due to the weather conditions



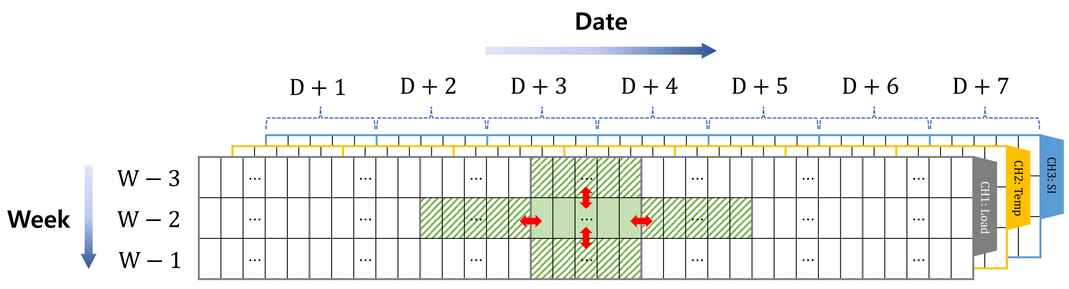
- Duck curve phenomenon intensifying → the effect on the base load → the base load generators such as nuclear power plants required to change output power → cannot change generating power within a few hours like daytime



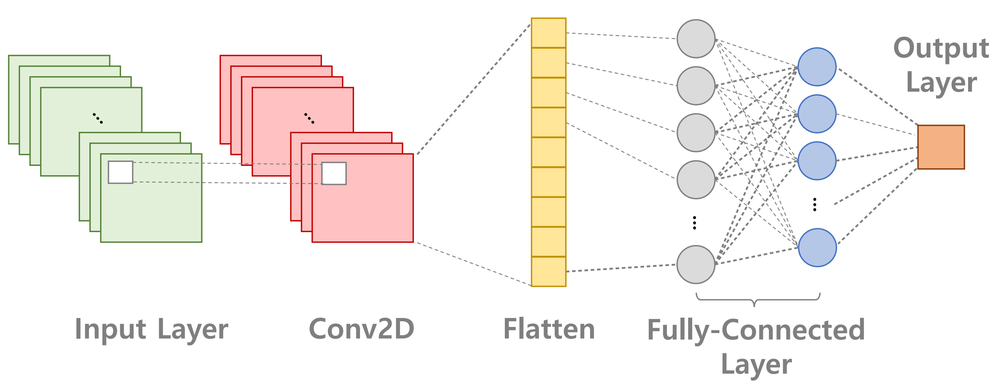
- The importance of week-ahead load forecasting accuracy growing
- A new week-ahead load forecasting method based on CNN proposed → week-ahead load forecasting accuracy improvement

2. Proposed method

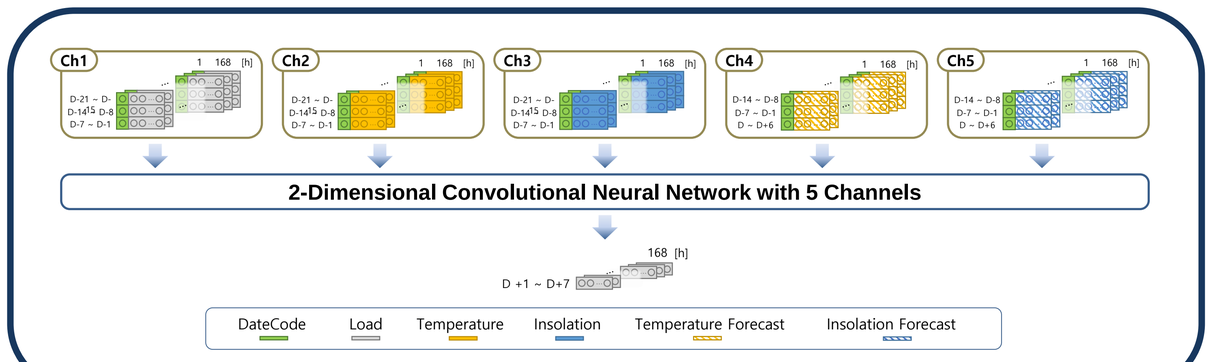
- 2-Dimensional Convolutional Neural Network
  - The input data of the 2-dimensional CNN : the plane with respect to a 2-dimensional shape (horizontal, vertical)
  - Each point of the 2-dimensional plane : pixel information of an image
  - Information on the top, bottom, left, and right relationships of the pixel → convolution operation → feature extraction of an image
- 2D CNN and time series data mapping
  - Daily load : closely related to the load of the previous hour and the next hour + similar characteristics to the same day of the previous week → Very similar to each point on the image closely related to the points on the top, bottom, left, and right
  - 3 weeks time-series data → mapped into (168 x 3) 2D CNN structure



- The proposed CNN model
  - 5 channels input layer → Covn2D operation → Flatten layer → Fully connected layer → Output layer (168h electrical load)
  - No pooling ← no low-importance features in time-series data



- Week-ahead load forecasting input and output data structure
  - This structure intended to consider the effect of multiple channels by arranging load, temperature, insolation, predicted temperature, and predicted insolation in different channels
  - Channel 1 : the start date information of D-21 and the historic loads of the 3 weeks immediately before
  - Channel 2 to 5 : historic temperature, historic insolation, predicted temperature, and predicted insolation data
  - The output values : 168-hour electrical loads
  - The horizontal size is 169, the vertical size is 3 and the kernel size is selected as 2 x 2.



3. Performance evaluation

- Input data
  - The actual South Korea load data from KPX (Korea Power eXchange)
  - Meteorological data from KMA (Korea Meteorological Administration)
  - Weighted temperature and insolation by 8 major cities in South Korea
  - Temperature and insolation historical data were used instead of temperature and insolation forecasts for performance evaluation
  - Performance metric : MAPE (Mean Absolute Percentage Error)

$$MAPE = \frac{1}{n}\sum_{i=1}^{n}\left|\frac{\hat{y}_i - y_i}{y_i}\right| \times 100\ [\%]$$

where, n : number of data, y_i : actual, $\hat{y}_i$: forecast

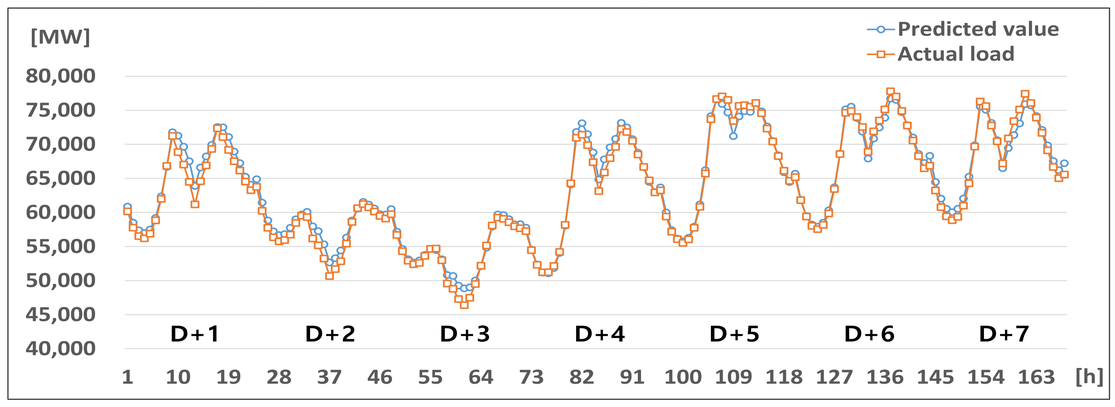
- 2020 week-ahead load forecasting results MAPE

Error	D+1	D+2	D+3	D+4	D+5	D+6	D+7	Avg.
Min Load	1.5444	1.7228	1.7799	1.8545	1.9013	1.9738	2.0303	1.8296
Max Load	1.9523	2.0757	2.1562	2.2342	2.2926	2.3900	2.4592	2.2229
Max	3.6830	3.8801	3.9785	4.0125	4.0950	4.1932	4.3807	4.0319
24h Avg.	1.6986	1.8403	1.9201	2.0031	2.0517	2.1131	2.1980	1.9750

- 2021 week-ahead load forecasting results MAPE

Error	D+1	D+2	D+3	D+4	D+5	D+6	D+7	Avg.
Min Load	1.1798	1.3910	1.5340	1.6083	1.6436	1.7085	1.7832	1.5498
Max Load	1.2646	1.3887	1.4914	1.5464	1.5630	1.6088	1.7339	1.5138
Max	3.2977	3.4650	3.5912	3.6880	3.7334	3.8080	4.0874	3.6672
24h Avg.	1.3226	1.4534	1.5525	1.6156	1.6450	1.6853	1.8145	1.5841

- Week-ahead load forecast results for 2021/11/26~2021/12/02 - the week including weather condition changes (sunny/cloudy/sunny)



  - Nov. 30th in D+5 cloudy day : different load pattern from other days
  - Dec. 1st in D+6 sunny day : load pattern including the influence of photovoltaic generation unlike D+5 due to clear weather
  - Excellent performance even weather condition changes
  - The 168-hour MAPE for this period : 1.2477[%]

4. Conclusion

- A week-ahead load forecasting based on 2D CNN is proposed.
- In order to reflect the characteristics of week-ahead load, a new method is proposed by mapping hourly load and weather data to each channel of 2-dimensional CNN structure.
- The effect of photovoltaic generation is appropriately reflected even in the interval between sunny and cloudy weather.
- The proposed week-ahead load forecasting MAPE for 2020 is 1.9750[%], and the MAPE for 2021 is 1.5841[%].

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