Spatio-temporal prediction of crime occurrence spots

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Abstract

This paper proposes a method for spatiotemporal prediction of crime occurrence locations based on previous data. In recent years, Japanese government has begun to release data on crime occurrences to improve the efficiency of policing. In addition, the development of maps that can manage patrol and assist residents' crime prevention has been planned. For statistical crime prediction, while several methods are invented abroad, it has just begun to develop a specific crime prediction model for a low-crime country, Japan. One of the known methods uses LSTM to predict crime occurrences only from a temporal perspective, but it cannot predict points of crime occurrences and is insufficient to generate a map. Therefore, we propose a method that combines this LSTM based method with CNN that can adopt geographic locations. As a result of computer experiments, this method seems to be able to make predictions with a tendency to capture actual characteristics.

Keywords: Crime occurrence, Spatio-temporal prediction, LSTM, CNN

1. Introduction

This study examines the method for predicting crime locations in time and space using information on crime occurrences opened by the police to create maps that will assist police patrols and serve as crime prevention for residents. In Japan, the Basic Act on the Promotion of Government and Private Data Utilization (Act No. 103 of 2016) was enacted, and through the "Promotion of the Release the Data on Crime Occurrences Information", each prefectural police have started to release data on crime Occurrences. The purpose of this attempt is to share and utilize data on crime to improve the efficiency of police activities and prevent crimes by predicting their occurrences. In this paper, we propose a method that combines Long Short Term Memory (LSTM) and Convolutional Neural Network (CNN) to address this issue. There are studies based on the idea that the prediction needs a unique model in Japan, that is a low-crime country [2]. Among them, Method [1] predicts crimes in the same area using a neural network with LSTM layers, and it has achieved some success. Therefore, we came up with the idea that if we could combine CNN that enables spatial predictions with LSTM, we could predict crime spatiotemporally. Based on this idea, this paper proposes a method that modifies the output layer of the method created for weather predictions with ConvLSTM2D layers [4]. We verified it by comparing data from Kanagawa Prefecture and Osaka Prefecture to examine the usefulness of the proposed method. We created crime map data by dividing the information on bicycle thefts in

Kanagawa Prefecture in 2018 into monthly grid data. We used this to learn the data from January to November and predicted the data for December, and were able to create crime map data with a trend similar to the actual December data.

2. Related Studies

This section describes recent mathematical-based crime prediction in Japan and shows that there are few studies on geographic crime prediction. According to Oyama et al. (2017) [3], researches and system developments on geographical crime predictions have been conducted mainly in Europe and the United States, but there is no accumulation of researches on these methods in Japan. Therefore, it is necessary to study the prediction methods suitable for Japan. The occurrence locations and times are important in predicting crime. Existing geographical prediction methods can be classified into four categories: detections of temporal clusters, intensity estimations of crime occurrences considering spatiotemporal interaction of crimes, predictions of risks of crime occurrences from environmental factors, and prediction of the number or probability of crime occurrences by regression analysis [3]. In both cases, the prediction is conducted by setting up a model in advance and adjusting a relatively small number of parameters. Detections of temporal clusters use spatiotemporal scan statistics to find spatiotemporal clusters of crimes since the accumulation of past crimes predicts future crime occurrences. Intensity estimations of crime occurrences considering the spatiotemporal interaction of crimes focus on the near-repeat victimization and obtain the risk of crime occurrences by modeling that considers temporal proximity in addition to spatial proximity. ProMap and SEPP are typical methods. Prediction of the risk of crime occurrences from environmental factors does not rely on past information on crime occurrences but focuses on the socio-economic and physical characteristics of the region, seasonal variations, etc. The typical method is RTM using overlay analysis in GIS. Prediction of the number or probability of crime occurrences by regression analysis is a method in which regression analysis is not used to analyze past crime factors, but to predict the number of crime occurrences and crime rates in the future. ST-GAM, which also uses environmental factors as variables, is a typical example. Whereas, there are a few methods that do not assume a model and make predictions from criminal records. Zhang et al. (2019) focus only on the temporal proximity of crimes and use LSTM to predict the number of crime occurrences. LSTM is a neuronal network layer that may acquire data-specific time series models through training. In the paper, they extracted data on sneak-thieving, bicycle theft, and shoplifting from the Tokyo Metropolitan Government's open data on crime recognition (177131 crimes from 2014 to 2018). This work, used LSTM to predict the number of crime occurrences in the following month based on the number of same crime occurrences in the past six months. As a result, we have obtained some success, but there is still room for improvement in the prediction accuracy. Therefore, to improve this, we performed a verification based on the idea that the addition of convolutional neural networks (CNN) to LSTM would permit spatiotemporal predictions. CNN is a neural network developed for advanced image recognition, which can obtain a model about the positional relation specific to the data.

3. The Proposed Method

In this section, we explain the proposed method. This method combines LSTM, which handles time series data, with CNN, which can easily use geographic data, to achieve prediction based on geographic relevance, which has been a problem of the previous method [1]. Fig. 1. shows the proposed model. It is a three-layer coupling of ConvLSTM blocks, which LSTM block plus a convolutional layer, via Batch Normalization. The output function was set to Relu. The data used is crime map data, which is created by counting the number of crime occurrences in each grid cell of a certain size, divided by month, and the model predicts and outputs the crime map data for the month following the input data. We use 11 months as input and the next month as the correct answer for learning. Specifically, we take a span between Jan. 2018 to Nov. 2018 as input and set Dec. 2018 as the correct answer, then shift the data by one month until the span between Jan. 2020 and Nov. 2020 as input and set Dec. 2020 as the label of a training data, which is one epoch. We used Adam as the optimizer and MSE as the loss function.

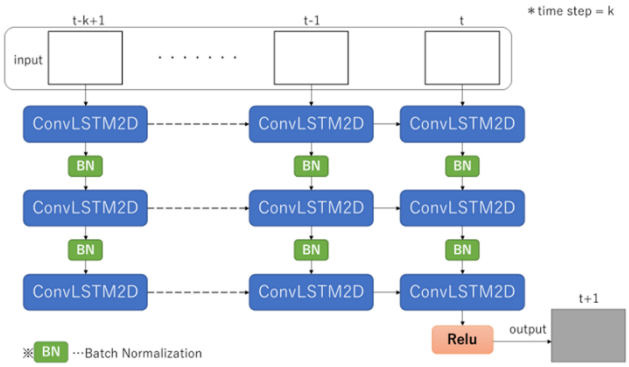

Fig. 1. Proposed Model.

An example of the learning process is shown in Fig. 2. This shows the learning process of the proposed method for a bicycle theft that occurred in Kanagawa Prefecture in 2018 (11,388 cases). The horizontal axis is the number of epochs and the vertical axis is Loss (MSE). At first, there was a major error, but in the 14th epoch, the error decreased to less than 0.3, indicating that learning had progressed.

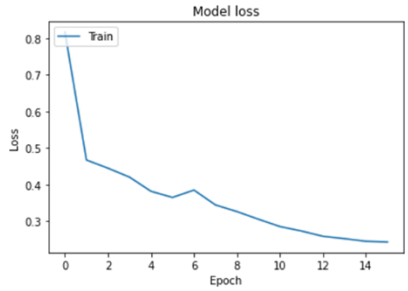

Fig. 2. Model Loss.

4. Experiments

In this section, we describe two experiments. In Experiment 1, we verify the crime prediction using the proposed method. In Experiment 2, we examine whether the proposed method can predict crime in any region of Japan using data from a different region than in Experiment 1.

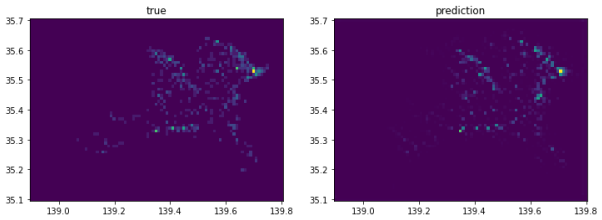

Fig. 3. Experiment 1. Kanagawa's 2018 bicycle thefts data

4.1. *Experiment 1: Kanagawa's 2018 bicycle thefts data*

In this experiment, we predicted the December by learning the period from January to November in the data of Kanagawa's 2018 bicycle thefts. The left of Fig. 3. shows the actual number of this crime of this month, the right illustrates the predicted number of this crime. Comparing them, we could see that the hotspots (the areas close to yellow in the figure) generally match, indicating that the predicted crime map captures the characteristics of the actual data.

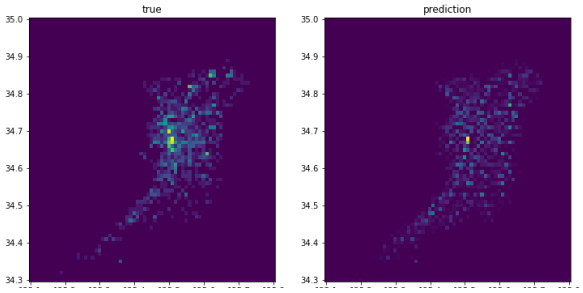

Fig. 4. Experiment 2. Osaka's 2018 bicycle thefts data

4.2. *Experiment 2: Osaka's 2018 bicycle thefts data*

In Experiment 2, we used Osaka's 2018 bicycle thefts data to make predictions in the same way as Experiment 1, and the results are shown in Fig. 4. Comparing the actual crime raster data with the predicted one, we can say that the hotspots are generally captured the same as Experiment 1, although the prediction is slightly rougher overall.

5. Conclusion

In this paper, we proposed a method to predict crime spatially and temporally by combining CNN with the temporal crime prediction method using LSTM in existing research based on the idea that a unique model is necessary to predict crime in Japan with a low-crime rate. We examined this method using three years of bicycle thefts data in Japan, and found that the predictions were generally good, indicating that the proposed method is effective in predicting crime in Japan.

References

1. Xiaoqi Zhang, et al. “Study on Forecasting Crime and its Temporal Proximity Using Open Data and LSTMs”, journals of Informatics, vol16.1, pp56-70, 2019.
2. Tomoya Oyama, et al. “A Metric Comparison of Geographical Crime Prediction Techniques ― An Examination for Developing the Crime Prediction Technique for Japan―”, 2017.
3. Tomoya Oyama, et al. “Recent Research Trends on Geographical Crime Prediction”, Theory and applications of GIS, 25(1), pp. 33-43, 2017.
4. https://qiita.com/eycjur/items/85baee1c397b74c3b6bd

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