C309

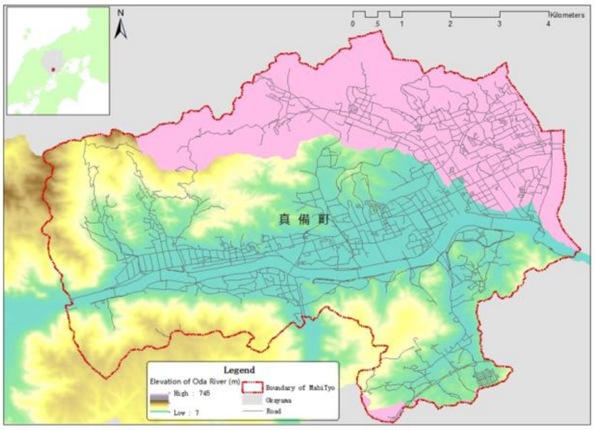
An Intelligent Decision Making Model for Flood Evacuation Based on Deep Learning

〇Mengtong LI, Tomoharu HORI

Introduction

Since the heavy rain in western Japan in 2018, there has been increasing recognition that not only river course modification and storage of flood flow by governments but also evacuation and disaster response by residents are important to prevent damage. However, it is not easy for residents who have never been affected by the flooding to decide to evacuate at the right time. Therefore, there is a need for a system that supports evacuation decisions.

In this study, we attempt to develop a system to determine the appropriate timing to start evacuation, using an agent model with a deep learning function.



Methodology

In this study, the most appropriate evacuation time is obtained by using the point function. The score function [1] is as in Eq. (1)

$$S(t_s) = \min\left(\frac{T_0}{T(t_s)}, \frac{t_s}{t_c}\right) \qquad (1)$$

where, S(t) is evaluation score at time t, T_0 is the time of evacuation (sec) from the initial position to the shelter in normal time (when there is no flooding). T(t) is the time required for actual evacuation (sec) to the shelter. t_c is the latest evacuation timing. t_s is evacuation start time. If the evacuation has failed (when $t_s > t_c$), it is assumed that T (t_s) = ∞ and the score S (t_s) = 0. Walking speed [2] of evacuees is as in Eq. (2)

$$v_t = 1.1 \times \left(1 - \frac{d_t}{0.7}\right) \qquad (2)$$

where, v_t is the walking speed at time t (m / sec), d_t is the inundation depth at time t. According to the formula, when the depth of water exceeds 0.7 m, the speed becomes 0 (m / sec), it is means that it is impossible to walk, and the evacuation fails at that time. From this formula, it can also be found that the walking speed is affected by the depth of water. Therefore, RRI [3] model is used to simulate the real-time depth of water. The DEM data used are the 10m resolution provided by the Ministry of Land, Infrastructure, Transport and Tourism. Meteorological stations data from the Japan Meteorological Agency are used for hourly rainfall data for simulation. RRI computes water depth data every minute. The road data are obtained from the numerical map 2500 (CD-ROM) issued by the National Land Research Institute.

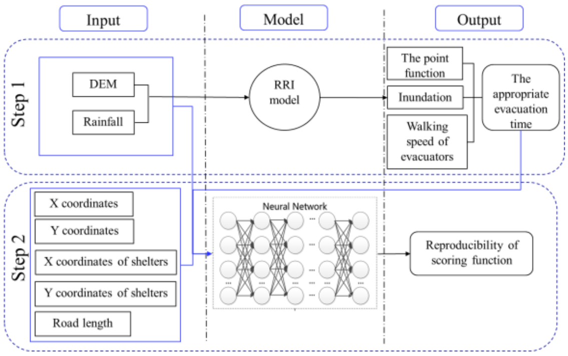


Fig 2 Methodology

Results

The result of scoring function is used as the training data for deep learning. Therefore, it is necessary to evaluate the reasonableness of the result of score function. In the score function, the output values are between 0 and 1, it close to 0, indicating that evacuation is not required (or at home), and close to 1, indicating that evacuation is required. Then, 200 evacuation points are selected randomly from all evacuation points in the study area, output value of every evacuation point is calculated and the appropriate evacuation start time is determined.

Two hundred sets of data are used to build the deep learning model. The model has 8 sets of input data, including accumulative rainfall, location coordinates and DEM data of evacuation points, location coordinates and DEM of shelter, and road length. Output data is appropriate evacuation time. The number of hidden neurons is set to 10. The input data and output data will be randomly divided into three sets, 1. 70% are used for training. 2. 15% to validate that the network is generalizing and to stop training before overfitting. 3. The last 15% are used as a completely independent test of network generalization. This study uses matlab2019 software to build the deep learning model, the training algorithm is Levenberg-Marquardt (trainlm) algorithm, and set the algorithm's epocks = 40. The result is shown in Figure 4

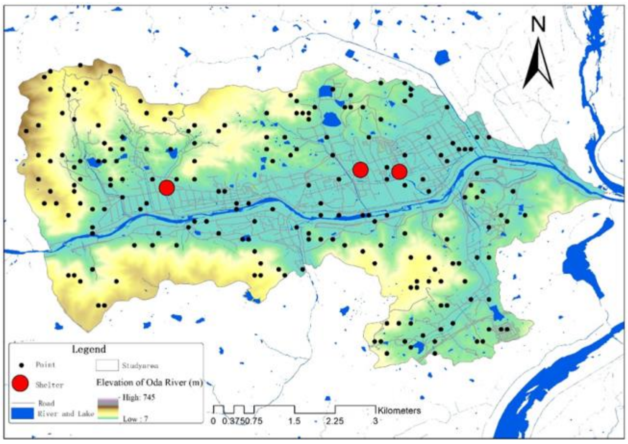


Fig 3 Spatial distribution of 200 evacuation points

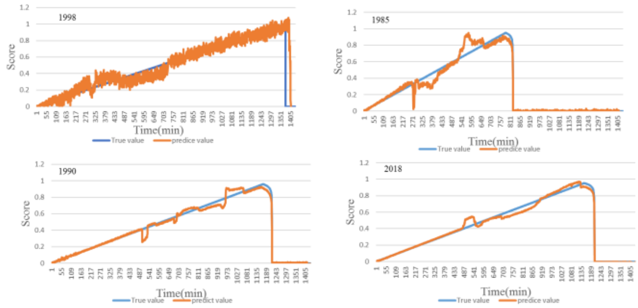


Fig 4 Reproducibility of scoring function

Conclusion

Based on the above results, the following conclusions can be drawn. (1) The score function of this study can be used to calculate the most appropriate evacuation time, the calculation cost is high and time consuming. (2) Deep learning methods can be applied to the calculation of the most appropriate evacuation time. With higher accuracy, less time consumption and high efficiency. (3) There is no specificity in the data of this study, which shows that the training model has a satisfied probability in theory. but considering that the flood evacuation behavior belongs to the behavior with geographical characteristics, which has a strong uncertainty. The usability of the algorithm in different environments remains to be discussed.

References

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[3] T. Y. I. Sayama, “Development and application of rainfall runoff inundation (RRI) model,” *Civ. Eng. J.*, vol. 56, no. 6, p. 4, 2014, [Online]. Available: http://www.pwrc.or.jp/thesis_shouroku/thesis_pdf/1406-P018-021_sayama.pdf.