第 II 部門　　Rainfall pattern generation for probabilistic short-term flood stage prediction

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1. Introduction

A stochastic rainfall pattern simulation process capable of generating input for a distributed rainfall-runoff model is developed to facilitate a short-term probabilistic forecast of river discharge at multiple locations in a watershed. Generation of rainfall patterns is achieved using a translation vector rainfall forecasting process modified to account for uncertainties in rainfall pattern development. The stochastic rainfall generation model is coupled with a distributed rainfall-runoff model in a Monte-Carlo simulation to provide a short-term ensemble forecast of distributed flood discharge. An example application is provided for a typhoon event that occurred in the vicinity of the Nagara River watershed.

2. Monte Carlo simulation

A Monte Carlo simulation of rainfall conditions is used to produce an ensemble forecast considering the effects of uncertainty in the rainfall forecast, referred to here as precipitation uncertainty. The translation vector model developed by Shiiba *et al.* (1984) is extended to include a time series analysis of observed rainfall patterns to allow for generation of future rainfall patterns based on the statistical properties of rainfall pattern translation and growth-decay characteristics.

Rainfall at time t at a point on a horizontal surface with the Cartesian coordinates of x, y, is given as $z(x,y,t)$. The translation model can be described as:

$$\frac{\partial z}{\partial t}+u\frac{\partial z}{\partial x}+v\frac{\partial z}{\partial y}=w \tag{1}$$

where u and v are the translation vectors and w is the growth-decay head. These terms are further described with the following one-dimensional functions:

$$\begin{aligned} u &= c_1 x + c_2 y + c_3 \\ v &= c_4 x + c_5 y + c_6 \\ w &= c_7 x + c_8 y + c_9 \end{aligned} \tag{2}$$

Here, $c_1 \sim c_9$ are parameters identified through analysis of past rainfall patterns using the method of linear least squares. The identified vectors can be used to extrapolate the observed rainfall patterns into the future, essentially providing a deterministic short-term rainfall prediction.

The time series of a typhoon event expressed in terms of rainfall pattern translation vectors is analyzed using the Autoregressive Integrated Moving Average (ARIMA) model (Box and Jenkins, 1976). A general ARIMA model of order (p,d,q) can be expressed as:

$$\phi(B)\nabla^d c_t = \theta(B)a_t \tag{3}$$

where c_t is the translation vector parameter at time t, and a_t is the random error term at time t having mean zero and variance σ_a^2. $\phi(B)$ is a stationary autoregressive operator, and $\theta(B)$ is a moving average operator. B is a backward shift operator defined by $Bc_t = c_{t-1}$ and related to the backward difference operator ∇ by $\nabla^d = (1-B)^d$, where d is the order of differencing.

An ARIMA (1,0,1) model is considered here for parameters c_3 and c_6, and a white noise process is considered for parameters c_7, c_8, and c_9. Generated time series of each parameter are converted to rainfall patterns using the translation vector model for subsequent input into a rainfall-runoff model.

3. Distributed rainfall-runoff model

A distributed rainfall-runoff model is configured to accept radar-observed precipitation inputs at a 1-kilometer mesh scale at 5-minute intervals. The watershed is modeled as a uniform array of multi-layered mesh cells, each containing information regarding surface land use, surface slope and runoff direction. An approximation of the kinematic wave method is used to model watershed runoff.

4. Application

The typhoon event that occurred in the vicinity of the Nagara River watershed in Japan's Chubu region over the period of the 10th to 13th of September, 2000 is used here as an example. A time series plot of the c_3 parameter calculated from observed rainfall patterns in the vicinity of Nagara River over the period 11/9/2000 17:05 – 20:00, is shown in Figure 1(a) together with an example simulated time series for the following 6 hours. The discharge results of 25 sets of 6-hour generated rainfall patterns at the midstream location of Inari are given in Figure 1(b).

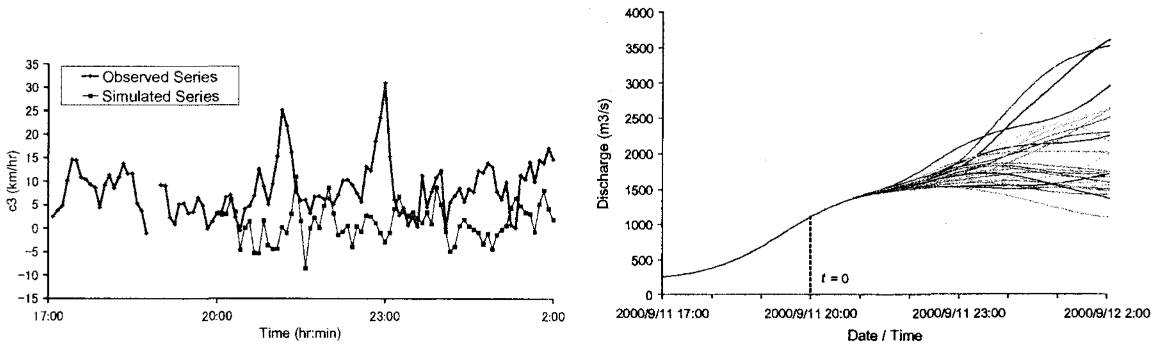

Figure 1: (a) Time series of c_3 and example generated series, and (b) Simulated future discharges

5. Conclusion

A strategy for providing a probabilistic forecast of flood stage at each point within a watershed, considering precipitation uncertainty, has been proposed. An application of the Monte Carlo simulation for rainfall generation and creation of an ensemble runoff forecast has been given.

6. References

Box, G. E. P. and Jenkins, G. M. (1976). Time series analysis: forecasting and control. Holden-Day.

Shiiba, M., Takasao, T., and Nakakita, E. (1984). Investigation of short-term rainfall prediction method by a translation model. Proc. 28th Japanese Conf. on Hydraulics, JSCE, 423-428.