Discharge and Parameter Estimation Using 2D Dynamic Wave Model with Particle Filter

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1. Introduction

Various parameters within a system are not perfectly determined. So, there are a lot of sources of uncertainty in any mathematical models [1]. In connection with verifying hydrological model and water resource management, river discharge is a critical factor. However, the underlying idea of river discharge estimated from rating curve is that it generally has too many uncertainties.

Therefore, we try to present the improved discharge estimation method in this study. In dealing with this method, a simple 2D dynamic wave model [2], which can reflect the effect of channel bed, and Monte Carlo sequential data assimilation scheme (so called Particle Filtering), which is adequate to non-linear system and able to reflect the time variation of state variables and parameters, are introduced.

2. Methodology

Under an assumption that inlet discharge and flow resistance are not exact, we sequentially assimilated observed water stage data to figure out the precise discharge and flow resistance. We adopt Sequential Importance Resampling(SIR) of particle filter in this study to reflect the variation of the flow condition every hour.

The SIR method based on importance sampling method calculated the weight of each particle, which can be described as follows[3][4]:

$$w_t^i \propto w_{t-1}^i \frac{p(z_t \mid x_t^i)\, p(x_t^i \mid x_{t-1}^i)}{q(x_t^i \mid x_{t-1}^i, z_t)} \qquad (1)$$

$$p(x_t \mid Z_t) \approx \sum_{i=1}^{N} w_t^i \delta(x_t - x_t^i) \qquad (2)$$

where, x_t^i, w_t^i denote the i th particle and its weight, respectively, and $\delta()$ denotes the Dirac delta function. Weights (w_t^i) are defined and It can be shown that as $N \to \infty$, the approximation (2) approached the true posterior density.

And then the particles are resampled by systematic resampling method. The multiplied particles from higher weight particles by resampling procedure are added Gaussian noise to avoid the degeneracy problems. This sequential updating procedure makes it possible to consider time variant state variables, parameters, and system errors.

In natural channel, there are so many uncertainties like flow resistance, lateral flow, boundary condition and so on. Therefore, we test this method through the synthetic experiment, which exclude the lateral flow, because we considered the main factors of uncertainty as the inaccuracy of inlet discharge and Manning coefficient. Moreover, we can reduce the uncertainties and verify the capability of this presented method more easily.

And then we will apply the method to the natural channel with consideration of lateral flow.

Keywords: discharge estimation, 2D dynamic wave model, particle filter
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3. Results and discussion

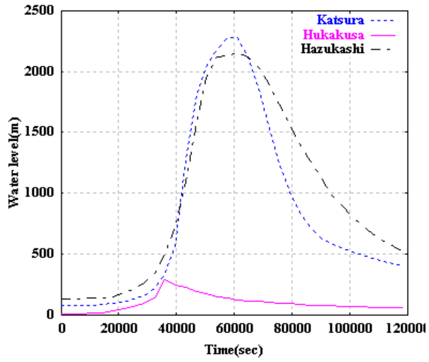
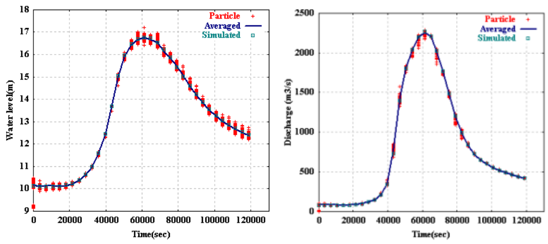
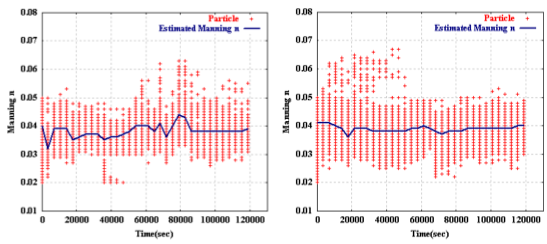


Figure 1. Hydrograph of River Discharge



(a) Water stage (b) Discharge

Figure 2. The Result Comparison of Water Stage and Discharge with 100 Particles



(a) 100 particles (b) 200 particles

Figure 3. The Variation of Manning Coefficient according to the Number of Particles

The dynamic wave model with particle filter applied to Katsura River, which is located in Kyoto, Japan. And the total length is about 10km. There are 3 water level stations, which are Katsura water level station, Hazukashi water level station, and Noso water level station, and 4 weirs. The discharge of Katsura water level station is an upstream condition and the water level of Noso water level station is a downstream condition for simulation.

Figure 1 shows the discharge estimated from the rating curve. The Hazukashi water level station is located downstream of the point, where the discharge of Hukakusa water level station in tributary, Kamogawa River, joins to the discharge of Katsura water level station in main channel. Although Figure 1 is plotted without consideration of lag time, we can assume it is likely that the discharge of Hazukashi is bigger than the estimated value.

For imaginary simulation, Manning coefficient was 0.04 and above mentioned boundary condition was used. The result of imaginary simulation is utilized as updating data of synthetic experiment. In the synthetic experiment, the inlet discharge and Manning coefficient of initial stage are randomly distributed by uniform distribution. When updating, 10% Gaussian noise is added to the discharge and Manning coefficient of resampled particles.

The result of this method is quite well matched to the imaginary simulation result in terms of discharge and water level (figure 2 (a), (b)). The averaged Manning n gradually approaches to 0.04 (Manning coefficient of imaginary simulation), but the capability of convergence is influenced by the number of particle (figure 3 (a), (b)).

In conclusion, we confirm this method is able to present the appropriate result in Manning coefficient estimation and discharge estimation with enough particles. Furthermore, the study about the application to natural river with observed water level updating is in progress. It will be presented in the presentation.

4. Reference:

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