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Construction simulation of high arch dams based on fuzzy Bayesian updating algorithm

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Current Research Status

- Bayesian updating algorithm is an effective method of the update of simulation parameters.
- The shortage of site construction data reduces the reliability of the traditional Bayesian updating algorithm.
- The construction parameters of high arch dams change during the construction process, which cannot be resolved with the Bayesian updating algorithm.

Tab. 1 Overview of Simulation Parameter Update

Authors (year)	Method	Application
Zhong, 2004; Zhong, 2010	Mathematical statistics	High arch dams
Zhang, 2013	Bayesian updating algorithm	Underground project
Razavi, 2012	Hybrid data-fusion method	Industrial construction project
Vahdatikhaki, 2014	Location tracking technologies	Earthmoving projects
Gardoni, 2007	Bayesian updating algorithm	Civilian nuclear power plants
Kim, 2009	Bayesian betaS-curve method	

Research Method

- To realize the construction simulation of high arch dams based on fuzzy Bayesian updating algorithm, the fuzzy set theory, Bayesian updating algorithm, construction simulation theory, and 4D visualization are adopted in this research.

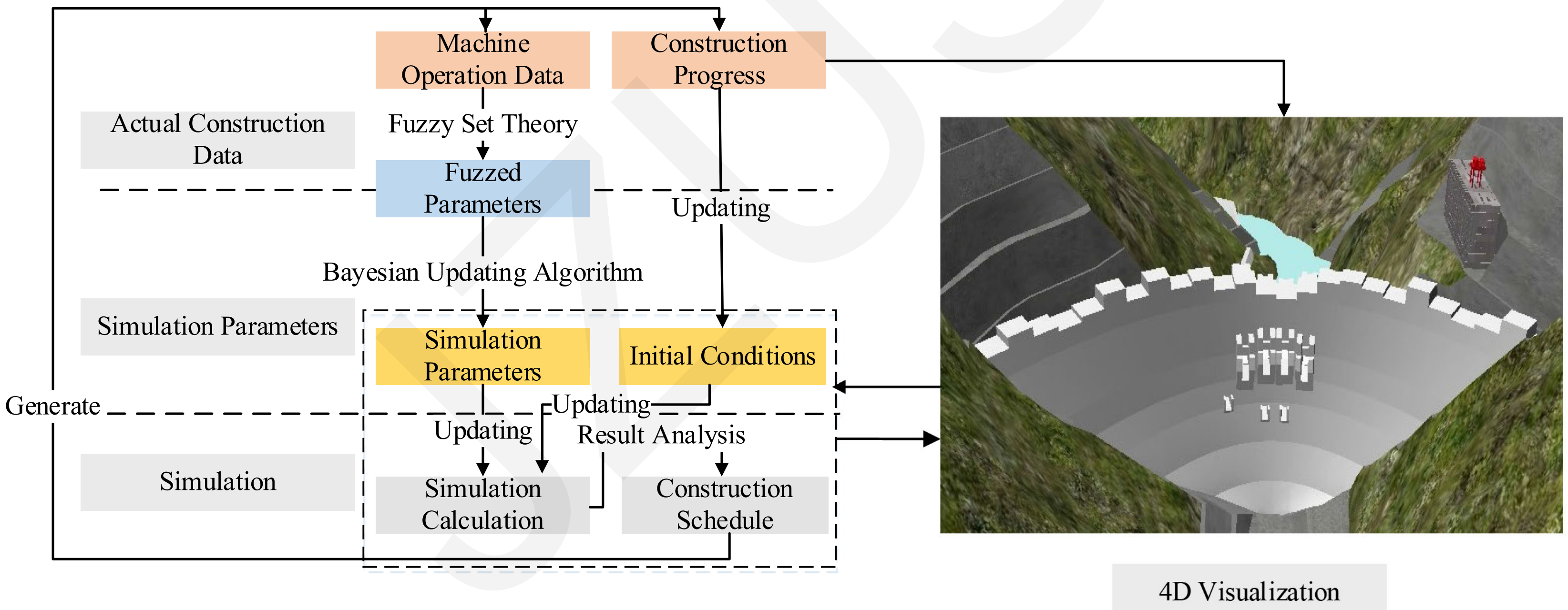

Fig. 1 Construction Simulation Framework

Research Method

- The logic model is a mathematic model set, which contains the initial condition, statue transfer, simulation calculation process and constraints of construction simulation of high arch dams.

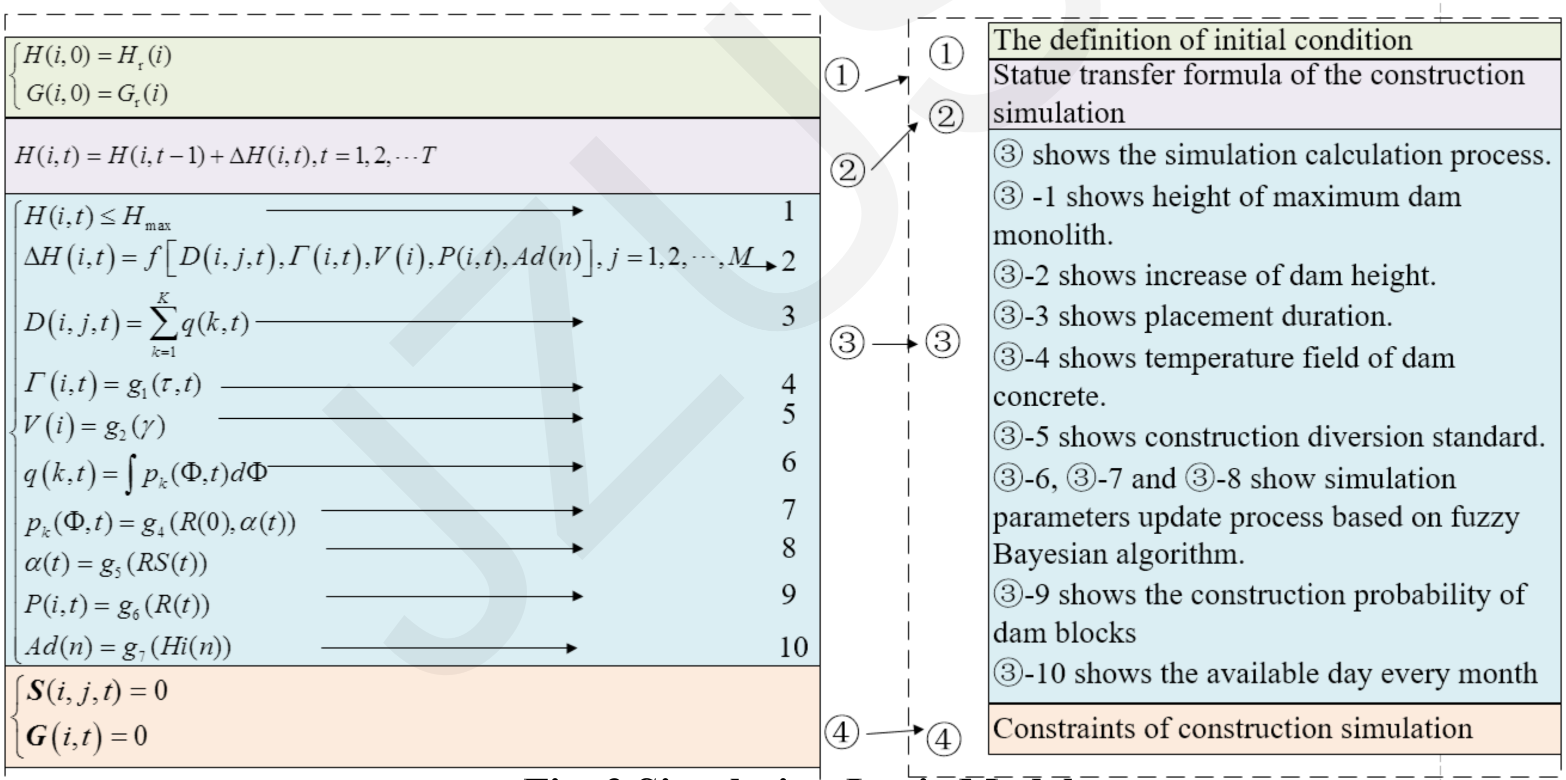

Fig. 3 Simulation Logic Model

Research Method

- The fuzzy Bayesian updating algorithm combines fuzzy set theory with the Bayesian updating algorithm.

$$\begin{cases} \tau_1 = n_1, \\ \beta_1 = \dfrac{(n_1-1)S_1^2}{2}, \\ \hat{\mu}_1 = \bar{x}_1, \\ \hat{\sigma}_1^2 = \dfrac{2\beta_1}{\tau_1 - 1}, \end{cases}$$

$$\begin{cases} \tau_i = \tau_{i-1} + n_i, \\ \beta_i = \beta_{i-1} + \dfrac{\tau_{i-1} n_i (\hat{\mu}_{i-1} - \bar{x}_i)^2}{2\tau_i} + \dfrac{(n_i-1)S_i^2}{2}, \\ \hat{\mu}_i = \dfrac{\tau_{i-1}\hat{\mu}_{i-1} + n_i \bar{x}_i}{\tau_i}, \\ \hat{\sigma}_i^2 = \dfrac{2\beta_i}{\tau_i - 1}, \end{cases}$$

Bayesian Updating Method

$$\alpha = f(\mu) = \exp\left(-\frac{n(\mu - \bar{x}')^2}{2(S')^2}\right),$$

$$\alpha = f\left(\frac{1}{\sigma^2}\right) = \exp\left(-\frac{(n-1)\left(\dfrac{1}{\sigma^2} - \dfrac{1}{(S')^2}\right)^2}{4\left(\dfrac{1}{(S')^2}\right)^2}\right)$$

Membership Degree Function

$$\begin{cases} \tau_1 = n_1, \\ (\beta_1)_\alpha^+ = \dfrac{(n_1-1)(S_1^2)_\alpha^+}{2}, \\ (\beta_1)_\alpha^- = \dfrac{(n_1-1)(S_1^2)_\alpha^-}{2}, \\ (\hat{\mu}_1)_\alpha^+ = (\bar{x}_1)_\alpha^+, \\ (\hat{\mu}_1)_\alpha^- = (\bar{x}_1)_\alpha^-, \\ (\hat{\sigma}_1^2)_\alpha^+ = \dfrac{2(\beta_1)_\alpha^+}{\tau_1 - 1}, \\ (\hat{\sigma}_1^2)_\alpha^- = \dfrac{2(\beta_1)_\alpha^-}{\tau_1 - 1}, \end{cases}$$

$$\begin{cases} \tau_i = \tau_{i-1} + n_i, \\ (\beta_i)_\alpha^+ = (\beta_{i-1})_\alpha^+ + \max\limits_\alpha\left(\dfrac{\tau_{i-1} n_i ((\hat{\mu}_{i-1})_\alpha - (\bar{x}_i)_\alpha)^2}{2\tau_i}\right) \\ \qquad + \dfrac{(n_i-1)(S_i^2)_\alpha^+}{2}, \\ (\beta_i)_\alpha^- = (\beta_{i-1})_\alpha^- + \inf\limits_\alpha\left(\dfrac{\tau_{i-1} n_i ((\hat{\mu}_{i-1})_\alpha - (\bar{x}_i)_\alpha)^2}{2\tau_i}\right) \\ \qquad + \dfrac{(n_i-1)(S_i^2)_\alpha^-}{2}, \\ (\hat{\mu}_i)_\alpha^+ = \dfrac{\tau_{i-1}(\hat{\mu}_{i-1})_\alpha^+ + n_i(\bar{x}_i)_\alpha^+}{\tau_i}, \\ (\hat{\mu}_i)_\alpha^- = \dfrac{\tau_{i-1}(\hat{\mu}_{i-1})_\alpha^- + n_i(\bar{x}_i)_\alpha^-}{\tau_i}, \\ (\hat{\sigma}_i^2)_\alpha^+ = \dfrac{2(\beta_i)_\alpha^+}{\tau_i - 1}, \\ (\hat{\sigma}_i^2)_\alpha^- = \dfrac{2(\beta_i)_\alpha^-}{\tau_i - 1}. \end{cases}$$

Fuzzy Bayesian Updating Method

Research Method

- During simulation, on the basis of the characteristics of the parameters, the membership degree is chosen.

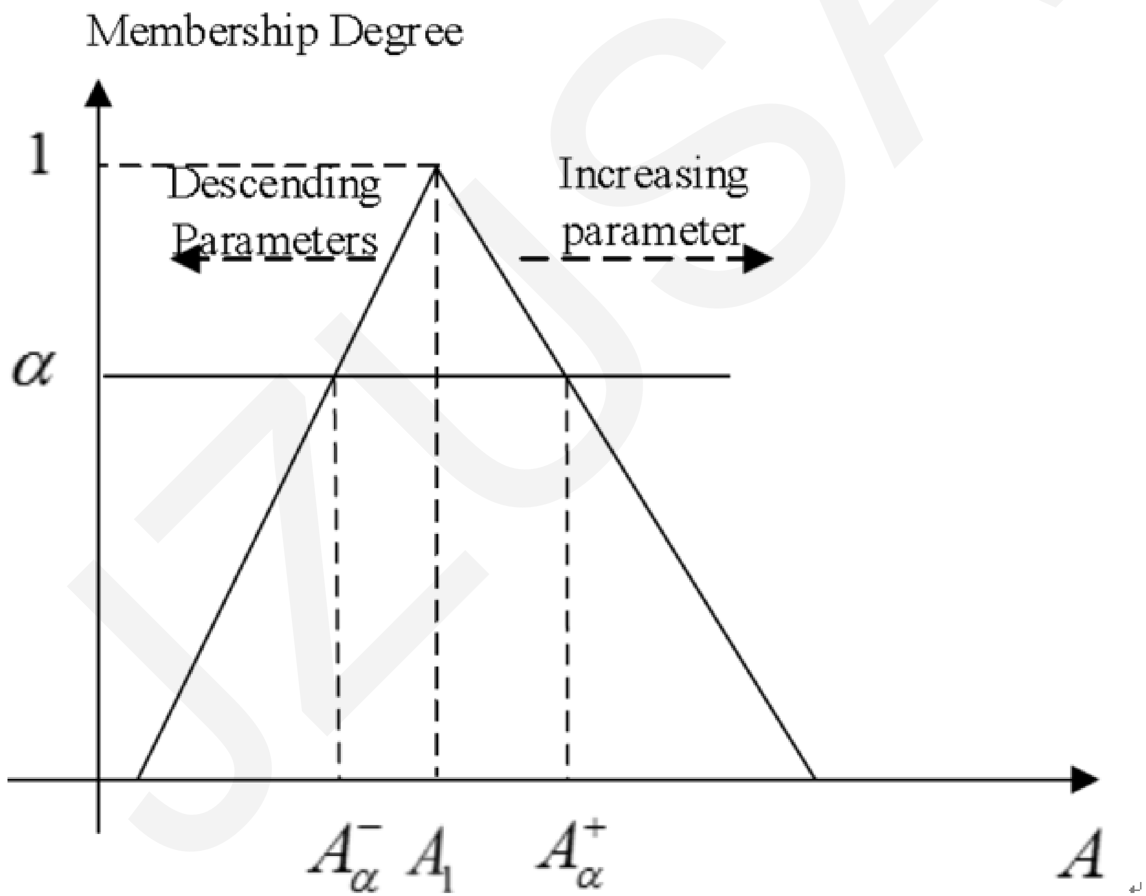

Fig. 6 Value Selection of membership degree

Research Method

- The simulation process shows the main process of construction simulation, including the initial condition update, the simulation parameters update, the selection process of cable cranes, the selection and placing process of dam blocks, the process of joint grouting and others.

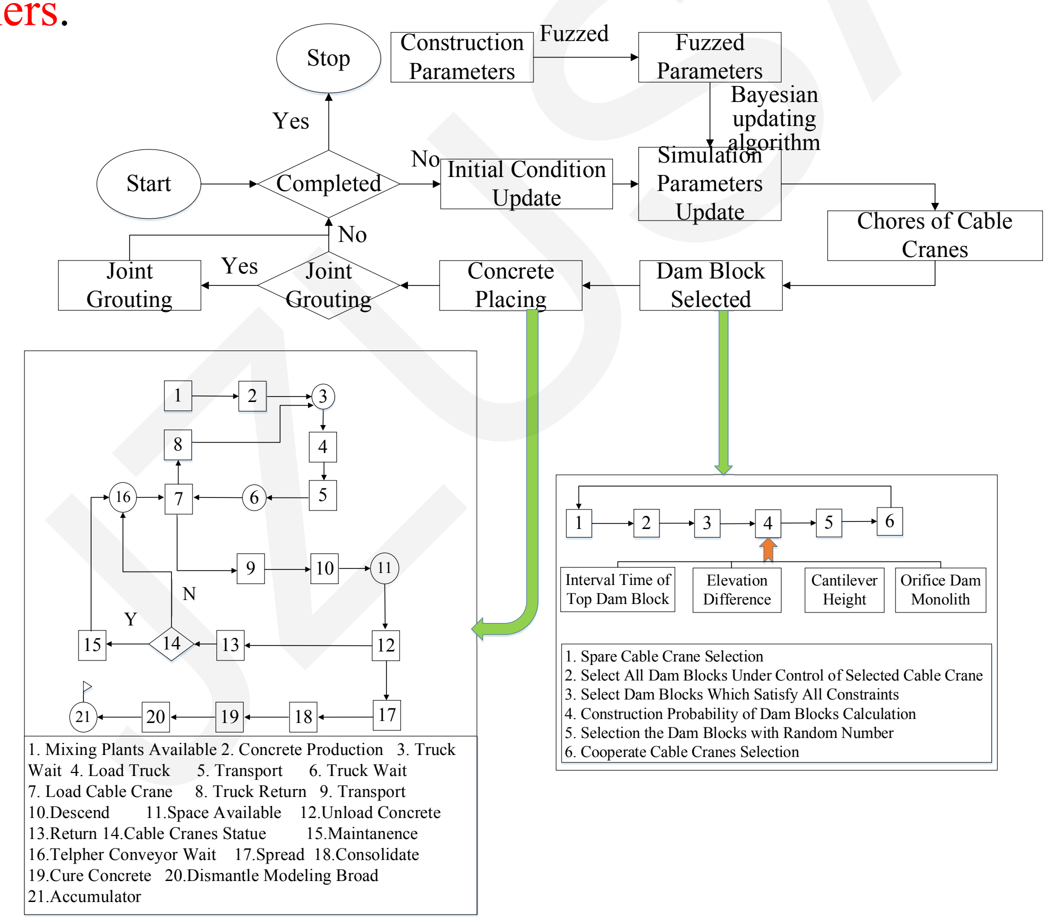

Fig. 4 Simulation Process of High Arch Dams

Conclusions

- Basing on the fuzzy Bayesian updating algorithm, the updated simulation parameters are more in accordance with the construction parameters in situ than the original parameters, which can provide a foundation for the change of simulation parameters during the simulation process, and the simulation results are agreed with the actual construction situation.

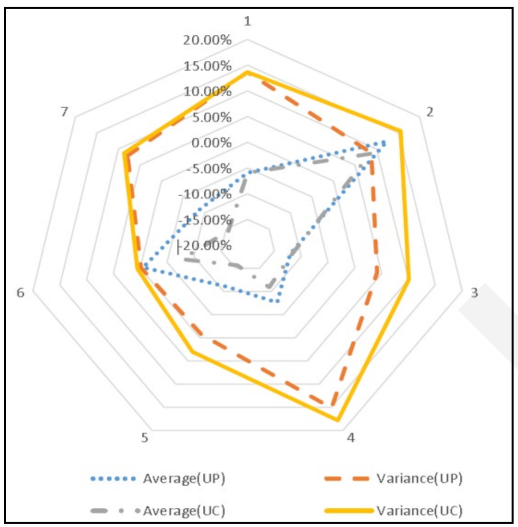

Fig. 8 Comparison between Updated Parameters and Unchanged Parameters

Fig. 13 Simulated Appearance on Mar. 3rd of the 9th year

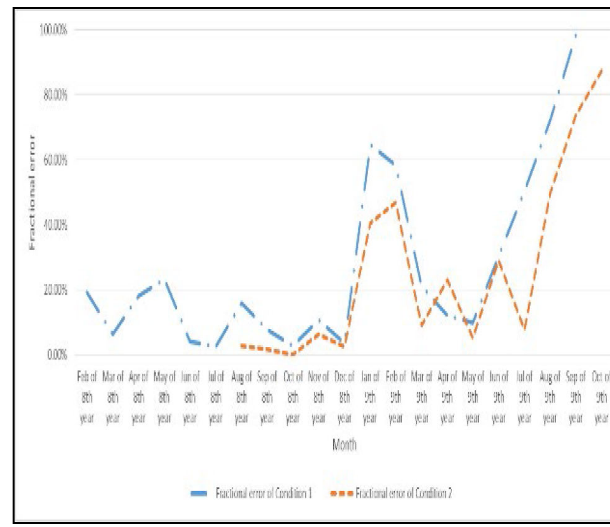

Fig. 15 Fractional Error between Actual Construction Intensity of Two Conditions