Hydrological Forecasting Real-time Adjustment Technique

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Abstract. The parameters of flood forecasting model are optimized in the information of the previous data. It will cause the forecast result deviate from reality when the job forecasts. If we select the appropriate real-time correction, we can use the error message of the reservoir flood forecast model. In this paper, we use the modern stochastic system theory, combine with the real-time adjustment technology of the modern stochastic system theory. The real-time adjustment model is applied to the reservoir flood forecasting project, which is beneficial to improve the accuracy of flood forecasting.

1. Introduction
The error of the forecast model is large, which will greatly reduce the accuracy of the forecast[1]. Based on the measured information[2], real-time correction is in the real-time flood forecasting system before each forecast[3]. It is the key of the real-time flood forecasting system, which improves the present accuracy and corrects the parameters[4-6], states variables, inputs vectors or forecast values of the forecast model to make it more objective and realistic[7].

The accuracy of the real-time forecasting model has a significant impact and is critical to the acquisition of the maximum foresight period[8]. Real-time correction ability is the key to build a water regime automatic measurement and reporting system. In order to sufficiently utilize water resource and ensure reservoir flood control safety[9], it is necessarily further researched and developed flood forecast project as applied[10]. Research on real-time correction methods is the focus of this paper.

There are many types of real-time correction methods, mainly related to the selected forecasting model[11]. The "mathematical expressions" and "algorithms" are related. Such as time-varying parameter method, Kalman filter method, type parameter dynamic identification method and so on.

2. Real-time Adjustment Prediction Way

2.1 Correlation adjustment prediction way
For flood forecast error problems, the paper adopts correlation analysis prediction method, establishes correlation connection model, which directly utilizes hydrological model calculated flow and actual estimated flow of reservoir. Then the least squares technique is used to determine the model parameters and the flood forecast correction model is established. It enhances flood forecast precision, consequently reduces forecast error of system model.

2.2 Residual autoregressive real-time adjustment prediction way
The method uses the residual list \{dQ(j), j=1,...,t\}, which is the yield and flow prediction model list...
\{Q_m(j), j=1,\ldots,t\} minus to observe the flux list \{Q_r(j), j = 1,\ldots\} in real time, establish a residual prediction model. And then predict the future residual error \{dQ(j), j = t+1,\ldots\}, add to the forecast flow \{Q_m(j), j = t + 1,\ldots\} to complete the basin flood forecast adjustment. Thereby it improves the accuracy of flood forecasting. This paper mainly considers the first-order and second-order cases for example.

### 2.3 Adaptive real-time adjustment prediction way

This method increases the reliability between the scorers for different time and date, and improves the variable forgetting factor least squares algorithm. It can enhance the function of the real-time hydrological tracking system, and can adaptively adjust its forgetting factor according to the actual flood conditions in various fields to achieve the best tracking parameters and effectively improve the accuracy of flood forecasting. This paper mainly considers the first-order and second-order cases for example.

First-order adaptive real-time adjustment model structure form:

\[
Q_f(t+1) = Q_n(t+1) + a_0(t) + a_1(t)dQ(t)
\]  

Recursive algorithm:

forecast:

\[
Q_f(t+1) = Q_f(t+1) + X(t+1)\theta(t)
\]  

parameter estimate:

\[
\hat{\theta}(t) = \hat{\theta}(t-1) + G(t)((Q_r(t)-Q_m(t))-X(t)\hat{\theta}(t-1))
\]  

gain factor:

\[
G(t) = \frac{P(t-1)X^T(t)}{\lambda(t)+X(t)P(t-1)X^T(t)}
\]  

covariance array:

\[
P(t) = (I-G(t)X(t))P(t-1)/\lambda(t)
\]  

variable forgetting factor:

\[
\lambda(t) = 1 - \frac{((Q_r(t)-Q_m(t))-X(t)\hat{\theta}(t-1))^2}{(1+X(t)P(t)X^T(t))R}
\]  

In above expression:

\[
X(t+1) = (1,dQ(t))
\]

\[
\theta(t) = (a_0(t),a_1(t))^T
\]

where \(Q_f(t)\) is predicted flux list, \(Q_n(t)\) is the yield and flow prediction model list, \(Q_r(t)\) is real-time observation flux list, \(a_0(t), a_1(t)\) are variable parameters, \(dQ(t)\) is the residual error, \(dQ(t) = Q_r(t) - Q_n(t)\).

Second-order adaptive real-time adjustment model structure form:

\[
Q_f(t+1) = Q_n(t+1) + a_0(t) + a_1(t)dQ(t) + a_2(t)dQ(t-1)
\]  

Its predictions, parameter estimates, gain factors, covariance arrays, and variable forgetting factors are similar to the first-order case, except:

\[
X(t+1) = (1,dQ(t),dQ(t-1))
\]

\[
\theta(t) = (a_0(t),a_1(t),a_2(t))^T
\]

### 2.4 Kalman filter algorithm for real-time correction prediction way

The Kalman filter real-time adjustment uses a linear recursive algorithm to perform real-time prediction based on the state equations and observation equations established by the hydrological system. That is,
the calculated filter utilizes the predicted data and the observed values, and then predicts the state of the system for the next time interval. When there is an observed date for the next time interval, it is filtered again and predicted, and then continues to loop.

The Kalman filtering method is applied in the real-time flood forecasting calculation. Firstly, the hydrological forecasting system model is expressed as the system state equation and the observation equation. Based on the Kalman filter real-time flood forecasting, the Kalman filter real-time flood forecasting model and calculation method are further derived by using the residual of the second-order regression model.

Residual structure of second-order regression correction model with constant flood prediction is as follows:

\[
Q_t(t+1) = Q_s(t+1) + dQ(t+1) = Q_s(t+1) + a_dQ(t) + a_sQ(t-1)
\]

(12)

One constant of second-order regression to the residual prediction model, can be expressed as:

\[
dQ(t+1) = a_dQ(t) + a_sQ(t-1)
\]

(13)

where \(Q_s(t+1)\) is predicted flux list, \(Q_s(t+1)\) is the yield and flow prediction model list, \(a_d(t), a_s(t)\) are variable parameters, \(dQ(t)\) and \(dQ(t-1)\) are the residual error.

The type (9) second-order regression residual prediction model, adapted into a Kalman filter state equation and observation equation of expression:

State equation:

\[
\begin{pmatrix}
    dQ(t+1) \\
    dQ(t)
\end{pmatrix} = \begin{pmatrix}
    a_1 & a_2 \\
    1 & 0
\end{pmatrix} \begin{pmatrix}
    dQ(t) \\
    dQ(t-1)
\end{pmatrix} + \begin{pmatrix}
    1 \\
    0
\end{pmatrix} W(t+1)
\]

(14)

Further abbreviated as:

\[
X(t+1) = \Phi X(t) + \Gamma W(t+1)
\]

(15)

where \(X(t+1) = (dQ(t+1) \ dQ(t) \ 1)^T\) One state variable, \(\Gamma = (1 \ 0 \ 0)^T\) the noise distribution matrix, \(\Phi = \begin{pmatrix}
    a_1 & a_2 \\
    1 & 0
\end{pmatrix}\) the state transition matrix.

3. The choice of real-time adjustment method in Zhang He reservoir

This article uses the above method for real-time adjustment to Zhang He reservoir, yield and conflux forecast model adopts XinAnjiang model [12–13], the results are shown in table 1.

| Model method                        | Deterministic coefficient (%) | The qualified rate of flood peak (%) | The qualified rate of time to peak (%) |
|-------------------------------------|-------------------------------|-------------------------------------|---------------------------------------|
| Yield and conflux forecast model    | 80.12                         | 83.33                               | 83.33                                 |
| Correlation adjustment way          | 84.17                         | 45.15                               | 81.82                                 |
| First-order residual autoregressive real-time adjustment | 91.27                         | 100.00                              | 81.82                                 |
| Second-order residual autoregressive real-time adjustment | 90.20                         | 90.91                               | 81.82                                 |
| First-order adaptive real-time      | 91.09                         | 100.0                               | 90.91                                 |
adjustment

|                      | 90.18 | 81.82 | 81.82 |
|----------------------|-------|-------|-------|
| Second-order adaptive real-time adjustment |       |       |       |
| Kalman filtering real-time adjustment prediction way | 88.14 | 100   | 90.91 |

We can see from the tables, real-time adjustment model can improve the accuracy of hydrological forecast effectively, it is recommended that apply suitable way to improve forecasting precision.

The Kalman filter gives an optimal estimate of the state only in the ideal case. It uses physical methods to describe the runoff process, many simplified or near a similar approach to the hydrological system, which makes it difficult to apply the Kalman filtering method. But because it is still not possible to meet the exact requirements of the system mathematical model and noise statistics, is harmful for the application of Kalman filter in hydrology, so it needs further research and discussion.

The first-order adaptive real-time adjustment model can enhance the real-time performance of the real-time hydrological system. It can adaptively adjust its forgetting factor according to the actual flood conditions in various fields to achieve the optimal tracking parameters and effectively improve the accuracy of flood forecasting. So the effect is the best. For Zhanghe Reservoir, the determination coefficient is 91.09%, the flood pass rate is 100%, and the pass rate reaches 90.91% after real-time adjustment.

4. Conclusions

Based on past observation data, runoff flood forecasting model method was developed. The flood forecasting model parameters are reflected in the information below the previous average. When working is predicted, due to the best value of the general and average values, it will lead to the prediction of the deviation. If we choose the right real-time correction prediction, we can use the error message at any time during the forecasting operation. The appropriate adjustment plan for the estimated runoff from the numerical forecast will greatly improve the accuracy of real-time flood forecasting for reservoir flood control and provide a scientific and reliable basis for making decisions. This text develops the forecast project based on analyzing these error generation characteristics, and then improves real-time adjustment technique.

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