A METHOD FOR PREDICTING LIQUID LEVEL IN A TANK OF AN INDUSTRIAL PROCESS

FIELD OF INVENTION

The invention relates to the field of process control. More particularly, the invention relates to a method for predicting liquid level in a tank of an industrial process.

BACKGROUND OF THE INVENTION

Process control involves the use of control means to achieve consistency and safety in a process which could not be achieved solely by manual control of an operator. In process control, monitoring and control means are used to minimize or prevent variability in process parameters as such variability may adversely impact the physical, chemical, or biological properties of end products or safety of operators. Generally, process control may utilize sensors at various location of a process for collecting information of the process, processors for processing the information collected by the sensors, and controllers to execute control commands based on the processed information. Additionally, process control may also utilize historical data for process optimization.

Over the years, various methods of process control have been developed. For instance, US Patent No. US11264121B2 discloses a method for predicting real-time production of a chemical product in a plant. The prediction is based on a set of parameters monitored by a set of sensors at a set of measurement frequencies. Accordingly, the method uses a predictive model based on machine learning algorithms, wherein the predictive model uses a series of time stamped historical sensor data and historical production data to provide real-time prediction of production rates of chemical product. Additionally, the method uses an optimization model based on machine learning

algorithms, wherein the optimization model uses clustered historical sensor data and the historical production data to provide optimal values for maximizing production of the chemical product.

However, machine learning requires a huge amount of data sets for training and optimization, which may be time consuming to develop, especially when there are fluctuations in the process parameters. Accordingly, it would be desirable to provide a method of process control with improved accuracy and efficiency. This invention provides a solution to the problem.

SUMMARY OF INVENTION

One objective of the invention is to provide a method for predicting liquid level in a tank of an industrial process with improved accuracy and efficiency. In particular, the method is capable of taking historical data with regards to fluctuations in inlet flow rates, liquid consumption rates of different processes and/or equipment, and operation status of the processes and/or equipment into account to improve prediction of liquid level.

In a first aspect of the invention, there is provided a method for predicting liquid level in a tank of an industrial process, the method comprising the steps of obtaining a first set of historical data, a second set of historical data, and a third set of historical data, wherein the first set of historical data includes past inlet flow rates of the liquid into the tank, the second set of historical data include past liquid consumption rates of different processes and/or equipment, and the third set of historical data includes past operation status of the processes and/or equipment; computing a projected inlet flow rate of the liquid into the tank and a projected outlet flow rate of the liquid from the tank; and determining a change in the liquid level by calculating a difference between the computed projected inlet flow rate and the projected outlet flow rate, wherein the

projected inlet flow rate of the liquid is computed by the steps of adopting a distribution fitting algorithm to determine a best fit probability distribution for the first set of historical data and subsequently obtaining the projected inlet flow rate based on the best fit probability distribution, and wherein the projected outlet flow rate of the liquid is computed by the steps of converting the second set and the third set of historical data into matrices using a matrix algorithm and subsequently performing one or more matrix operations on the matrices to obtain the projected outlet flow rate of the liquid.

Preferably, the best fit probability distribution is determined by the steps of identifying a portion of the first set of historical data that represents the past inlet flow rates at a period of interest; converting the portion of the first set of historical data into a plurality of probability distributions; and determining the best fit probability distribution from the plurality of probability distributions by adopting the distribution fitting algorithm.

Preferably, the probability distributions includes normal distribution, log-normal distribution, Poisson distribution, or any combinations thereof.

Preferably, the projected inlet flow rate is obtained by the steps of determining a plurality of parameters from the best fit probability distribution and generating a set of distribution data of the first set of historical data based on the parameters to obtain the projected inlet flow rate.

Preferably, the second set and the third set of historical data are converted into matrices by the steps of providing an assumption of the processes and/or equipment; identifying a portion of the second set of historical data that represents the past liquid consumption rates of the processes and/or equipment at a period of interest and a portion of the third set of historical data that represents the past operation status of the processes and/or equipment at that period of interest; and converting the portion of the second set and the portion of the third set of historical data into a first set of matrices and a second set

of matrices using the matrix algorithm, respectively, according to the provided assumption.

Preferably, the projected outlet flow rate is obtained by the steps of performing a first matrix operation using the first and second sets of matrices to generate a third set of matrices which represent predictions of liquid consumption rate of individual processes and/or equipment at a period of interest and performing a second matrix operation using the third set of matrices to generate a fourth set of matrices which represent the projected outlet flow rate.

Preferably, the first matrix operation is matrix multiplication and the second matrix operation is matrix summation.

One skilled in the art will readily appreciate that the invention is well adapted to carry out the objects and obtain the ends and advantages mentioned, as well as those inherent therein. The embodiments described herein are not intended as limitations on the scope of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

For the purpose of facilitating an understanding of the invention, there is illustrated in the accompanying drawing the preferred embodiments from an inspection of which when considered in connection with the following description, the invention, its construction and operation and many of its advantages would be readily understood and appreciated.

Fig. 1 is a schematic diagram illustrating an overview of a method for predicting liquid level in a tank of an industrial process.

Fig. 2 is a schematic diagram illustrating a matrix algorithm used in the computation of the projected outlet flow rate of liquid..

Fig. 3 is a schematic diagram illustrating the steps of updating liquid level in the tank based on change in liquid level.

Fig. 4 is a schematic diagram illustrating Kraft process.

DETAILED DESCRIPTION OF THE INVENTION

The invention will now be described in greater detail, by way of example, with reference to the drawings.

Referring to Fig. 1, an overview of a method (100) for predicting liquid level in a tank of an industrial process is illustrated therein. The industrial process can include but not limited to a pulp production process. Generally, the method is capable of taking historical data with regards to fluctuations in inlet flow rates, liquid consumption rates of different processes and/or equipment, and operation status of the processes and/or equipment into account to improve prediction of liquid level.

In a preferred embodiment of the invention, the method (100) begins by obtaining a first set of historical data, a second set of historical data, and a third set of historical data (110). Preferably, the first set of historical data includes past inlet flow rates of the liquid into the tank, the second set of historical data includes past liquid consumption rates of different processes and/or equipment connected to the tank, and the third set of historical data includes past operation status of the processes and/or equipment connected to the tank. By way of example, the equipment can be an evaporator of the pulp production process.

Subsequently, the method (100) computes a projected inlet flow rate of the liquid into the tank (120) and a projected outlet flow rate of the liquid from the tank (130) using the sets of historical data obtained. In the preferred embodiment of the invention, the projected inlet flow rate of the liquid is computed by the steps of adopting a distribution fitting algorithm to determine a best fit probability distribution for the first set of historical data and subsequently obtaining the projected inlet flow rate based on the best fit probability distribution. Conventional mass and energy balance in steady state Model Predictive Control (MPC) method is not preferable as there may still be fluctuation in the first set of historical data represented in probability distributions.

Preferably, the best fit probability distribution is determined by firstly identifying a portion of the first set of historical data (121) that represents the past inlet flow rates at a period of interest. Then, the identified portion of the first set of historical data is converted into a plurality of probability distributions (122). The past inlet flow rates of liquid into the tank fluctuates over time due to inconsistency in the liquid consumption rate by the process and/or equipment in the process. In view of this, the first set of historical data is converted into the plurality of probability distributions to minimize adverse effects of such fluctuation in the first set of historical data on the computed projected inlet flow rate. By way of example, the probability distributions include normal distribution, log-normal distribution, Poisson distribution, or any combinations thereof. Next, the best fit probability distribution is determined from the plurality of probability distributions (123) by adopting the distribution fitting algorithm. Advantageously, the distribution fitting algorithm determines the probability distribution that best fits the first set of historical data, thereby improving the accuracy of the projected inlet flow rate computed.

Preferably, the projected inlet flow rate is obtained by firstly determining a plurality of parameters from the best fit probability distribution (124). Then, a set of distribution data of the first set of historical data is generated based on the parameters (125), wherein

the set of distribution data is used to obtain the projected inlet flow rate.

In the preferred embodiment of the invention, the projected outlet flow rate of the liquid is computed by the steps of converting the second set and the third set of historical data into matrices using a matrix algorithm and subsequently performing one or more matrix operations on the matrices to obtain the projected outlet flow rate of the liquid. Preferably, the second set and the third set of historical data are converted into matrices by firstly providing an assumption of the processes and/or equipment (131). By way of example, the assumption in which the equipment is operating at optimal condition is provided. Alternatively, the assumption in which an outflow from a process is an input to a subsequent process without interruption is provided. Optionally, the aforementioned assumptions are provided. Advantageously, the assumption simplifies the computation of the projected outlet flow rate. Subsequently, a portion of the second set of historical data that represents the past liquid consumption rates of the processes and/or equipment at a period of interest and a portion of the third set of historical data that represents the past operation status of the processes and/or equipment at that period of interest are identified (132). Next, the identified portion of the second set and the identified portion of the third set of historical data are converted into a first set of matrices and a second set of matrices using the matrix algorithm (133), respectively, according to the provided assumption. Fig. 2 illustrates the matrix algorithm used in the computation of the projected outlet flow rate of liquid. Preferably, elements in the first set of matrices (201) represent the past liquid consumption rates of the processes and/or equipment at a period of interest. More preferably, the first set of matrices (201) are in a size of 1×1. Preferably, elements in the second set of matrices (202) represent the past operation status of the processes and/or equipment at a period of interest. More preferably, the second set of matrices (202) are in a size of 1×n, wherein the row represents a process and/or equipment and the column represents different periods of interest. By way of example, an element “0” in the second set of matrices (202) indicates that the process and/or equipment is not operating whereas an element “1” in

the second set of matrices (202) indicates that the process and/or equipment is operating.

Preferably, the projected outlet flow rate is obtained by firstly performing a first matrix operation using the first (201) and second sets of matrices (202) to generate a third set of matrices (203) which represent predictions of liquid consumption rate of individual processes and/or equipment at a period of interest. Preferably, elements in the third set of matrices represent liquid consumption rates of processes and/or equipment at different periods of interest. Subsequently, a second matrix operation is performed using the third set of matrices to generate a fourth set of matrices (204) which represent the projected outlet flow rate. Preferably, the first matrix operation is matrix multiplication and the second matrix operation is matrix summation.

Lastly, the method (100) determines a change in the liquid level in the tank (140) by calculating a difference between the projected inlet flow rate and the projected outlet flow rate computed (301), as illustrated in Fig. 3. Preferably, the change in the liquid level determined is then used to update the liquid level in the tank at the period of interest (304). By way of example, the liquid level in the tank at the period of interest is decreased (302) when a negative change in the liquid level is obtained. In contrast, the liquid level in the tank at the period of interest is increased (303) when a positive change in the liquid level is obtained.

Preferably, the method can be used for predicting liquid level in a tank in Kraft process as illustrated in Fig. 4. More preferably, the method is used for predicting level of weak black liquor in a weak black liquor tank or heavy black liquor in a heavy black liquor tank based on the consumption of evaporators.

The present disclosure includes as contained in the appended claims, as well as that of the foregoing description. Although this invention has been described in its preferred

form with a degree of particularity, it is understood that the present disclosure of the preferred form has been made only by way of example and that numerous changes in the details of construction and the combination and arrangements of parts may be resorted to without departing from the scope of the invention.

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CLAIMS

1. A method (100) for predicting liquid level in a tank of an industrial process, the method comprising the steps of:

obtaining a first set of historical data, a second set of historical data, and a third set of historical data (110), wherein the first set of historical data includes past inlet flow rates of the liquid into the tank, the second set of historical data include past liquid consumption rates of different processes and/or equipment, and the third set of historical data includes past operation status of the processes and/or equipment;

computing a projected inlet flow rate of the liquid into the tank (120) and a projected outlet flow rate of the liquid from the tank (130); and

determining a change in the liquid level (140) by calculating a difference between the computed projected inlet flow rate and the projected outlet flow rate (301),

wherein the projected inlet flow rate of the liquid is computed by the steps of:

adopting a distribution fitting algorithm to determine a best fit probability distribution for the first set of historical data and subsequently obtaining the projected inlet flow rate based on the best fit probability distribution, and

wherein the projected outlet flow rate of the liquid is computed by the steps of:

converting the second set and the third set of historical data into matrices using a matrix algorithm and subsequently performing one or more matrix operations on the matrices to obtain the projected outlet flow rate of the liquid.

2. The method (100) according to claim 1, wherein the best fit probability distribution is determined by the steps of:

identifying a portion of the first set of historical data (121) that represents the past inlet flow rates at a period of interest;

converting the portion of the first set of historical data into a plurality of probability distributions (122); and

determining the best fit probability distribution from the plurality of probability

distributions (123) by adopting the distribution fitting algorithm.

3. The method (100) according to claim 2, wherein the probability distributions includes normal distribution, log-normal distribution, Poisson distribution, or any combinations thereof.

4. The method (100) according to claim 1, wherein the projected inlet flow rate is obtained by the steps of:
determining a plurality of parameters from the best fit probability distribution (124) and generating a set of distribution data of the first set of historical data based on the parameters (125) to obtain the projected inlet flow rate.

5. The method (100) according to claim 1, wherein the second set and the third set of historical data are converted into matrices by the steps of:
providing an assumption of the processes and/or equipment (131);
identifying a portion of the second set of historical data (132) that represents the past liquid consumption rates of the processes and/or equipment at a period of interest and a portion of the third set of historical data that represents the past operation status of the processes and/or equipment at that period of interest; and
converting the portion of the second set and the portion of the third set of historical data into a first set of matrices and a second set of matrices using the matrix algorithm (133), respectively, according to the provided assumption.

6. The method (100) according to claim 1, wherein the projected outlet flow rate is obtained by the steps of:
performing a first matrix operation using the first (201)and second sets of matrices (202) to generate a third set of matrices (203) which represent predictions of liquid consumption rate of individual processes and/or equipment at a period of interest and
performing a second matrix operation using the third set of matrices to generate a fourth

set of matrices (204) which represent the projected outlet flow rate.

7. The method according to claim 6, wherein the first matrix operation is matrix multiplication and the second matrix operation is matrix summation.