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WATER POLLUTION BASED ABRUPT EVENT MONITORING USING KPCA AND SVM

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Abstract—
Water is an important biological component, so it is important to maintaining good water environment with the help of good methods and technologies. Various major issues are present in the water environment due to thousands of reasons. One of the critical issue in water environment systems is abrupt event monitoring. There is occurrence of two main different abrupt events in the monitoring system, such as, the emergency water pollution accident and the abrupt sensor fault. The presence of these two different abrupt events are very hazardous and both of them have similar data characteristics under observation, very few methods are used to recognize the presence of these events. In this paper, a novel abrupt event monitoring approach based on kernel principal component analysis (KPCA) and support vector machines is proposed . KPCA is used to detect the abnormality and SVM is used to recognize the type of abnormality. The trust mechanism is introduced into the approach to improve performance of quick response for the abrupt events.
Keywords: *Abrupt events, water environment system, sensors, remote center, trust mechanism, kernel principal component analysis (KPCA) and support vector machine(SVM,).*

I. Introduction

Water is an important resource and an very important biological component for all the living organics on the earth that helps in the survival and acts as catalyst for all the mechanisms on the earth. Water environment, consisted of two, one is surface water environment and other one is underground water environment, which can be differentiated to different water bodies like we can say river, lake, reservoir, ocean, glacier, spring and shallow/deep underground waters. Once a change or damage of water body or environment is observed in this complex environment, change in the occurrence of other environmental elements also occurs. Water bodies are suffering from various pollutions due to thousands of uncontrollable reasons. Due to the development of society and economy, water pollution and its hazards have become one of the most prominent and noteworthy problems in the human society.

The frequent occurrence of hazardous water pollution accidents have attracted more and more attention in the whole human society, so it is very important and need of time to monitor the water environment systems .Due to high water complexity, there are two main different abrupt events in the water environment sensor system, they are, the emergency water pollution accident and the abrupt sensor fault .The cause of emergency water pollution is mostly due to discharging the harmful polluted water into the water environment directly without any sort of prior treatments [1]. However, the abrupt sensor fault is one type of sensor fault, which is mostly caused by monitoring objects as heavy corrosive pollutants or the design flaws.

If abrupt event is an emergency water pollution accident, then it should be detected and dealt with in time to avoid further hazards. Otherwise, it will lead to harmful and serious consequences. The consequences most commonly observed can be increase of fish death rate, shortage of drinking water which is the most important biological component, and high economic losses. If it is second type, an abrupt sensor fault, the faulty sensor should be detected and replaced timely to keep the sensor system working normally and in a proper way.

II. Related Work

Various methods to deal with the transmission of water parameters and its representation at the remote centre have been proposed.

Jianjun Ni, Member, IEEE, Chuanbiao Zhang, Li Ren, and Simon X. Yang, Senior Member,IEEE proposed "Abrupt Event Monitoring for Water Environment System Based on KPCA and SVM" [1] a Trust mechanism that improve the performance of quick response to the abrupt events and its monitoring. In this proposed work a spare data area is set up to store the data for the KPCA modelling which is used to detect the abrupt events. The data in the spare data area are updated continuously and so as the KPCA model, is updated subsequently so as to improve the adaptability of the KPCA model for the abrupt event monitoring and here support vector machines (SVMs) is used to detect the type of abrupt event Ning Jin, Renzhi Ma, Yunfeng Lv, Xizhong Lou, Qingjian Wei Department of Information Engineering China JiliangUniversity Hang Zhou, 310018, China proposed " A Novel Design of Water Environment Monitoring System Based on WSN" [2] a novel design of water environment monitoring system based on wireless sensor networks. In this proposed work the sensor nodes have been constructed with various arbitrary parameter modules such as PH, dissolved oxygen (DO), temperature and conductivity.

Xia Hong-bo, Jiang Peng Institute of Information and Control Hangzhou Dianzi University, Hangzhou, China , Wu Kai-hua Institute for Biomedical Engineering and Instrumentation Hangzhou Dianzi University, Hangzhou, China proposed " Design of Water Environment Data Monitoring Node Based on ZigBee Technology" [3] a design of a new water environmental monitoring system based on wireless sensor networks which is best suitable for the monitoring in complex and large-scale water environment. This system research is based on the low-power data monitoring node which is based on ZigBee wireless technology, and develops its hardware and software. This proposed work was been tested on the water monitoring in an artificial lake, to realize the remote and automatic on-line monitoring both on the pH value and temperature of the lake water.

B. Scholkopf,A.Smola, and K.-R. Muller,proposed "Nonlinear component analysis as a kernel eigenvalue problem,"[4] describle a new way of performing non linear form of pc analysis.

Jong I. Park, Seung H. Baek, Myong K. Jeong, *Member*, *IEEE*,and Suk J. Bae, *Member*, *IEEE, proposed,"* Dual Features Functional Support Vector Machines for Fault Detection of Rechargeable Batteries"[5]describes dual features functional support vector machine approach that uses profiles for early detection of faulty batteries with the reduced error rate.

Shuiping Zhang, Lin Zhang JiangXi University of Science and

Technology, GanZhou 341000 ,P.R.China proposed" Water Pollution Monitoring System based on Zigbee Wireless Sensor Network" [6] a water pollution monitoring system based on Zigbee wireless sensor network taking into account the current severe situation of global water pollution, with Low-cost, low-consumption and easy-expansion, the system is capable of inspecting the water pollution level timely, which provides important proofs for related departments of environments to make decisions and take appropriate actions based on that decisions. This work described the detailed hardware and software designs of sensor node. The system possess a feature of self-organized and self-adaptive, and works in terms of communication even if the location of network node changes. This system is applicable to synchronized monitoring on water pollution in water bodies like rivers, lakes, springs and oceans. If it is considered that the differences of energy demand and energy consumption of different nodes in the same sensor network may bring bottleneck of the whole network since the energy consumption of some nodes in the same sensor network is much bigger, to balance the energy consumption of all thenodes, the system collects and transfer data via cluster network.

Shuang-chun Yang, Yi Pan Liaoning University of Petroleum

& Chemical Technology Fushun, China proposed "The

Application of the Wireless Sensor Network (WSN) in the Monitoring of Fushun Reach River in China" [7] the possible application of WSN technology in the water quality monitoring area to overcome the shortcomings of the existing system in China .A new remote river quality monitoring system based on the wireless sensor network is proposed which was introduced for its low power consumption, lower cost, self communication, long lasting operation time and ease of implementation in large area. This was applied in the Monitoring of Fushun Reach River in China. Whenever the pollution emergencies occur, the environmental department is capable of detecting these emergencies on-time and dispose them quickly.

Dong He, Li-Xin Zhang, 1Institute of Mechanical and electronic information, China University of Geosciences

(WuHan), WuHan,China proposed" The Water Quality Monitoring System Based on WSN" [9] a water quality monitoring system that can be used by environmental protection department in a particular area of the water quality requirements .This system is based on the Wireless Sensor Network (WSN). It consists of Wireless Water Quality Monitoring Network and Remote Data Centre as its major parts. In this system the sensor network is built in accordance with Zigbee wireless transmission agreement. WSN Sample the water quality and then send the data to Internet with the help of the GPRS DTU which has a built-in TCP/IP protocol function.

Through the Internet, Remote Data Centre gets the real –time water quality data, and then it is analysed, processed and recorded (data). Based on this the environmental protection department can provide real-time guidance to those industries which depends on regional water quality conditions, like industrial, plant and aqua culture. The most important is that this work is more efficient and less cost.This proposed design works in mesh network which can be convenient to build an automatic network, and has a good expansibility.

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proposed " A

Remote Wireless Sensor Networks for Water Quality Monitoring" [10] a novel system of remotewater quality measuring and monitoring based on wireless sensornetwork (WSN) and Code Division Multiple Access (CDMA) technology.These functions of remote detection and real-time monitoring of natural water areimplemented through the CDMA wireless data transmission. The system has a simple architecture, and is not confined by the geographical position .The proposed system uses cluster technique.

Steven Silva , Hoang N ghia Nguyen , Valentina Tiporlini and Kamal Alameh Electron Science Research Institute, Edith Cowan University, 270 Joondalup Dr, Joondalup, WA 6027,

Australia proposed "Web Based Water Quality Monitoring with Sensor Network: Employing ZigBee and WiMax Technologies" [11] the development of a webbased wireless sensor network application for monitoring water pollution using Zigbee and WiMax technologies. Web based sensor network application for monitoring water pollution is based on the use of Zigbee and WiMax that is used for collecting and processing information and making decisions in real time via a remote web server. The technologies used for developing the system consist of a local Zigbee network,which is capable of acquiring various water quality parameters with a WiMax network and capable a host computer for web based monitoring. The data is being sent from sensor nodes through the Zigbee gateway to theweb server via WiMax network, thus it allows users to remotely monitor the water quality from their offices instead of gathering data from the scene. In the system. proposed WSN has been deployed for monitoring the water quality of a university's manmade lake using five different types of sensors.

This paper is organised as follows. Section I presents introduction, Section II describes related work, , Section III describes proposed methodology, working methods and proposed approach. Finally the conclusion is given in Section IV.

III. Research Methodology

WSN is a kind of AD-Hoc network which is easily configurable, without infrastructure and much costing, such as cables. This leads saving system investment a lot.

The system consists of mainly three parts for collection of water parameters

wireless
sensor
node sink
node
remote centre

Node is the important basic functional unit of wireless sensor Network. As sensor nodes are distributed in the water environment. Each node is expected to detect events of interest and estimate related parameters . Node is responsible for the collection and storage of on-site parameters, such as water temperature, PH value, conductivity, then send and receive data, or we can say mainly acquire information of the source of pollution. The resulting acquired information of each inspected area from node needs to be transmitted to the sink node via wireless communication media like ZigBee.

In the system as shown in the Fig. the parameters from the water environment will be collected by the sensors of different types namely temperature sensor, conductivity sensor and PH level sensor that are interfaced with nodes. These collected parameters such as water temperature, conductivity and ph level will then be transmitted to the remote centre via sink node. After analysis this remote centre is responsible for transmitting this information to the environmental department.

To get the data with high degree of accuracy, a sensor network including many sensors is distributed in water environment. Then data monitored by a sensor node of the water environment sensor system are analysed. For simplification without losing generality, mainly three types of important water quality parameters are monitored in this sensor node, namely, temperature (in degrees Celsius), pH (dimensionless), conductivity (in microsiemens per centimetre).The data from node is transmitted to remote centre via a sink node.

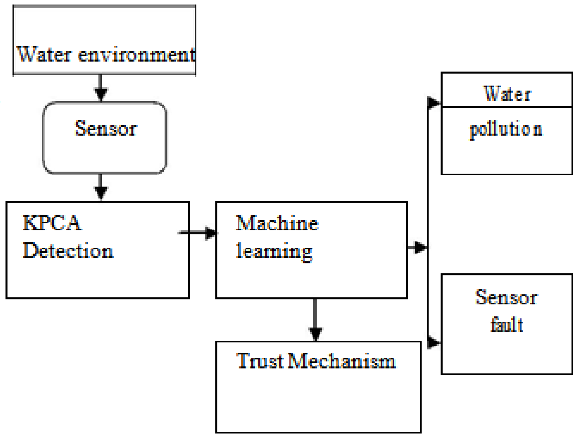

Fig. 1 Flow diagram for abrupt event monitoring water environmental system

At remote centre the data is studied , the presence of application software, analyse, process and record water quality data and display of the collected data takes place. Remote Data Centre includes the PC, application software and database. At remote centre if any abrupt event occurrence is encountered in the environment, based on the data of parameters, it is being detected and then recognised. This data will be helpful for industrial, agricultural production, environmental departments. Users can access the remote monitoring centre at real-time, enquire and even monitor the system. There are various functions of remote monitoring centre they are display graphic display of data, Memory and output: Storing and reporting data by the real-time monitoring, statistically analysing the historic data, draw the historic trend curve and output and print different report form for future use, when a pollution emergency is encountered, the environmental department could be able to detect it on-time and dispose quickly. This information can be broadcasted to the environmental protection department and this can provide real-time guidance to those industry which depends on regional water quality conditions, like industrial, plant and aquaculture etc. The most important is that the work can be more efficient and less costly.

There are many researches done on monitoring the abrupt sensor fault or the emergency water pollution accident, but very few considered the two problems together. As changed characteristics of the measured data during the two different abrupt events are similar, so presence of conventional methods is not capable of recognizing the abrupt event efficiently. There are two main tasks in the monitoring of abrupt event. First task is that the abnormality in the sensor system should be detected quickly and in an accurate way. Second one is that the type of abrupt events should be recognized correctly as soon as after the abnormality is being detected.

A. Trust Mechanism

To increase the diagnosis accuracy of the approach and make use of minimum additional sensors as possible, a trust mechanism is being introduced in the approach. Before the introduction of the trust mechanism, it is defining some flags is important.

One flag is denoted by $f1(xi)$ to indicate the abnormality in the input data xi is present or not. Another flag is denoted by $f2(sj)$ for the sensor sj , to indicate whether its measured parameter of the input data is abnormal or not. The flags $f1(xi)$ and $f2(sj)$ can be determined by the methods KPCA and the SVM, respectively.

$f1(xi)$ = 0, -- If it is normal data
1, -- Otherwise

$f2(sj)$ = 1, -- If its measured parameter is abnormal
0, -- Otherwise.

Each sensor is assigned with a specific trust value, which indicates the trust degree of the measured parameter by that particular sensor. We can say the trust value of the jth sensor at the ith step is denoted by $Tj(i)$. If there is presence of some abnormality in the information of the new data that is being detected by the SVM model, the trust value of that sensor is being decreased. Otherwise, the trust value of this sensor will be increased. Furthermore the calculating rule of the trust value for the sensors is defined as follow

$Tj(i)$= $Tj(i-1)+e$, If the sensor data are normal data
$Tj(i-1)-f$, Otherwise

where e and f are constants.

Sometimes the abnormal information is not diagnosed as an abrupt event immediately to reduce the false diagnosis because it may be caused by noise (if present) . Until the trust value of a sensor decreases continuously and is lower than the trust threshold (which is defined as Th), the occurrence of the presence of an abrupt event is confirmed at this time. Taking into consideration the complexity of the water environment, an use of additional sensor is used to monitor the same type of water parameter. If an abnormity is detected on both of the two sensors for the same parameter is same, it can be confirmed that the emergency water pollution accident has happened. As both of the two sensors are showing same readings so this is for sure that the probability of two sensors showing wrong reading is very less. Otherwise, it is an abrupt sensor fault. The basic idea of the above decision as mentioned earlier is that the fault probability of two sensors for the same parameter at the same time will be very low or we can say negligible. So, an additional sensor must be placed at the same place of the first sensor, to monitor the same water quality parameter at the same time. Then, the effect of a sensor location in the decision can be removed. If occurrence of a water pollution accident is encountered, the trust values of the affected sensors are directly increased to the maximum value at the next step to eliminate the further influence of environment, and the new data are inserted again to update the diagnosis model.

B. KPCA and SVM method

Abrupt events are the events which causes sudden change in the water environment unlike drift event which causes slow change. So abrupt events are more dangerous than drift events . As mentioned earlier there are two types of abrupt events, namely, abrupt sensor fault and environmental water pollution. The change in the characteristics of the measured data during the occurrence of two different abrupt events is similar, so conventional methods is incapable of recognizing the abrupt event efficiently and effectively. So there are two main tasks in the abrupt event monitoring which is performed at remote centre. One task is that the abnormality in the system should be detected quickly and accurately. The other one is that the type of abrupt events should be recognized correctly as soon as the occurrence of abnormality is detected. First task of detection of abnormality is accomplished by KPCA and the second task after abnormality is detected i.e. recognition is accomplished by SVM , which is a type of machine learning mechanism.

The KPCA method is the extension of Principal Component (PC) analysis in the nonlinear area, which is a novel non-linear multivariate analytical redundancy method [4]. In the system, the KPCA method is used to detect the presence of abrupt event. If any abrupt change in parameters results in some abnormality defect . The main objective of KPCA method in the system is to detect the presence of abrupt event. The SVM method is a new machine learning algorithm based on statistical learning theory, which can solve the small sample, nonlinearity, high dimension, and local minimum problems. The SVM method has been used in classification, prediction, and fault diagnosis[5].

In the system three types of measurement sensors are used .The measurement sensors for these parameters are denoted by $s1$, $s2$, $s3$ for temperature, PH, conductivity respectively. One additional sensor for each type of water quality parameter is used. So, over all six sensors are used, which are denoted by $\{s11, s12, s21, s22, s31, s32\}$. The corresponding sensor faults and trust values of these sensors are denoted by $\{F11, F12, F21, F22, F31, F32\}$ and $\{T11, T12, T21, T22, T31, T32\}$, respectively.

The work flow is as follow:

1. Initial samples must be obtained from the historical data collected collected from online monitoring system.
2. The data with normal information in the initial samples are used to set up the initial database. Then KPCA is set up by initial data in the database.
3. The SVM model is set up by abnormal data in initial samples. sensor is a faulty sensor is confirmed. In this way the KPCA model and SVM model is to detect and recognise the water
4. The proposed approach is used for online monitoring. pollution or abrupt sensor fault respectively. Then the data is The new data are analyzed by the KPCA model to detect whether there is any abnormal information.
5. The abnormal data are isolated and recognized by the SVM model.
6. Decide which abrupt event occurs by the decision rules introduced before, and update the diagnosis model.
7. Go to step 4.

```
Initialization();
Detect (new data xi)
{
Call_KPCA();
    If f1(xi) = 0
        For j = 1 to u
        Tj=Tj + e;
    End
Else
    Call_SVM( )
    If f2(sj)= 1
    Tj = Tj – f;
End
For j =1 to v
   If Tj1 = Tj2 < Th
    Output {“ It is an emergency water pollution !”};
    Tj1 = Tj2= Tmax
End
 If (Tj1< Tj2)and(Tj1 < Th)
```

```
    Output {" The sensor Sj1 is failure !"};
  Elseif  If (Tj2< Tj1)and(Tj2< Th)
    Output {" The sensor Sj2 is failure !"};
End
End
End
Call_
updat
e();
```

The online monitoring of data begins. Then in next step new data is analysed by KPCA- for fault detection. If it is a normal data , then the trust value of all the sensors ,1 to u- sensors used in the system, are increased. But if the data analysed by KPCA seems to be abnormal data then the abnormal data is introduced in the SVM model. Here SVM model is used to isolate and recognise the abnormal data.

Here in SVM if the parameter measured by sensor *sj is* abnormal then the trust value of sensor *sj* is reduced. For all the parameters monitored by the system,1 to v, if the trust value of both the sensors i.e. first and additional sensor is same but it is less than threshold then water pollution accident is confirmed.

But if the trust value of first sensor is less than the second sensor and the trust value of first sensor is less than threshold too then first sensor is a faulty sensor is confirmed. Or else if the trust value of second additional sensor is less than the first sensor and it is less than threshold too then second additional updated.

In this way the data from the sensors are examined and abrupt events are detected and recognized.

IV. Conclusion

There are two types of abrupt events in water monitoring system. In order to recognize the abrupt event accurately, a novel approach based on KPCA and SVM method has been introduced. Moreover, a trust mechanism is introduced make quick, accurate diagnosis and use of few sensors as possible.. In the approach use of one additional sensor for each type of parameter, is introduced for increasing accuracy of the result. The approach is suitable for various situations, such as abrupt sensor fault and water pollution accident.

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