# UAV Assisted Automated Remote Monitoring and Control System for Smart Water Bodies

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***Abstract*— Water is a scarce resource and hence it should be used efficiently in all aspects. Water bodies like dams, lakes, ponds play major role in storing and distributing the water in efficient manner. Stored water is used for drinking purpose, agriculture irrigation, electricity generation, etc. Sometimes excess storage of water causes flood during heavy raining season and kills valuable resources including human life. This mandates that the water bodies should be frequently monitored and controlled for the benefits of mankind. Water body monitoring involves the quantity and quality of water stored, input and output water flow through inlet and outlet shutters respectively, condition of the inlet and outlet shutters, condition of the channels carry the water to oceans during flood, etc. Conventional manual monitoring of water bodies consists several disadvantages including high manual overhead, low accuracy and excess time in measurements, high communication delay, high cost, life threatening risks during measurements, etc. The objective of the proposed work is to automatically monitor and control the smart water bodies to sort out the disadvantages of conventional monitoring. The proposed system consists of Remote Monitoring and Control Station (RMCS), Field Control Unit (FCU), Patrol Unmanned Aerial Vehicle (PUAV), different floating sensors like rainfall sensor, water quality sensor, inlet and outlet shutter interfaces, alarms. The proposed system is able to monitor the water body frequently and prepares accurate report that includes quantity of water, rainfall rate, input and output water flow rate, quality of water like existence of any poisonous chemical contents, working condition of the inlet/outlet shutters, etc. This report is quickly sent to the RMCS for further actions. The RMCS can pull the complete report or any particular information on demand. Further the RMCS processes the report to extract the knowledge for further actions like opening/closing shutters, replacing damaged sensors, directing PUAVs to capture the pictures, sending messages to field officials and operators, etc. As a whole, the proposed system significantly reduces the manual overhead, cost, time required to measure/check various factors while increasing the accuracy of measurements and enables the remote monitoring unit to monitor and govern the water body in all aspects.**

***Keywords: Smart water body, UAV, remote monitoring system, water quality, water quantity.***

## I. INTRODUCTION

Water is essential to health, social and economic development. Over 70% of the earth's surface is covered by water. The oceans account to about 97 percent of Earth's water, only the rest three percent is freshwater. 70% of the world wide water is used for irrigation, 22% for industrial purposes and 8% for domestic purposes. There are several disputes that exists between countries and states over the sharing of water resources. Few of the notable conflicts are Jordan River conflict among Israel, Lebanon, Jordan and the State of Palestine and Kaveri river conflict between the two Indian states of Tamil Nadu and Karnataka.

Water body is any significant accumulation of water, generally on a planet's surface. The term most often refers to oceans, seas and lakes. Water bodies should be managed to avoid problems such as water scarcity, floods and to maintain water quality. Poor management of water bodies leads to floods, quality of water may be decreased. Measuring water quality, amount of water coming through inlet and outlet shutters, condition of the reservoir shutters are challenges in water body management.

The main disadvantage of manual monitoring systems is that they can be highly labor-intensive to operate. It relies heavily on the actions of people, which increases the possibility of human errors. Manual monitoring does not give accurate results and also leads to more delay in processing and making decisions. It is impossible to collect data frequently in manual monitoring. There may also happen loss of life during manual measurements.

An UAV assisted remote monitoring and control system is proposed in this paper to sort out the drawbacks and limitations of the conventional management of water bodies. The section II gives the reviews on conventional strategies of water body management and development of UAVs. The proposed system architecture is given in the section III. Section IV gives the data flow diagram of the system. Section V compares and discusses the conventional and proposed schemes. The concluding remarks is given in section VI.

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## II. RELATED WORKS

Manual monitoring for water quality involves setting water quality monitoring objectives, assessment of available resources, reconnaissance survey, sampling and laboratory work. The overall objective is to obtain clear knowledge of the issues, relevant background information, dynamics and characteristics of water systems. The availability of equipments like sampling equipment, trained manpower in adequate number, chemicals/glasswares and other gadgets for analysis etc should be assessed.

In manual monitoring it is not possible to get data regularly and accurately. Information collected such as water quality, shutter condition, leakage are not accurate in manual monitoring. Authorities will never get the correct information on time. This will cause very severe consequences in critical situations. Existing systems are not sufficient to handle these issues. These flaws can cause dangerous consequences like flood. The authors [1] introduced the methods and processes for remote sensing monitoring of flood disaster, which includes the methods of extracting basic water body and the process of remote sensing analysis of the flooded areas. A cloud based system is proposed [2] to manage the flood, where the sensor nodes are distributed across many regions of water bodies at different locations to monitor the rainfall rate and water level. This information is frequently collected and processed to take counter actions to handle the flood.

An automatic multi-agent system based dam safety management is proposed [3] by providing an efficient aggregating of different sensor data values from four different software agents, structure monitoring agents, data manager agents, application agents and user interface agents. If one of these system fails to operate or reports false alarm, the triggering information would lead to multiple-retransmissions of sensor data with high energy consumption.

The authors in [4] investigated the development of a novel water detection algorithm based on imaging spectroscopy data, where the diagnostic features for surface water are identified. Water quality plays vital role in many applications like drinking water supply, agriculture as they influence human health. A novel method of monitoring the dissolved oxygen in rivers is proposed in [5]. A low-cost optical sensor for monitoring the aquatic environment is developed [6], which is autonomous, environmentally robust, easily deployable and simple to operate. This system gives qualitative data. A water grade monitoring system using fiber optics to continuously monitor multiple water related parameters is developed [7], where the system can detect the changes in parameters of the river-water parameters continuously for long distances and alert the authorities if necessary.

Over the recent years, UAVs have been tremendously increased in many commercial applications like search and rescue operations, disaster control, surveillance, tracking of vehicle movements and other environment monitoring aspects. As the technology advance, UAVs have been equipped with high end gadgets in measuring the water quality in ocean level with various acquisition such as oxygen, soil moisture, temperature etc. Recently, UAVs has been designed and developed to carry out information sharing of navigation, orientation for localization and sensing payloads from source to another wireless communication device mounted over them. Authors [8] developed a novel method to analyze a solar-electric, high-altitude, long-endurance, unmanned aircraft to improve the flight-time of UAVs. The authors [9] have addressed Light Detection and Ranging (LIDAR) an active remote sensing method for monitoring and management of water body via airborne LIDAR which has been successfully employed in dynamic evaluation of soil erosion, river mapping etc. This airborne LIDAR technology can be used to monitor and manage area of water blooms in water bodies. Compared with ordinary light, LIDAR is monochrome has good direction, coherency etc. Using LIDAR to measure distances can improve the reliability and accuracy when compared with field sampling and laboratory analysis. [10] discusses the evolution and state-of-the-art of the use of Unmanned Aerial Systems (UAS) in the field of photogrammetric and remote sensing.

## III. SYSTEM ARCHITECTURE

The proposed system consists of floating sensors and a Patrol Unmanned Aerial Vehicle (PUAV) to periodically monitor the various parameters of the water bodies like water level, water flow, water quality, water body capacity etc. The sensor data are sent to the Remote Monitoring and Control Station (RMCS) for further actions. The Field Control Unit (FCU) coordinates the flow of data from PUAVs to the RMCS. The Alarm System triggers an alarm when the parameters vary above the threshold and the Automated Shutters are initiated. All the Sensor data are stored in the Smart Water Body Cloud. The Remote Monitoring and Control Station has a GUI through which Alarm system and PUAV operations can be controlled. The system architecture of the proposed system is shown below in Figure 1.

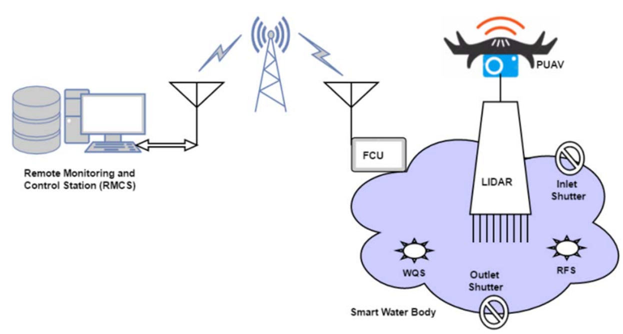


Fig 1: The Proposed System Architecture

Sensors are used to measure the vital parameters of the water body like water level, water flow and water quality. The sensors RFS (RainFall Sensor), WQS(Water Quality Sensor) and WFS (Water Flow Sensor) are deployed in the water body. The PUAV (Patrol Unmanned Aerial Vehicle) uses LIDAR technology to find the water level, capacity of the water body etc. These data are transmitted from PUAV to the Field Control Unit (FCU).

Field Control Unit is connected with various sensors such as water quality sensor, rainfall sensors, water flow (both inlet and outlet) sensor, etc using wireless communication. The PUAV is directed to fly over the water body to measure the depth and to capture the images of various locations. PUAV fitted with LIDAR is made to fly over the water body in order to measure the data related to water body such as depth of the water body, volume of water body etc. The ideal power supply for UAV is Lithium-Polymer batteries, which can provide continuous power for more than two hours. The PUAV is controlled by the Ground Control Station (GCS) and guided by the Global Positioning System (GPS) based waypoint navigation. The trajectory of the PUAV is loaded into the PUAV, so that it can follow the defined path using GPS and compass. The PUAV collects the data and aggregates it. After completing the Data Aggregation process it is stored in FCU Database. The aggregated data is then sent to the RMCS through wireless link.

Remote Monitoring and Control Station receives the raw sensor data from the Field Control Unit through wireless communication. It preprocesses and validates the collected data. Then the validated data is classified and transformed into knowledge. The transformed knowledge about the water body is stored in the Water body Knowledge Database. The Monitoring Unit of RMCS continuously checks the sensor data from the Water body Knowledge Database with the predefined standard values. If the measured value is greater than threshold value then it sends a report to the Operation and Control Unit of RMCS. It notifies the FCU to trigger the Alarm and send information to the field workers. The Shutter Operation and Control Unit of the FCU automates the necessary opening and closing of the shutters through a motor, which is connected to a power supply. RMCS sends information to the field workers such as shutter opening, shutter closing, condition of the shutters etc through SMS/Call.

## IV. WORKING OF THE SYSTEM

The proposed system works as follows. The sensors deployed in the water body monitors the critical parameters like rainfall rate, input water flow, output water flow, water quality, etc. Similarly in a well defined interval, the patrol UAV flies over the water body and measures the volume of the water body using LIDAR sensor. Also the PUAV takes pictures of the water body. The information collected by all sensors and PUAV are aggregated in FCU. The block diagram of the proposed system is given in Figure 2.

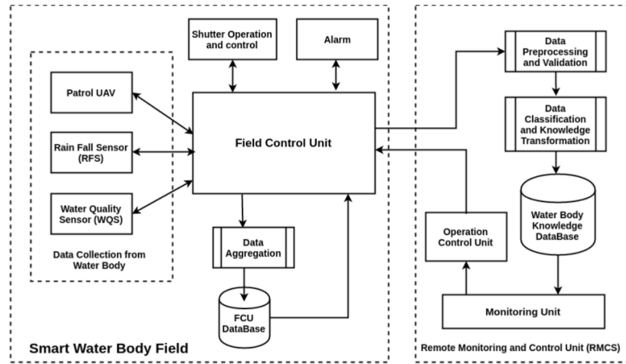


Fig 2: Block Diagram of the Proposed System

The raw sensor data which is aggregated in the FCU is stored in the FCU database. The aggregated data is sent to the Remote Monitoring and Control Station in regular intervals through wireless communication. The data received from FCU is preprocessed and validated. Then the validated is classified and transformed into knowledge in the RMCS. The transformed knowledge about the water body is stored in the water body knowledge database. This knowledge is used by monitoring unit. The monitoring unit continuously checks if the acquired data exceeds the threshold. The monitoring unit consists of a GUI to display the data received from the Field Control Unit (FCU) and control the operations of PUAV, inlet/outlet shutters through motors, and the Alarm System. Based on the received data, if the parameters are above the threshold value the Alarm system is initiated thereby alerting the field workers and avoiding the human risks.

## V. COMPARISON OF CONVENTIONAL AND PROPOSED REMOTE MONITORING SYSTEM OF WATER BODY MANAGEMENT

The proposed system brings more advantages in all directions in the smart water body management domain. Table 1 gives the comparison between both the proposed and conventional schemes of water body management.

TABLE 1 : COMPARISON OF CONVENTIONAL AND PROPOSED REMOTE MONITORING SYSTEM

| **Performance Metrics** | **Conventional Strategies of Water Body Management** | **The Proposed Automated Remote Monitoring and Control System** |
|---|---|---|
| Manual Overhead | • Needs lot of manual intervention for measuring water quality, operating inlet/outlet shutters, locating the blocks, measuring depth in various locations, taking pictures, etc.<br>• It needs well trained field workers. | • Different types of sensor like water quality sensor, rainfall sensor are deployed.<br>• Shutter controls are operated using remote control system.<br>• PUAVs are directed to capture the images and measure the depth at different locations. |

| | | |
|---|---|---|
| | • Higher officials are highly depending on the field workers to observe the critical parameters. | • These components significantly reduce the manual overhead and save human life. |
| Risk Factor | • High risk in sending field workers to take these measurements in bad weather conditions and during night time.<br>• It causes loss of human life. | • The sensors can be queried at any time to observe the status of the critical parameters.<br>• The PUAV can be directed at any weather condition to capture the images at any location in the water body.<br>• These components saves human lives. |
| Frequency of Data Collection | • It is really tedious to send field operators often to take the measurements.<br>• The availability of well trained field workers will not be sufficient always and hence this affects the frequent monitoring. | • The PUAV flies in well defined interval to to capture the picture and measure the depth/blocks.<br>• Similarly the sensors can measure the parameters in well defined intervals.<br>• This considerably increases the frequency of monitoring without the involvement of the field workers. |
| Accuracy of Observation | • Most of the time, the manual measurements and readings reduces the accuracy of the parameter values like quality of water and its chemical contents.<br>• Manual data entry process produces considerable amount of mistakes and take more time.<br>• This requires lot of verification by the concern authorities. | • Sensors and PUAVs collects data with improved accuracy.<br>• Automated data storage reduces errors and saves time.<br>• Automated data preprocessing and validation processes improves the accuracy of the data observed and enables the RMCS to take accurate decisions. |
| Time Required for Observation and Data Transmission | • Usually field workers use boats to reach all/particular location to make the readings.<br>• This process takes lot of time for the field workers depends on the distance.<br>• Also the observed values take lot of latency to reach the authorities as both the field and control station are geographically separated by larger distance.<br>• This latency causes delay in taking critical decisions and will have bad consequences. | • PUAV takes relatively less time than the boat rides and completes the tasks in less time.<br>• Similarly sensors transmit the data to the FCU quickly over the wireless links.<br>• This reduces the field observation time and collects the data quickly.<br>• Also the FCU automatically transfers the collected data to the RMCS in less time (whether in defined interval or triggered by any critical event like sudden damages in shutters)<br>• This helps the RMCS to take decisions quickly to avoid the dangerous consequences. |
| Cost | • Well trained field workers (eg. trained swimmers) are required.<br>• Frequent field observation increases the cost.<br>• Human loss causes troubles to the government. | • Only installation cost of the system will be huge.<br>• Once installed, the operation and maintenance cost will be considerably lower than the conventional system. |

From the above table, it is observed that the proposed system outperforms the conventional system by reducing the manual overheads and risks, increasing the frequency of field observation, improving the accuracy of critical parameter readings, reducing the time required for both data collection and transportation, reducing the cost requirements and improving the decision making capability of the monitoring and control station.

## VI. Conclusion

A novel remote monitoring and control system is proposed to monitor the water body frequently to observe the critical parameters like quantity of water, rainfall rate, input and output water flow rate, water quality, working condition of the inlet/outlet shutters, etc. This information is quickly reported to the RMCS for further actions. The proposed system also enables the RMCS to pull the critical parameters on demand. Further the RMCS processes the observed field data to extract the knowledge for further actions like opening/closing shutters, replacing damaged sensors, directing PUAVs to capture the images, sending messages to field officials and operators, etc. As a whole, the proposed system significantly reduces the manual overhead, cost, time required to measure/check various factors while increasing the accuracy of measurements and enables the remote monitoring system to monitor and govern the water body in all aspects.

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