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Design and fabrication of 3D printed Acrylonitrile Butadiene Styrene (ABS) dam automation structure with integrated flood monitoring system using data analysis and computation techniques

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Abstract.
In general, the natural catastrophic event causes damage to the life and economy. The proposed work focuses on forecasting of flood using Internet of Things (IoT). The correlation techniques for multivariate datasets acquired from sensors have been used for better flood forecasting scheme. The flood forecasting system incorporates monitoring features, such as, water level of dam, humidity, water flow and rate of rainfall. These parameters are to be analyzed to monitor and control the release of water from the dam at moderate rate in advance to avoid any losses on downstream due to the flood. The datasets are collected by the Wireless Sensor Network (WSN) via PLC. The sensor information can be analyzed using correlation techniques and system creates an alert to the people community, dam authorized person through siren, alert message using a smart communication device and IoT dashboard. The analyzed result can be appended to show a considerable development over the current existing methods. The manual gate control mechanism results in the insufficient supply of water due to the flow of excess water and human errors which leads to failure in monitoring and controlling the opening and closing of shutter. The water leakage in dam is due to poorly sealed pipes or the improper concrete structure. The designed flood control system was intended to acquire the real time data for flood prediction by correlation techniques for integrated PLC and servo based control of dam and canal shutter instantaneously without any time lag. Further, the webpage and mobile application can be created in which the data could be monitored frequently by the officials and the people who live in that locality thereby creating an alert.

Keywords: Wireless sensor networks, Correlation method, Data analysis, Automation and PLC based servo control, Internet of Things (IoT).

1 Introduction

A dam is constructed mainly for irrigation, flood prevention and power generation. More than 2.3 billion people were facing severe crisis due to flood in the last 20 years. On the other hand, due to unplanned opening of dam's water, scarcity goes on increasing. Comparatively, there are numerous reports showing the rapidity of increase in domestic and industrial demand for water, apart from agriculture. The rapid growth in demand for water will occur in the countries with developing or emerging economies [1]. The energy production through hydro power plants is one of the best renewable green energy sources. Globally, the hydroelectric power plants have a combined capacity of 6,75,000 MW that generates over 2.3 trillion kilowatt-hours of electrical power every year, supplying 24% of the world's electricity. It is essential to uphold the speed of the turbine for achieving a good efficient model [2]. In order to prevent flooding, the shutter level should be maintained based on the prior prediction of flood from several scenarios, such as, rainfall in water catchment areas, water level in dams and allowing calculated amount of water through canal branches. The study proposed to forecast the river flow using ANN model and validated the accuracy on upstream locations. These approaches have been evaluated to predict the flood at Dongola station [3]. The repetitive flood damage is to be protected by nomograph based flood forecasting method for saving human lives from real time rainfall analysis [4]. The research proposed IoT based smart flood monitoring and forecasting architecture by combining big data and HPC.

2 Literature Survey

The K-mean clustering algorithm tends to predict the status of flood, and the forecasting has been carried out using Holt-Winter's method [5]. EnjiSun et. al. [6] discussed the real-time monitoring of the inundated line, confiscated water level and deformation of dam. IoT based monitoring of dam safety to provide safety alert information during critical weather condition was discussed. The manual system is lagging in terms of speed of the process. In order to open or close the shutter, the traditional methodology involves getting access from ministry, communication between ministry and control room, manual calculation of water quantity allowed in each canal and so on. For eliminating the above-mentioned problems, an automated system would be the ultimate solution. The issues in the current system tell that the advanced development of automated unit would provide regular control over every process in a dam [7]. The most critical challenge in automation system is gathering the information about the individual process in each section of the dam set-up. The increase in water level and inrush flow of water in the dam due to rainfall will damage the routine life of the habitants. In order to avoid the damage, IoT dashboard creates an alert to the surrounding people through SMS (short message service) which can help people to evacuate from the place thereby preventing the loss of life. The developed application can be useful to assist the people to check the water level, rainfall, and flow rate in the dam. The data science management can predict the flood using appropriate data in the cloud computing. The officials can see the level of water and can schedule the opening of shutter accordingly.

The proposed system is to design an intelligent control system for automation of dam and shutter gate integrated with flood monitoring system for preventing the in-rush flow of water during flood by analyzing the sensor data using correlation method. This system uses an IoT technology to incorporate the details regarding dam, canal and flood monitoring areas with visualization of sensor data and timely prediction of flood by analyzing the parameters, such as, level, water discharge (inside and outside dam areas) and rainfall.

3 Methodology

The digitization of automation process is to be effectively included in the dam automation with integrated flood forecasting system that infers the real-time data from which the statistics can be analyzed by correlation method based on the information stored using cloud computing. The IoT device communicates with all other devices to exchange the information remotely thereby monitoring and controlling the process. The cloud computing technology provides a platform to access the stored information about the products for monitoring and analyzing. It gives feedback to the Dam Automation System through API. The flood forecasting system involved in our prototype offers frequent monitoring of dam water level, outflow of water, temperature & humidity with the help of ultrasonic, humidity, rainfall and flow sensor. The data from all the sensors will be investigated and appropriate relationship will be established using data analysis method. The flood prediction system will determine the occurrence of flood for controlling dam shutter in an automated manner. The habitants near the dam are alerted by sending updates in the case of high out flow of water from dam. This process ensures the prevention of life due to natural disasters. The flood can be predicted by the data retrieved from the sensors. This can be used by data science management structure as shown in Fig.1.

In the case of real time implementation of the process, the use of LIDAR sensor is exercised for monitoring the water level. The LIDAR sensor is used for surveying method which calculates distance by transmitting laser light and measuring reflected light with sensor. The surface temperature is to be measured with the help of STS-51 (Thermistor). The temperature and humidity can be measured in a real-time manner using Thermo-Hygrometer.

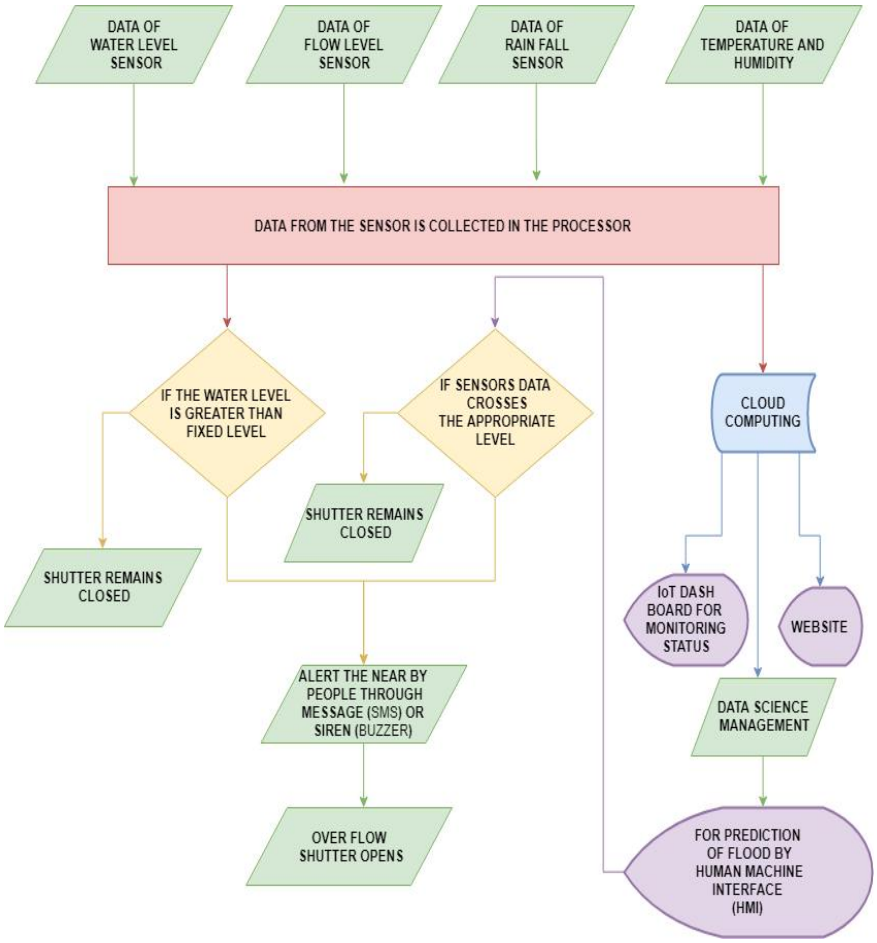


Fig. 1. Data science management structure

3.1 Conceptual design

The retrofit sensors are provided to the system in an appropriate manner. The data from the respective sensor is collected by the PLC and then pushed into the cloud using MODBUS communication. Using big data analysis, the correlation method is executed for processing the collective datasets from variant sensors for prediction of flood. The data related to flood prediction is to be read by the PLC using RTU protocol which gives input the servo-drive to control the position for stabilizing the outflow of water from dam and canal within the appropriate response time. The system has to send an alert through GSM module. The data retrieved from the cloud is used for predicting flood, creating alert and controlling dam shutter. The entire

process is to be monitored by web dashboard and mobile application. Fig 2 shows the conceptual design of the proposed system.

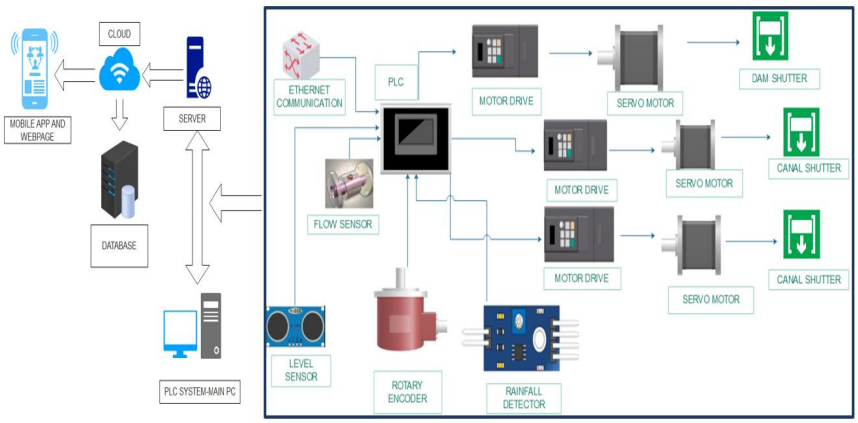


Fig. 2. Conceptual design of dam automation and flood monitoring system

4 Experimental setup

The IoT based dam automation and flood monitoring system is incorporated with the features, such as, self-monitoring and intelligent alerting. The sensors used in the prototype are ultrasonic sensor for water level measurement, raindrop sensor for measuring the rainfall, and temperature & humidity sensor for forecasting the weather, and flow sensor to calculate the outflow of water from the dam. The data from various sensors are to be analyzed using correlation method for predicting the occurrence of flood. The structure shown in Fig.3 is made of Acrylonitrile Butadiene Styrene (ABS) using rapid prototyping. ABS is amorphous and therefore has no true melting point, it is insoluble in water. The ABS material is recyclable and eco friendly. It holds pressure up to 450 psi. The conceptual design was made using SolidWorks, and the model is made using rapid prototyping in the form of injection modeling technique.

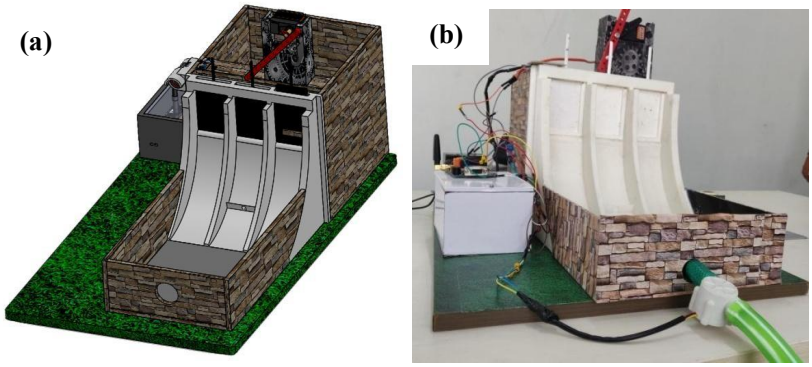


Fig. 3. (a) CAD design (b) system structure with retrofit sensors and control system

4.1 Mechanism for shutter control

The link 1 rotates in circular path in which link 2 is connected. When servo motor is actuated to rotate link 1, it makes the link 2 to move in translated path. The dam shutter is fixed to link 2 in an inclined manner. When link 2 translates, it makes the shutter to open. It receives feedback from data analysis system based on flood prediction method. When the desired distance is achieved, the motor actuates and opens the shutter.

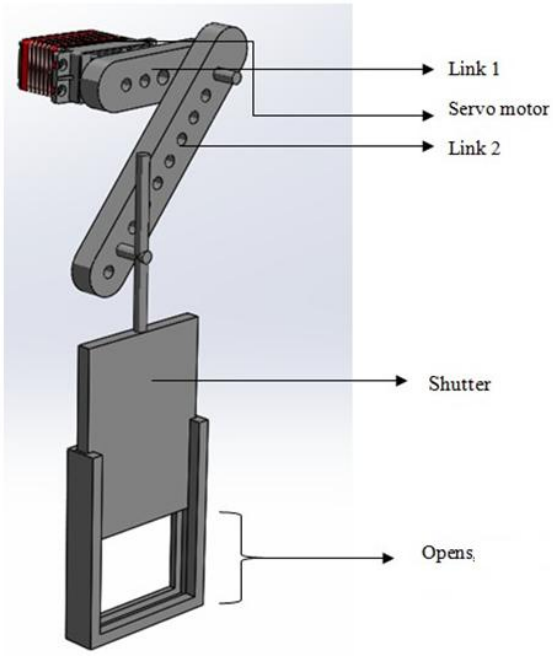
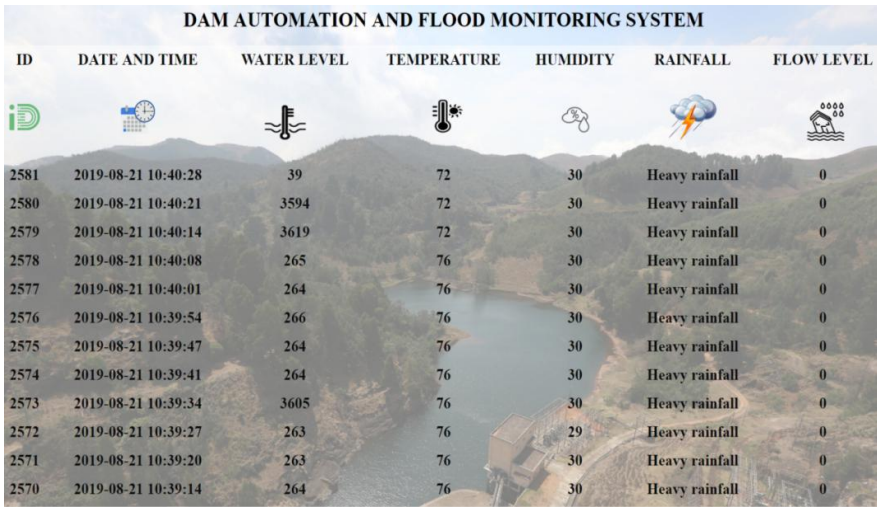


Fig. 4. Shutter control mechanism

4.2 Implementation of IoT and Data analysis

Mobile app & web – page. The mobile application is developed for android users made from an algorithm for viewing the real time update of the retrieved data. Google firebase cloud system can be used for data retrieval and authentication. The data acquired is stored in our firm's server and they are uploaded to mobile application which is used for monitoring. The mobile application consists of a login page incorporated with an introduction panel for real time data visualization which is updated for every 7 seconds from PLC as shown in Fig.5.



DAM AUTOMATION AND FLOOD MONITORING SYSTEM

ID	DATE AND TIME	WATER LEVEL	TEMPERATURE	HUMIDITY	RAINFALL	FLOW LEVEL
2581	2019-08-21 10:40:28	39	72	30	Heavy rainfall	0
2580	2019-08-21 10:40:21	3594	72	30	Heavy rainfall	0
2579	2019-08-21 10:40:14	3619	72	30	Heavy rainfall	0
2578	2019-08-21 10:40:08	265	76	30	Heavy rainfall	0
2577	2019-08-21 10:40:01	264	76	30	Heavy rainfall	0
2576	2019-08-21 10:39:54	266	76	30	Heavy rainfall	0
2575	2019-08-21 10:39:47	264	76	30	Heavy rainfall	0
2574	2019-08-21 10:39:41	264	76	30	Heavy rainfall	0
2573	2019-08-21 10:39:34	3605	76	30	Heavy rainfall	0
2572	2019-08-21 10:39:27	263	76	29	Heavy rainfall	0
2571	2019-08-21 10:39:20	263	76	30	Heavy rainfall	0
2570	2019-08-21 10:39:14	264	76	30	Heavy rainfall	0

Fig. 5. Data visualization of monitoring system

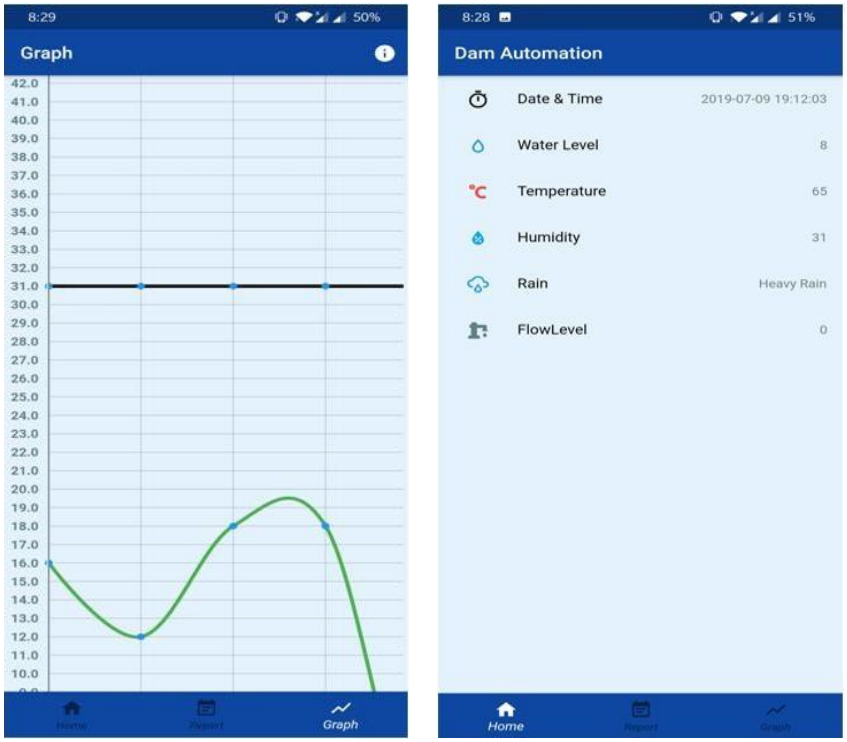


Fig. 6. Graph visualization in mobile applications

It tends to provide a graphical representation of the stored data in the form of analytical data as shown in Fig.6. The webpage holds the data, such as, date, time, water level, temperature, humidity, and rainfall. It was developed using HTML program for scaling the background of the work. Fig 7 shows the IoT dashboard for creating and importing the report of dam with its appropriate details for the particular period.

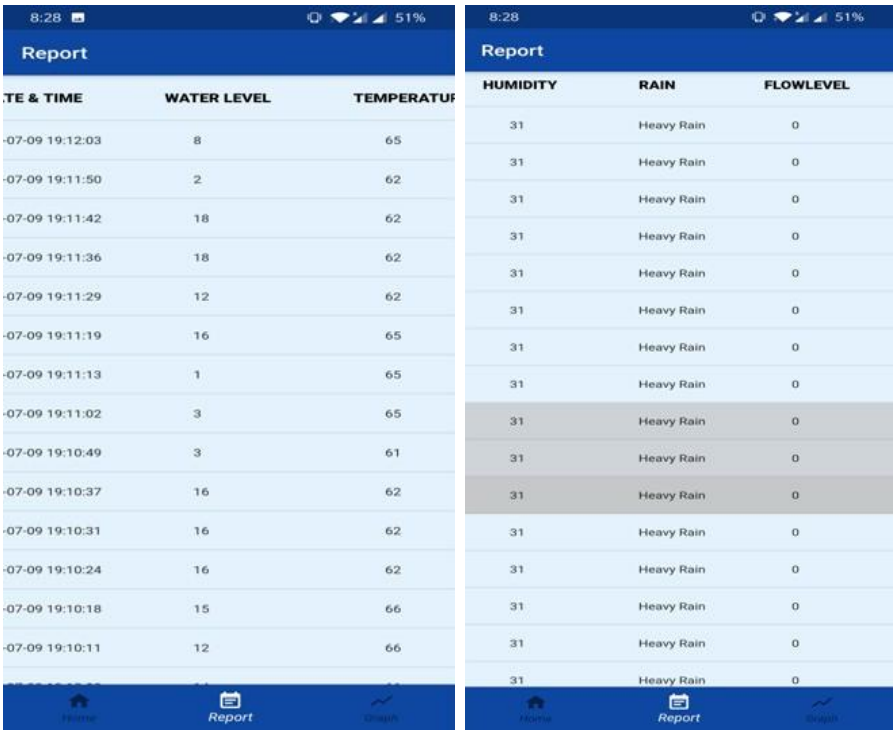


Fig. 7. Report generation in IoT dashboard

Correlation based data analysis. The correlation method of data analysis is a statistical technique for making relationship among the time related multi variable data sets captured from various sensors. The multivariate data sets provide appropriate information for predicting the occurrence of flood. In this method, the temperature is independently varying with humidity; water level is dependently varying with inlet flow to the dam. Rainfall is also dependent with respect to temperature and humidity. The correlation infers the variation in one parameter related to the other. The variation tells the forecasting of flood based on collective data sets from different sensors. This method is used to quantify the association between two continuous variables between three dependents, such as, rainfall, water level, water flow, and independent variables such as temperature and humidity. The correlation data are marked with different color indications by mentioning proper weightage as shown in Fig. 8. The correlation points are strongly associated in the range 0.5% - 6% and 21% - 22% of water level with 0 to 10% of water flow which was shown in x and y axis functions for the prediction of flood. Fig 9 shows the percentage of variation of flood during various seasons in every year.

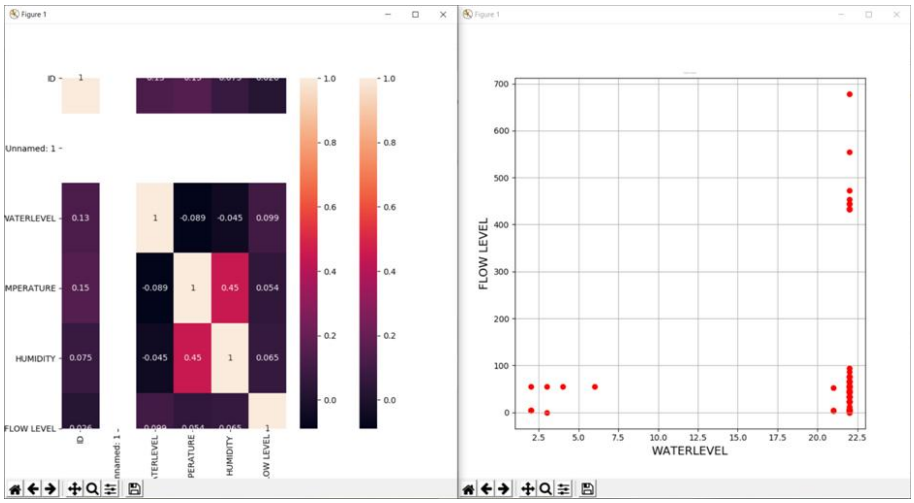


Fig. 8. graph visualization in IoT dashboard

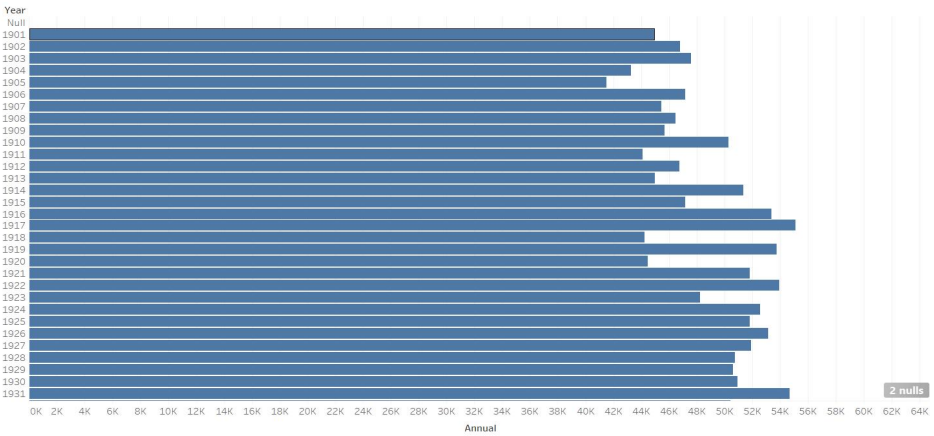


Fig. 9. analysis of data in Tableau

5 Conclusions

The data is made available on the webpage after retrieving it from the cloud storage. It helps in executing the analysis and prediction of flood based on correlation method of multivariate datasets. After utilizing the proposed system, it is having the facility to control or monitor the dam's shutter prior to the occurrence of flood based on forecasting. The IoT technology is implemented to visualize the dynamic changes in data sets. It creates an alert and provides possible control over the flow of water to prevent flood. Furthermore, this system can run without any human intervention, and an alert system is incorporated which will be helpful in the case of emergency situation. Based on the implementation of the data analysis approach, the system is able to predict the occurrence of flood through information acquired from the database about the environment for a period of 5 years.

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