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RASPBERRY-PI BASED DAM DATA COLLECTION AND MONITORING SYSTEM TO MAINTAIN THE SAFETY ASPECTS

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***Abstract* — In this paper we focus on harnessing Raspberry-Pi Microcontroller in monitoring and manage the dams. Large dam are of many importance, primarily because of their use for generating electricity, but risk which is associated with it should be greatly taken into account. There is a need to daily updated information related to the dam status in order to use for dam management. An information system has been invented based on the existing systems, allowing utilization of wireless sensor networks.**

The goal of this paper is the use of Raspberry-Pi Microcontroller within a specific system for dam safety purpose. The system must provide real time alerting in case of security parameters varies from the expected values. In the world thousands of dams are there, so security must be monitored. It is of major importance due to the fact that the collapse to such dams can harmful the millions of people. The continuous monitoring of dams via sensors and prevention the problems through prediction are of vital importance for the safety of dams.

This paper presents a system evaluation for wireless sensor network based Dam safety monitoring to validate the efficiency.

Index Terms*—*Raspberry-Pi Microcontroller; Dam safety monitoring

I. INTRODUCTION

At present, the dam safety monitoring information management system and the expert system function become increasingly powerful. But India is still in the middle or even lower level compared with developed countries, so the need for a dedicated automatically monitoring system using the advanced network technology, database security technology, security monitoring technology theory, is urgent. The system will automatically monitor the dam safety, analyze the real-time measured data and manually observed data, monitor the real-time dam operating status, and make the accurate, efficient assessment and decision to ensure the dam safety. Instrumentation consists of the various electrical and mechanical instruments or systems used to measure pressure, flow, movement, stress, strain, and temperature. Monitoring is the collection, reduction, presentation, and evaluation of the instrumentation data. Instrumentation and monitoring are tools that must be used with a vigilant inspection program to continually evaluate the safety of dams. Overtopping from inadequate spillway capacity, spillway blockage, or excessive settlement resulting in erosion of the embankment;

- Erosion of embankments from failure of spillways, failure or deformation Of outlet conduits causing leakage and piping, and failure of riprap;
- Embankment leakage and piping along outlet conduits, abutment interfaces, contacts with concrete structures, or concentrated piping in the embankment itself;
- Foundation leakage and piping in pervious strata, soluble lenses, and rock discontinuities;
- Sliding of embankment slopes due to overly steep slopes, seepage forces, rapid drawdown, or rainfall;
- Sliding along clay seams in foundations;
- Cracking due to differential settlements; and
- Liquefaction.

II. OBJECTIVES

The objective of this paper is to develop a system which will automatically monitor the dam safety parameters and generate Alerts/Alarms or take intelligent Decision by the Raspberry Microcontroller using concept of IoT and also design the system to take Intelligent Decision and Control Devices.

The purpose of instrumentation and monitoring is to maintain and improve dam safety by providing information to

- Evaluate whether a dam is performing as expected.
- Warn of changes that could endanger the safety of a dam.

The causes of dam failures and incidents have been catalogued (ASCE 1975 and 1988, Jansen 1980, National Research Council 1983, ICOLD 1992). The common causes of concrete dam failures and incidents are:

- Overtopping from inadequate spillway capacity or spillway blockage resulting in erosion of the foundation at the toe of the dam or washout of an abutment or adjacent embankment structure;
- Foundation leakage and piping in pervious strata, soluble lenses, and rock discontinuities; and
- Sliding along weak discontinuities in foundations.

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III. Existing System

Instrumentation and monitoring, combined with vigilant visual observation, can provide early warning of many conditions that could contribute to dam failures and incidents. For example, settlement of an embankment crest may increase the likelihood of overtopping; increased seepage or turbidity could indicate piping; settlement of an embankment crest or bulging of embankment slopes could indicate sliding or deformation; inelastic movement of concrete structures could indicate sliding or alkali-aggregate reaction. Conversely, lack of normally expected natural phenomena may also indicate potential problems. For example, lack of seepage in a drainage system could indicate that seepage is occurring at a location where it was not expected or contemplated by the designer.

Instrumentation and monitoring must be carefully planned and executed to meet defined objectives. Every instrument in a dam should have a specific purpose. If it does not have a specific purpose, it should not be installed or it should be abandoned. Instrumentation for long-term monitoring should be rugged and easy to maintain and should be capable of being verified or calibrated. Instrumentation typically provides data to:

- Characterize site conditions before construction;
- Verify design and analysis assumptions;
- Evaluate behaviour during construction, first filling, and operation of the structure;
- Evaluate performance of specific design features;
- Observe performance of known geological and structural anomalies; and
- Evaluate performance with respect to potential site-specific failure modes.

Installation of instruments or accumulation of instrument data by itself does not improve dam safety or protect the public. Instruments must be carefully selected, located, and installed. Data must be conscientiously collected, meticulously reduced, tabulated, and plotted, and must be judiciously evaluated with respect to the safety of the dam in a timely manner. A poorly planned program will produce unnecessary data that the dam owner will waste time and money collecting and interpreting, often resulting in disillusionment and abandonment of the program.

The most common type of failure of embankment dams is overtopping. It may occur for different reasons such as: excessive inflows into the reservoir due to heavy rainfalls or the failure of upstream reservoir, landslide into reservoir, extreme waves and surges, inadequate design structure and maintenance of the structure, debris blockage of outlet or spillway and flood channel, and settlement of the embankment crest.

On 20 October 1982 when the dam was still under construction but almost completed, heavy rain occurred in the river Jucar basin close to Tous dam. Heavy rain quick-ly filled the reservoir up to 600 hm3 that exceeded its capacity. The estimated inflow was 5000 m3/s and the gates of the spillway had to be opened. The electric network was out of order, as it usually happens due to such weather conditions, and one of the gates was under repair and the other could not be started. It was even impossible to raise them manually.

The overtopping started at 17:00 p.m.; the water rose 1.10 m above the crest at 19:15 p.m. After 16 hours it was clear that gates were not able to operate and the dam was overtopped. within 1 hour it was washed out by erosion of a greater part of shoulders and central core.

The dam break wave overflowed already filled river bed ad its floodplain. Peak dis-charge was estimated at 1500 m^3/s. The wave flooded a populated area of about 300 km2, where 8 people lost their lives and huge damage was estimated.

A new Tous dam was reconstructed on the same site using remaining part of the clay core material, which had proved significantly high resistance to water flow.

According to investigation of the Public Service Commission established after the failure, it was stated that the cause was deficiency in the control system of the upper reservoir water level during filling phase: a computer software problem caused the reservoir filling even though it was already at its maximum water level. The overtopping was inevitable and a rapid increase in pore pressure at the dike/foundation interface brought to the failure. The owner's decision to continue operating Taum Sauk after the discovery of the unreliability of the piezometers readings, upon which the upper reservoir control system was based, was considered very imprudent.

No casualties were reported; nevertheless the breach produced significant property and environmental damage. The lower reservoir accommodated a huge amount of the flood, avoiding damage to a larger extent. The upper reservoir was replaced with a roller compacted concrete dam together with changes in the safety management structure for the whole system.

IV. Proposed System

A. *Overview*

There are thousands of dams in the world, the security of which must be monitored. It is of vital importance due to the fact that the damage to such dams can harm millions of people and cause the loss of cultivated areas.

A Dam is usually kept partially full, even if it has large capacity. So, when it rains heavily or there is a big snow melt-off, a large amount of water can be occupied in the dam and released slowly downstream. If the dam hadn't been there, a large amount of water could have rushed down the rivers and flooded downstream. Dams can steady the water levels of rivers and seas. When water increases to a dangerous level and is not monitored by the authorized person and then dam failure can cause potential disastrous damage to life and property.

However, if the authorities always know the current status of the water level this condition can be prevented. Therefore a technology needs to be developed to implement this problem and making the system more organized. Therefore, water level indicator designing is one of the technological advancement to transmit data and received by authority for controlling. If water level increases to dangerous level, the

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systems also give an alert to authority to take immediate action.

Instrumentation in dam is necessary for verification of design assumptions, construction technique & modifies design. Data collected from instrument can be extremely valuable in determination of specific cause of failure. By instrumentation constant watch over the performance of the structure during service & obtain timely warnings in respect of distress spots. Safety in dam can be assist by instrumentation.

Also different sensors are deployed in various clusters of the dam then the various parameters like

1. Water level,
2. Pressure on the wall of dam
3. Vibrations on the dam wall
4. Water flowing out from the dam through main pipe line i.e. flow rate of water.
5. Sensing of the pipeline leakage that to with approximate location can be sensed and the information regarding the concern parameter be made available to the observer at a glance.

During both the extreme conditions like water scarcity and excess water and even normally monitoring the dam i.e. safety parameters and water management is very necessary. In the modern age the dam safety needs to be based on physical parameters and supported technically. IoT (Internet of Things) plays a vital role in meeting the above requirements and can make available the online information about both the parameters to the remote operator. Generally the dams and the water management are monitored through traditional surveillance techniques except the water level in some of the dams which is atomized.

If the different sensors are deployed in various clusters of the dam then the various parameters like 1. Water level, 2. Pressure on the wall of dam 3. Vibrations on the dam wall 4. Water flowing out from the dam through main pipe line i.e. flow rate of water and 5. Sensing of the pipeline leakage that to with approximate location can be sensed and the information regarding the concern parameter be made available to the observer at a glance.

This will definitely leads to proper utilization of the natural resource water and ultimately it will be a great support towards the Nation.

This paper concentrates on the following three important parameters in case of Dam safety. They are

- Sediment-deposition of dust particles
- Seepage
- Flow Meter in water entry point in hydro-power generation

B. PROPOSED MODEL

- To implement the monitoring and control of the parameters in water storage dam, we would like to go in for Raspberry-Pi Microcontroller as a central core of the paper.
- Also with microcontroller using of wi-fi applications, we will monitoring and control the industrial parameters anywhere at any places.

In this proposed electronic design the dam area is divided in various clusters and the different sensors sensing independent parameters are deployed as shown. All the sensors in the cluster of dam namely Level Sensor (LS) / Vibration Sensor (VS) / Pressure Sensor (PS) and Flow Sensor (FS) senses Water level / Vibrations on the wall of dam / Pressure exerted on the wall of dam and the water flowing out from the dam into the main pipeline in Liters per minute respectively.

While the sensors DP1, DP2, are the Differential Pressure sensors fitted periodically along the main pipeline which will sense the pressure difference because of the breaking or leakage of the pipeline and will immediately be communicated to the observer. All these sensor nodes are connected together through Gateway to common storage area CLOUD and the observer can access the on line information from the cloud.

Block Diagram

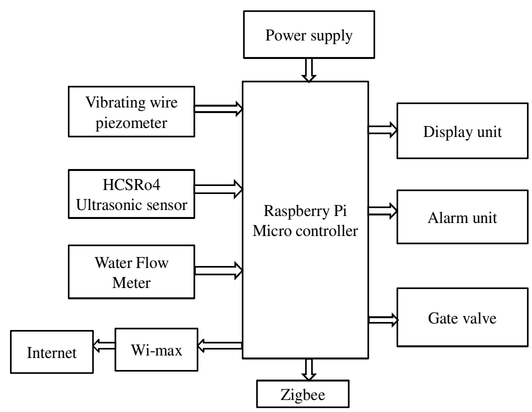

Fig 1: Block Diagram

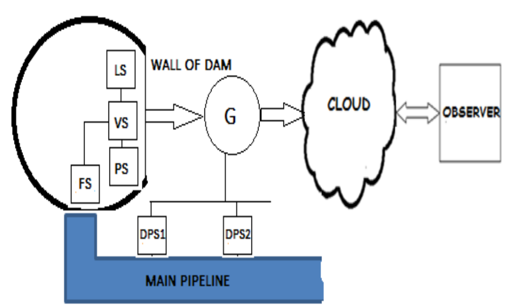

Fig 2: Proposed Electronic Design

C. RASPBERRY-PI MICROCONTROLLER

i. Overview

Raspberry Pi seems to be new in the world and many people really don't know what the Raspberry Pi is. Raspberry Pi can be defined as a low cost, credit-card sized computer that plugs into a computer monitor or TV, and uses a standard keyboard and mouse. It is a capable little device that enables people of all ages to explore computing, and to learn how to program in

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languages like Scratch and Python. It's capable of doing everything you would expect a desktop computer to do, from browsing the internet and playing high-definition video, to making spreadsheets, word-processing, and playing games. It is great bonding with Arduino and can do a lot with Arduino.

ii. Exploring the Raspberry Pi Board

There are two models of Raspberry Pi, model A and model B. These two are bit similar with few advance features on model B compared to model A. Model B has 512 MB RAM, two USB port where as Model A has 256 MB RAM and just a USB port. Besides, Model B has Ethernet port while Model A does not.

The overview of the Raspberry Pi Model B is shown in Figure.

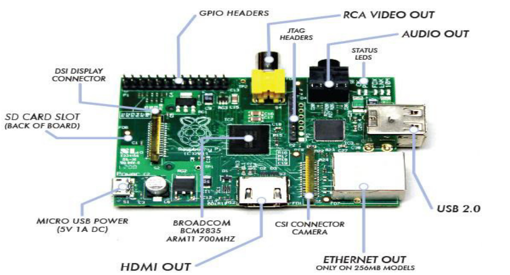

Fig 3: Exploring the Raspberry Pi Board

Different components of the Pi are named in the Figure 4-1 and brief description on each component is given in following sections.

iii. SD Card Slot

Raspberry Pi doesn't have the real hard drive as in laptop and computer, SD card is taken as solid state drive (SSD) which is used to install operating system and all others software and store everything. This card is needed to insert into the slot for using the Raspberry Pi. SD card may be 2GB, 4GB or 16GB.

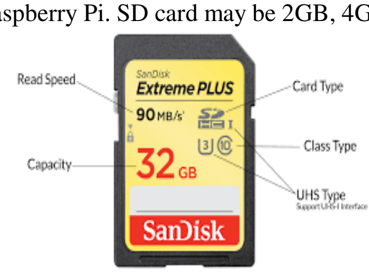

Fig 4: Secure Digital Card

iv. Micro USB Power

The power port is a 5V micro-USB input and supply should be exactly 5v as it doesn't have onboard power regulator. So, power supply shouldn't exceed than 5V.

v. HDMI Out

This output port is used to connect the Raspberry Pi with a monitor via HDMI (High Definition Multimedia Interface). Hence, any screen or TV can be connected to it which consists of HDMI port.

vi. Ethernet and USB port

Both the Ethernet port and USB port on Model B are supplied via the onboard LAN9512 chip. It is a high-speed USB 2.0 hub with a 10/100 Ethernet controller (Donat, 2014). USB ports are used to connect the inputs (keyboard, mouse). Almost everything that can connect to computer via USB also can connect with Raspberry Pi.

vii. RCA Video Out and Audio Out

Audio and RCA video jacks are present on the board for audio and video out. The Raspberry Pi does support sound over its HDMI output, but there is a standard 3.5-mm audio jack to plug in headphones but USM mikes may work or not.

For video, the RCA jack sends video to any connected RCA video device.

viii. GPIO Headers(Pins)

GPIO pins stands for general purpose of input output pins. These pins are used to connect any number of physical extensions with the Raspberry Pi. Raspberry Pi has pre-installed libraries that allow us to access the pins using programming languages like C, C++ or python.

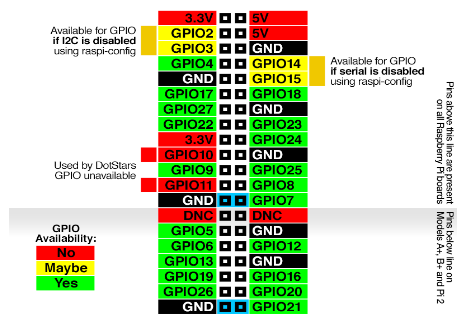

Fig 5: GPIO Headers(Pins)

ix. Raspberry Pi 2 Model B

Recently, Raspberry Pi 2 Model B has been lunched recently which Broadcom BCM2836 ARM Cortex-A7 Quad Core Processor has powered Single Board Computer running at 900MHz, 1GB RAM and 4 Quad USB ports. It is the advanced version of Model B and is 6 times faster than Model B Raspberry Pi. In addition, it has combined 4-pole jack for connecting your stereo audio out and composite video out and advanced power management. Figure 6 shows the top view of the board with labels of some important components .

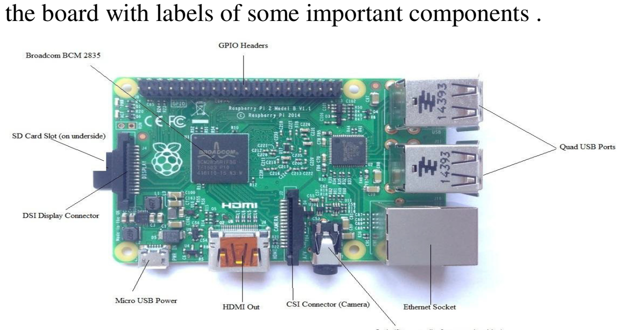

Fig 6: Raspberry Pi 2 Model B

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D. HARDWARE REQUIREMENTS

- Raspberry-Pi P-3 Model microcontroller and Wi-Fi Monitoring
- Measure Displacement
- Settlement
- Strain
- Piezometric pressure
- Seepage
- Uplift
- Water level
- Alarm System

i. Parameters Need To Be Monitored

- Headwater/tail water levels
- Pore pressure
- Uplift pressure
- Seepage / leakage
- Movement
- Stress / strain
- Temperature

ii. Selection of The Right Instrument

- The speed at which the failure could develop
- The challenges of the site (exposure, weather, etc.)
- Recourses available to monitor
- Consider more than just cost:
- Simplicity
- Reliability
- Durability
- Longevity
- Precision
- Accuracy
- Satisfactory performance history.
- Remember human eye may be the best instrument

V. HARDWARE REQUIRED FOR RASPBERRY-PI

Raspberry Pi can't start alone, it needs many others peripherals (hardware). There is brief description of the hardware requirements in the following section.

A. POWER SUPPLY

As mentioned already in above theory portion, Raspberry Pi needs 5V power supply. If supply exceeds 5V then it can't guaranteed to work properly. And the power supply also need to supply at least 500 milliamps (mA), and preferably more like 1 amp (A). If the supply is 500 mA or less, it is likely to have the mal-function of keyboard and mouse. It is not good idea to power the Raspberry Pi from USB port of computer and hub as they mostly provide current less than required. Hence, the Raspberry Pi requires a Micro-USB connection which is capable of supplying at least 700 mA (or 0.7 A) at 5V.

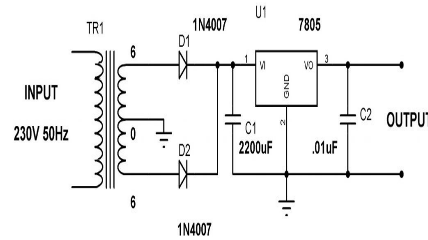

Fig 7: Regulated Power Supply

B. STORAGE

A separate hardware is required for the storage purpose in Raspberry Pi. For this, SD card is used, mostly 4 GB and 8 GB if needed. The operating system and all files are stored in the card. We can buy blank SD card and install operating system or buy a pre-installed one.

C. INPUT

External keyboard and mouse are required to provide input to the Raspberry Pi. No any additional software is needed to use the keyboard and mouse.

D. MONITOR

We can use monitor or TV with HDMI port or DVI inputs as the screen for the Raspberry Pi. For DVI inputs, HDMI-to-DVI converters are required which can be finding easily in a market. Monitor is most important for the Raspberry Pi as it is the only way to see what we have done on it.

E. NETWORK

As in laptop or computer, we can access to internet and network in Raspberry Pi as well. For that, we can use wired Ethernet connection which is easier option or Wi-Fi module to access Wi-Fi in the Raspberry Pi.

F. SEEPAGE FAILURES DETECTION

Seepage failures may occur due to the following causes :
(1) Piping through the foundation
(2) Piping through the dam
(3) Sloughing

i. Instrument for measuring the Seepage

- Casagrande Standpipe Piezometer
- Fully Grouted Multi-Point Piezometer String
- Pneumatic Piezometer
- Push-In Standpipe Piezometer
- Strain Gauge Piezometer
- Strain Gauge And Vibrating Wire Pressure Transducers
- Vibrating Wire Piezometer

ii. Vibrating Wire Piezometer-Measuring Seepage

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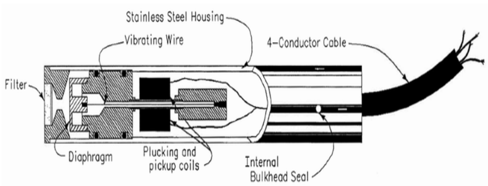

Fig 8:Vibrating Wire Piezometer

As fluid pressure is applied to the exposed side of the flexible diaphragm, the diaphragm deflects, causing a change in the tension of the wire behind it. The change in tension of the wire results in a change in resonant frequency of oscillation of the wire, with the square of frequency of oscillation being directly proportional to the applied pressure.

Features:

Not affected by barometric pressure
In-situ checks available
Air can be easily removed
Manual or automated readout
Reservoir can be sited away from construction area

Applications:

Subsurface point settlements/heave beneath:
Embankments
Surcharges
Fills
Dams
Landfills

G. INSTRUMENT FOR MEASURING SEDIMENT

- Optical Backscatter (OBS):
- Optical Transmission
- Focused Beam Reflectance
- Laser Diffraction
- Vibrating Tube
- Ultrasonic Sensor

i. HCSR04 Ultrasonic Sensor-Measuring Sediment

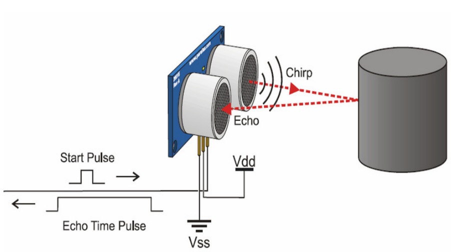

Fig 9: HCSR04 Ultrasonic Sensor

HC – SR04 utlrasonic sensor uses sound wave to measure the distance between sensor and object.

It emits an ultrasound at 40 000 Hz which travels through the air and if there is an object or obstacle on its path It will bounce back to the module. Considering the travel time and the speed of the sound you can calculate the distance. This change in distance provides the height of the water level. As compared to set level of the height one can find the deposits in the dam.

Technical Specifications:

- Working Voltage : 5V(DC)
- Static current: Less than 2mA.
- Output signal : Electric frequency signal, high level 5V, low level 0V.
- Sensor angle : Not more than 15 degrees.
- Detection distance : 2cm-450cm.
- High precision : Up to 2mm
- Input trigger signal : 10us TTL impulse
- Echo signal : output TTL PWL signal

H. FLOW METER AT THE INLET SIDE OF HYDRO POWER GENERATION

At present no flow meter is installed in the penstock. In some dams the inflow of water to the penstock is controlled by the manually opening the valve.

In order to maintain the correct flow of water to be very much essential for the power generation because the power is generated is depends in the speed of the turbine.

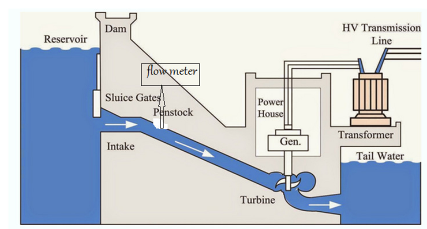

Fig 10: Flow Meter Installation

Fig 11: Water Flow Meter

Water flow sensor consists of a plastic valve body, a water rotor, and a hall-effect sensor. When water flows through the rotor, rotor rolls. Its speed changes with different rate of flow. The hall-effect sensor outputs the corresponding pulse signal. This one is suitable to detect flow in the pipe line.

- Compact, Easy to Install
- High Sealing Performance
- High Quality Hall Effect Sensor
- RoHS Compliant (Restriction of Hazardous Substances)

I. WI-MAX (WORLDWIDE INTEROPERABILITY FOR MICROWAVE ACCESS)

WiMAX supports mobile, nomadic and fixed wireless applications. A mobile user, in this context, is someone in transit, such as a commuter on a train. A nomadic user is one that connects on a portable device but does so only while stationary -- for example, connecting to an office network from a hotel room and then again from a coffee shop. Fixed

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wireless typically refers to wireless connectivity among non-mobile devices in homes or businesses.

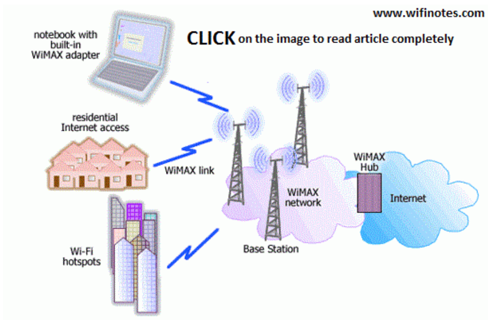

Fig 12: WiMAX

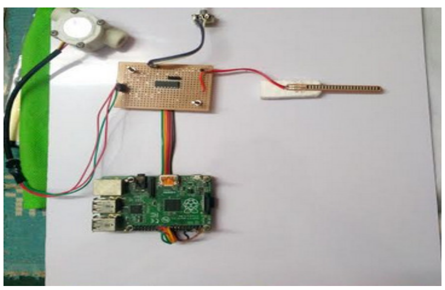

Fig 13: Proposed Kit

VI. Software Description

Python, C, C++, Java, Scratch, and Ruby all come installed by default on the Raspberry Pi. The people from Raspberry Pi recommend Scratch for younger kids. Other languages that can be used are: HTML5.

Python is a widely used high-level, general-purpose, interpreted, dynamic programming language. Its design philosophy emphasizes code readability, and its syntax allows programmers to express concepts in fewer lines of code than would be possible in languages such as C++ or Java.

Raspbian is a free operating system based on Debian optimized for the Raspberry Pi hardware. An operating system is the set of basic programs and utilities that make your Raspberry Pi run. However, Raspbian provides more than a pure OS: it comes with over 35,000 packages, pre-compiled software bundled in a nice format for easy installation on your Raspberry Pi.

The initial build of over 35,000 Raspbian packages, optimized for best performance on the Raspberry Pi, was completed in June of 2012. However, Raspbian is still under active development with an emphasis on improving the stability and performance of as many Debian packages as possible.

Note: Raspbian is not affiliated with the Raspberry Pi Foundation. Raspbian was created by a small, dedicated team of developers that are fans of the Raspberry Pi hardware, the educational goals of the Raspberry Pi Foundation and, of course, the Debian Paper.

A. PYTHON

Python is a remarkably powerful dynamic, object-oriented programming language that is used in a wide variety of application domains. It offers strong support for integration with other languages and tools, and comes with extensive standard libraries. To be precise, the following are some distinguishing features of Python:

_ Very clear, readable syntax
_ Strong introspection capabilities
_ Full modularity
_ Exception-based error handling
_ High level dynamic data types
_ Supports object oriented, imperative and functional programming styles
_ Embeddable
_ Scalable
_ Mature

With so much of freedom, Python helps the user to think problem centric rather than language centric as in other cases. These features make Python a best option for scientific computing.

B. OPENCV

OpenCV is a library of programming functions for real time computer vision originally developed by Intel and now supported by Willogarage. It is free for use under the open source BSD license. The library has more than five hundred optimized algorithms. It is used around the world, with forty thousand people in the user group. Uses range from interactive art, to mine inspection, and advanced robotics. The library is mainly written in C, which makes it portable to some specific platforms such as Digital Signal Processor. Wrappers for languages such as C, Python, Ruby and Java (using JavaCV) have been developed to encourage adoption by a wider audience. The recent releases have interfaces for C++.

It focuses mainly on real-time image processing. OpenCV is a cross-platform library, which can run on Linux, Mac OS and Windows. To date, OpenCV is the best open source computer vision library that developers and researchers can think of.

C. TESSERACT

Tesseract is a free software OCR engine that was developed at HP between 1984 and 1994. HP released it to the community in 2005. Tesseract was introduced at the 1995 UNLV Annual Test OCR Accuracy [2] and is currently developed by Google released under the Apache License. It can now recognize 6 languages, and is fully UTF8 capable. Developers can train Tesseract with their own fonts and character mapping to obtain perfect efficiency.

VII. Conclusion And Future Work

This paper describes a smart sensor interface for dam safety parameters. The system can collect identification information of sensor intelligently. Its design is based on Raspberry-Pi

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Microcontroller by combining WiMAX and the application of wireless communication.

It is very suitable for real-time performance and effective requirements of the high-speed data acquisition system in IoT environment. The application of Raspberri-Pi Microcontroller simplifies the design of peripheral circuit and it also provides parallel processing of data collection.

Raspberri-Pi Microcontroller also makes the whole system more flexible and it expand the range of applications in IoT for the sensor interface device. Application of Raspberri-Pi Microcontroller enables the system to collect sensor data intelligently. By using this device, information of different types of sensors can be connected to the system without writing any complicated program.

Future work will focus on improvement of above proposed work and adding features to make a reliable smart Dam Monitoring and Controlling system.

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