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Crowd sensing applications in Smart cities Urban Flood Management

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Abstract: *The projects of smart cities envisioned by the respective national governments face a lot of challenges, from development, deploy to operational stage. One such is urban flooding, that comes when the rain is enormous, more than the storm water design of the city, results in urban flooding, results in losses, both in property and life. Technologies like IoT, Data Science, Crowd sensing can help us mitigate such natural fury or an "Act of God". Data Science in support with IoT and communications can help people in warning, guiding, tackling and even rescuing people in danger during such disastrous occasions.*

Key Word: *Crowd sensing, Urban flood management, Public-Private-People(P4) business model, Citizen science*

I. INTRODUCTION

Smart City Projects involve lot of paperwork, planning and execution along the entire course from inception to operation. Greenfield projects, that are started from the beginning have a new proposal and storm water drains are designed to withstand a nominal rainfall of 12 to 20 mm per hour, above which results in urban flooding. This urban flooding may be caused by waterlogging, an operational defect of the drainage system, inadequate channels for water flow, a design problem or a cloud burst caused by violent weather. But smart cities now are not Greenfield's but Brownfield's, the projects done by modernizing, reconstructing existing cities. Here the entire city is not planned, but a part of the city or more additions are added, thereby using more of the existing infrastructure of the old city, that was designed for the former than the latter.

New infrastructures in brownfield projects create heavy stress on the existing drainage systems until a new drainage system is made available. Due to lengthy project timeline or a delayed drain line project, there exists a heavy impact on the normal working or operation of the existing superstructures like residential/commercial property as underground structures like canals or storm water drains are in due for construction.

Effective use of existing systems with some smart IoT's, data science algorithms, can minimize the impact of urban flooding and gives time and resources to plan and act accordingly. All these operations along with the man-machine communication is stored in real time, that can be used for case study purposes, which in turn can help the disaster management team to do an effective work which can be used as a benchmark for future reference.

Disaster management plans have bottlenecks such as two-way communication with the management team and the victim, one way communication to a group of people for guidance and messages. The communication from IoT to data control centers are an established one that can withstand rugged operations.

People usually don't come outside during a bad weather as they are issued a warning from the metrology department, but after the rain has passed or going on and reached abnormal water levels, victims of heavy flooding are required to move out of their places and look for a safe place to ensure personal safety. Inadequate data available to them confuses people and not let them to go for an escape plan. If they are provided with the data required, like a nearby assembly point.

An assembly point is a safe space where people can gather in case of emergency conditions, and it is a place that has quick access to the emergency management team for rescue operations and attend the victims for any necessary medical or food requirement. Assembly points are decided based on the merits of the location that has the least impact of the disaster compared to other locations nearby. There will be many numbers of assembly points in a particular area of the city that can be changed based on real time merits as the situation in a disaster is dynamic.

The latest scientific tools of Data Science, Analytics, IoT, Mobile communications can be used to alleviate natural disaster and help in an effective disaster management plan.

II. MATERIAL AND METHODS

A. Data Science

Data Science is a scientific methodology to study data, it works to gain useful information from available raw data from various sources, arrange them in order, organize based on similarity, patterns, systemize the way of sorting, classify them in groups to make a meaningful list of understandable inferences. Data sets can be used for simulating various events, simply with data and numerals without the real need for any change in the working environment.

Disaster management plan for smart city projects use Data Science methodologies for gathering bulk volume of data from devices, that are stored up along with processing in real time.

B. Data Analytics

Data Analytics involves in inspecting the received data, process the same with the available or programmed algorithms to take knowledgeable, up to date decisions in real time when environment working is a dynamic one.

Techniques that investigate a particular data group with fact-finding and probing methodologies is set out by the numerous validated analytical methods. Data Analytics uses the combination of statistical, scientific, advanced mathematical works in a simple streamlined form to achieve the expected result with less hard work and at the ease of the user.

C. IoT

IoT is a technology that uses single or multiple devices that are implanted with sensors, software and communication technologies for the intention of sharing information among and data with the working methodology of exchanging data with the internet or a wider connected network of computers and communication devices.

These devices are equipped with the capability of self-reporting in real time without the need for any human intervention. They work with an active network connection and can transmit data, the network can either be the internet or a WAN/LAN for communication purpose.

D. Public-Private-People Partnership (PPPP/P4)

The Public-Private-People partnership is a business model or contractual agreement that allows public firm or organization and private institution to work in projects where the capital requirement is made available by the private financing institution or individuals to manage/operate that provides a public service.

Here the tools of IoT sensors, communication devices, software are owned/operated by the private institutions or individuals that provide data to the metrology/government operated entity that serves the common public.

E. Crowd sensing

Crowd sensing is technique where sensor measurements or readings from various sensors of numerous devices do the work of sending data seamlessly to the cloud or data center.

F. Sensors

- Air Moisture sensor: Also called as humidity sensor, that measures relative humidity by using the thin strip of metal oxide inserted in between two electrodes. Here the metal oxide's capacitance varies with respect to the atmosphere's relative humidity and a corresponding electrical signal is generated. Signal converter unit gives the direct measurement of the engineering unit required to be monitored.
- Soil moisture sensor: These sensors measure the quantity of water present in the sample soil at the predetermined depth. More number of these sensors are planted to get an average value of the total moisture content in the soil in the sample area. Tensiometers are also used to calculate the tension between the soil and water particles. This is based on surface tension methodology.
- Rain sensor: This is also called rain switch or raindrop detector, as it does tell that there is some rainfall in the sample area, but not the quantity of rain or volumetric data above the downpour. This is a simple digital signal that tells, there is raining in the sample area.
- Rain flow sensor: This sensor is also called as rain and hail sensor that measures the rainfall in the region. The measurement is done by calculating the number of individual rains drops colliding on an impact sensor. The number of impacts over a period is used to calculate the intensity of rain, a direct indicator of volumetric flow of the same.
- Level sensor: Level sensors are used on the manhole to find the water level inside the stormwater channel. Here ultrasonic contactless measurement units are installed.
- Storm water flow sensor: Storm water flow sensors are used in the storm water channels to measure the flow of storm water. Pressure measurement is also available embedded in the sensor.
- Water quality sensor: Also, easily known as total organic carbon sensor/analyzer. This is a direct indicator of water quality to know whether the water is a sewage or storm water.

  This prospective comparative study was carried out on patients of Department of general Medicine at Dr. Ram Manohar

Methodology

The manholes are fitted with level sensors over the sample area or on the smart city locations. The rainwater sensors, air moisture sensors are fitted in a distributed area all around the smart city. The water flow sensor, pressure sensors are fitted with the water quality sensors inside the channels for monitoring. The soil moisture sensor is fitted in the soil area of the city where there is a permeation of rainwater is possible. These sensors can also be fitted in individual rainwater harvesting homes or community-based rainwater harvesters. This data is collected from all the individual sensors to the command center for further analysis.

The elevation or terrain of various smart city locations are surveyed in reference to the mean sea level by the survey department. This gives an idea of the low-lying areas in the city as the danger of water logging always happens in low lying areas as water flows towards these areas. The level sensor's locations are geo-tagged with information about the elevation they are fixed. These data are already fed to the central processing unit to make engineering calculations accurately that can help in making clear-cut decisions.

Data centers communicate with the individual sensors using dedicated wireless internet or 4G/5G network. The existing wireless networks sometimes fail in the event of a natural disaster and alternate networks dedicated for only the IoT to data centers like LoRa or SIGFOX (a LPWAN-Low-Power Wide area network). These technologies connect for seamless communication with the IoT's for regular and real-time data acquisition.

Embedded systems platform that can connect various operating systems (like Raspbian, Angstrom Linux, Ubuntu MATE, Micro python, Windows 10 IoT Core, Yocto Project) is used as the data is collected from a various number of people including private individuals, community owners, smart city operator, metrology department and other government agencies. Each one of them may use their own embedded operating system as per their convenience. So, a common programming language like C, Java, Python, Visual Studio, Bonescript, Wiring is used to support individual embedded systems that are used in field data collection.

Crowdsensing, a part of Crowdsourcing is utilized here in collecting data and interpretation by individual contributors. A common platform that has location enabled maps and sections for typing texts with authorization given to the individuals and organizations contributing weather updates in their locality. Contributors can even give inferences about the data they have got from their sensors, and the responsibility lies on the one posting them. Here a clear data policy to post messages and updates are framed to avoid any error or false messages as the events involved are critical and decisions based on the inferences directly affects any disaster management operation.

Crowdsensing helps in collecting data about the headcount of the people in the assembly points and then send to the government authorities working with disaster management team to get a quick check of the missing ones. Data from other assembly points are cross checked based on the resident information available with the smart city authority and the available victims. Stranded victims in inaccessible locations can be send in food and medical supplies with the help of drones. Here the exact location to drop the supplies is send to the drone by the data collected from the contributors and exact point of drop of supplies is assisted by the data obtained from crowdsensing technique of gathering data other than received from sensors.

The data from Crowdsensing is also verified by drone and satellite images to know the exact condition of the situation. Contributors of data are scrutinized by the metrology team before posting them officially to the residents of the smart city/ outside world. Disaster management team can also seek help like a peer from the individual in identifying assembly points in the flood affected area. Individuals other than management team like trained volunteers can also be communicated in case of a requirement. The platform for communication must have the minimum requirements of a map with direction assisting facility, GPS enabled SOS, place for text for communications and direct calling facility with the ground and field team. The authorization to the users is enabled/disabled by the high priority administrator with the delegation facility in case the former is not available for communication.

Data analytics with the necessary algorithms are used to interpret the information from the data and to take real time decisions to instruct emergency management team to act accordingly. Warning messages to smart city residents is also based on the analytical inferences.

Event driven approach methodology is preferred here than procedure or object driven methodology, because in a dynamic situation, most of the parameters become variables than constants, the situation can become worse if a wrong decision is taken. Here procedure driven methodology is used as a final approach. When interactive communication exists in the event of rescue of victims in a flood situation, then event driven is preferred, but if there is no communication from the victim side, then procedure driven methodology is implemented.

Application-1

When there is a heavy rain expected by the metrology department or the government is issuing a warning for a heavy downpour, the soil moisture sensors of various locations including rainwater harvesting pits are checked. If the moisture level is very low or low and based on the forecast expecting a nominal rain, then the rainwater pit maintenance is instructed to clean for any blockages leading to the rainwater sink. Adequate time is given for the ground to absorb the water in case the underwater aquafers, if present in the geology of the smart city. This will improve the ground water quality and quantity.

In other case if there is enough moisture in the soil indicated by the moisture sensors, then the excess water can be diverted to the channels through the gate valves or louvres to drain the excess water the channels as ground cannot absorb anymore.

Recent developments in metrology science can predict the duration the rain is expected, along with the volume of rain by the weatherman's expertise.

Manhole sensors can tell information the water level inside the stormwater channels and the flow, pressure along the water way. Interpretation techniques like for e.g., if the level of manhole is rising without any rain outside and a reduction in flow infers there is a partial block/choke in the channel that reduces the flow. Maintenance team is informed about the particular manhole and the louvre or gate in the downstream of the channel.

Data Analytics can help to go for inferences in other occurrences like e.g., if there is a TOC (total organic carbon) indication from the water quality sensor in the storm water, then it can be concluded as a seepage of sewage water in the storm water. The nearby sewage channels that are present in the upstream or in the line of the storm water channel are suspected of any leaks. Maintenance team can take proactive measures before the minor seepage becomes a heavy.

If there is TOC change towards downside observed in the sewage water or if the water purity is increasing more than the normal outside of the working TOC range, it is an implication that there is a seepage from storm water to sewage water or any of the manholes is kept open to drain the waterlogged near the manhole. Here if the sewage water is with less pollutants, then it can be sent to the dumping area without any treatment as the pollutants are diluted by the rainwater, bypassing the process station thereby reducing the workload of the station.

Application-2

In case of the aftermath of a heavy rainfall where there is water logging is all around the city a drone can be send to survey the conditions of the smart city. The drone accesses the information by the geo tagged sensors by flying exactly above the sensors. The height of water above the ground is measured by the drone or a group of drones to capture images in the real time in various intervals for time, with simple formulae in trigonometry using the data of available height of landmarks above the water (those unsubmerged), the angle of inclination from the top of the building and the location of the drone by GPS and the sensors fixed on the land along with their elevation data available (survey data). Then the areas with water levels above 2 feet are marked non-commutable by two wheelers or cars and further levels (due to the low-lying locations by nature/survey) are marked as access only with boats or amphibian transports. These locations are marked in the city map and updated on the internet through a map app like Google/Bing/Open Street/Apple or the customized metrology app that is available to everyone. This could give more information to the residents about the dangerous areas to travel inside the city. Even outsiders or visitor to the city without much knowledge of the catastrophe can have an awareness of the situation and follow the guided safe routes to reach their destinations. Individual waterlogged areas can be also indicated by injecting or mixing organic fluorescent dyes such as AMCA, CY3, Fluorescein, TAMRA or Texas red in the waterlogged zone. This injection could be automatic by automatic dye dispenser that disperses dye when receiving command from command center or a drone that could drop a dye bag on the affected area. This could even help people without mobile access or those with mobile but without signal (disrupted by bad weather). Fluorescent dyes are used as they can emit light by itself that can be easily viewed in dark.

People have the habit of crossing storm water channels or water ways that are in low level during summer, but during rainy season it is not advised as there will be less knowledge about the quantum and the velocity of water flowing on the channel. The same happens to the people residing near the riverbanks as people have no idea of how turbulent water flow will move in either direction. So, a warning system that sends message to the mobiles of the residents along the bank of the river. Here the phone numbers connected to all the towers along the bank irrespective of the operator is send a warning message about the condition of the river. Small channels can use dispensers with timed injection of the organic fluorescent dye (with less environmental impacts) is implemented. Residents are advised by messages or marked maps to avoid places with stagnant or flowing fluorescent dye. In case there is too much flow of rainwater, then dyes are not dispersed directly but long lasting glowsticks in lot of numbers are an option with added weight to get them submerged in the waterlogged areas than liquid ones.

Usually, the rainy season in tropical countries count for 3 to 5 months and in some geo locations it may go up for 6 months. So, the dye dispenser may not be needed for service in other months, and they can be either be installed only in the rainy months.

III.CONCLUSION

Urban flood and disaster management is not only the work of government or governmental agencies, but even individuals with self-interest can also involve themselves to help or volunteer other people affected by natural disaster. New business models like Public-Private-People partnership(P4) are emerging to make people involve in the group activities of helping victims. Individual owners using IoT equipment that could combine with the other government owned devices can collect and share real time data to the concerned data centers can help manage the disaster very well.

In addition to the data from IoT's, Crowdsensing is a boon to rescue activity as feedback from various users to the control center can help them allocate time and available resources wisely to tackle an emergency.

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