Existing Research

Flood Detection and Prediction System Development

There has been a rash of projects/publications in this topic area in the past two years (2019 to present). Most relevant will be the active (not yet published) NCHRP Synthesis having scope that specifically addresses Refai’s scope. Other related projects present methodologies for sensors and/or models.

RiP Database:

Current NCHRP Synthesis (2020, active): The objective of this synthesis is to document the integrated flood prediction and response systems being used by state DOTs. A critical issue facing DOTs is determining the extent and the severity of flooding events. Roadways and bridge flooding have significant economic impacts and are a major contributor to deaths during flood events. State department of transportation (DOTs) and other state and local agencies have implemented integrated flood warning and response systems. This is critical for staging personnel, inspecting bridges, and flood tracking through the state. Support for these efforts can come from internal products, flood inundation mapping using current and projected conditions, turnkey products on the market, the United States Geological Survey (USGS) gaging network and the National Weather Service flood forecast. In addition to anticipating flood areas, states are tasked with alerting the public about affected areas and protecting them from these hazards. DOTs and other agencies must determine the flood’s extent and severity to effectively work with emergency management and inform the public about road closures and detour routes. There are multiple methods of warning the public about floods including warning lights tied to gages, sensors, personnel blocking off areas, warnings on official websites, and using USGS and National Weather Service products. Communication is key to the effective response before, during, and after flood events. Communication gaps within and between agencies have been identified following recent flood events such as those in North and South Carolina between 2015 and 2018.

Information to be gathered includes, but is not be limited to:

· Flood prediction methods

· Risk thresholds that trigger action

· Methods and instruments used by DOTs to monitor flooding

· How DOTs determine the extent and severity of floods

· Available warning systems and methods

· Practices by DOTs for alerting the public, working with other agencies, and internal communication

· Successful systems as reported by DOTs

· Weaknesses in existing methods and what problems remain unsolved

Information will be collected through literature review, survey of DOTs, and follow-up interviews with selected agencies for the development of case examples that document successful practices. Case examples should cover a diverse range of geographic regions, flood causes and levels of government. Information gaps and suggestions for research to address those gaps will be identified.

(UTC, in progress, 2019): Real-Time Early Detection and Monitoring of Flooding using Low-Cost Highly Sensitivity Ultrasonic Sensing of Water Level

<https://trid.trb.org/Results?txtKeywords=flood%20warning&txtTitle=&txtSerial=&ddlSubject=&txtReportNum=&ddlTrisfile=&txtIndex=&specificTerms=&txtAgency=&sourceagency=&txtAuthor=&ddlResultType=&chkFulltextOnly=&recordLanguage=&subjectLogic=or&dateStart=&dateEnd=&rangeType=emptyrange&sortBy=publisheddate&sortOrder=DESC&rpp=25#/View/1644425>

Flooding poses safety hazards to motorists, emergency and maintenance crews and may cause costly damage to transportation infrastructure and its operation. Water level detection units are commonly designed for riverine flooding rather than flash flooding. Moreover, installation and maintenance of traditional water level sensing systems are expensive. The current cutting-edge water level detection techniques, on the other hand, have significant limitations: noise and erroneous signals from sensors, unstable power management, and slow data transmitting. Unmanned aerial vehicles (UAV) may also be used to sense flash floods in real time. The UAVs, however, have their limitations in that they only provide snap shots of flood information in the short period time they operate. As a promising solution, this study will evaluate a low-cost real-time ultrasound water-level measuring unit at critical corridors in Region 6, to develop integrated-sensing of the low-cost, highly sensitive ultrasonic water level detection (UWLD) unit to increase its reliability and resolution and to integrate it with a highly efficient solar power system and a reliable cellular network. The flood stage information will be transmitted using a cellular module in the UWLD unit to the Region 6 Flood Control District or sent directly to emergency command centers for early warning so that they may take timely action such as citizen/driver evacuation, route/ramp closures, and signal timing modification.

RNS Database: zero related results for “flood”, “flood detection”, “flood warning”

TRID/TRIS Database:

2019 ASCE: Towards Enhanced Response: Integration of a Flood Alert System with Road Infrastructure Performance Models

<https://ascelibrary.org/doi/10.1061/9780784482223.029>

This paper presents a conceptual framework for improved situational awareness in severe rainfall events like hurricanes or tropical storms by coupling a flood alert system (FAS) with a model for transportation infrastructure performance assessment referred to as the access to critical facilities (ACF) model. The FAS is a flood modeling and alert system that leverages state of the art flood modeling and rainfall radar data in an efficient manner. The ACF model comprises of a road network of the study area, census data, locations of critical facilities like hospitals and fire stations, and a spatial and network analysis toolbox written in Python. The proposed framework can be used to evaluate, in near real-time, system level performance such as accessibility to critical locations and component level performance such as potential impacts on roadways. As a proof of concept, the coupled framework is applied to the White Oak Bayou watershed, Houston, Texas. First, the hydrologic and hydraulic characteristics of the watershed are captured through inundation maps forming a floodplain map library (FPML). Second, five accessibility measures quantifying mobility and accessibility are evaluated for each inundation map to develop the accessibility map library (AML). During a storm event, real-time radar rainfall data is used to identify the pertinent scenario from the FPML and AML. The selected maps are then communicated to stakeholders to support emergency response and situational awareness. Further, the results from the framework can also be used for disaster mitigation planning. Although demonstrated on a single watershed, the methodology developed in this study is transferrable to other regions to develop an integrated flood alert system in support of emergency response and longer-term resilience goals.

2019 Portable Roadway High Water Detection System for Driver Safety and Infrastructure Assessment

<https://digitalcommons.lsu.edu/transet_pubs/51/>

The state of Texas, local governments, and community groups are adopting several initiatives to address this problem. The main goal of this project is to develop an approach to enhance prediction and detection of roadway flooding and help efforts to prevent driving into flood roadways. The motivation of this work was initiated by the alarming number of vehicle related flood fatalities in Texas, mostly at low-water crossings. Texas leads the nation in the number of flood fatalities and about 77% of flood fatalities in Texas are motor vehicle-related. This percentage is much higher than the national percentage reported in several previous studies. Motor vehicle-related flood fatalities in Texas are generally correlated with monthly climate, topography, and population density. For example, about half of the fatalities caused by Hurricane Harvey were transportation-related. The presence of numerous low water crossings throughout Texas contribute to the higher recurrence rates of floods that pose a danger to vehicles. The research team has been challenged to identify effective measures to improve safety at low-water crossings. Therefore, the research team developed an approach that combines data analysis, modeling, and high water detection and communication to improve safety at low-water crossings. Researchers conducted the following tasks: literature review, vehicle-related flood fatality analysis, review of transportation fatalities cause by Hurricane Harvey, and proposed the design of a warning systems at low-water crossings that can detect and predict water depth and velocity at these locations. It was suggested that flood detection and warning can be significantly augment by using sensing technologies that can detect not only the water depth but also the water velocity in combination with a physically-based hydrologic modeling system that can provide forecasts of water depth and velocity at locations of interest. The results of the model and information of the sensors can be used to provide timely and adequate warning to approaching motorists that flooded roadway conditions exist further up the road.

2019 VDOT (modeling) Computational Enhancements for the Virginia Department of Transportation’s Regional River Severe Storm Model: Phase II

<https://rosap.ntl.bts.gov/view/dot/42619>

Abstract Climate change is projected to increase the risk of flooding, which can cause severe damage and threaten lives. This increased risk makes it even more important to accurately forecast potential flooding impacts. The report details efforts by the University of Virginia to enhance key aspects of the Virginia Department of Transportation’s (VDOT) Regional River Severe Storm Model (R2S2) that aims to forecast potential flooding impacts in real-time for transportation infrastructure. This model serves as a planning tool for a large portion of the Hampton Roads District to assist residency administrators in efficientlyallocating scarce resources to close roads and to assist first responders in accessing flood prone areas. In this study, researchers first designed and implemented methods to improve the accuracy of R2S2 and reassessed the model against the stream data for two different storm events. The calibrated model shows good predictive capability for the majority of the study region, while the easternmost portion of the watershed, which has very flat terrain, remains the most difficult region to model accurately. The final task included automation of the cloud-based system that can provide end-to-end automation of flood warning for bridges and culverts in the region. The system is now available for implementation by VDOT for use during extreme weather events. The study recommends that VTRC brief executives in the Department of Natural Resources on the work accomplished to date on R2S2. The briefing should include the capabilities of the current model, its current limitations, and potential modifications that could improve the model. In the spring of 2019, the Governor and the General Assembly determined that coordinated state agency research activities in the areas of climate change, sea level rise, roadway flooding attributable to storm surge, and roadway management strategies in flooding events are desirable. The Department of Natural Resources has been identified as the lead agency for these initiatives; the study’s recommendation reflects that new interagency approach.

2016 Flooded Road LED Warning Systems

<http://worldcat.org/oclc/7529443>

Abstract A Flooded Road LED Warning System (FRWS) uses LED signage or beacons to alert motorists who are approaching water-covered roads. It is a dynamic system with sensors that can detect the rising of water to unsafe levels, which then triggers the alerting signals. This article discusses the use of such a system to promote traffic safety in areas that may flood due to heavy rains, tropical storms, tidal events, tsunamis, or other weather conditions.

2016 Transportation Infrastructure Flooding: Sensing Water Levels and Clearing and Rerouting Traffic out of Danger

<http://www.matsutc.org/transportation-infrastructure-flooding-sensing-water-levels-and-clearing-and-rerouting-traffic-out-of-danger/>

Flooding in urban areas, driven by both precipitation and high tide events, can have a devastating effect on a region’s transportation system and economic viability. In the City of Virginia Beach, the problem is acute as nuisance flooding in heavily populated areas impacts both communities and transportation infrastructure. The critical needs to identify the magnitude of floods are to measure and model precipitation intensity with a short lead time and relate to high tide events to plan proper protective measures for and diversion from problem areas. This study adopts a multi-disciplinary approach (hydrology, regional climate and precipitation forecasting, and transportation engineering) to predict roadway flooding and mitigate travelers’ danger from the flood and delays. We will study two flood-prone locations in Virginia Beach. From the hydrology/precipitation perspective, the research addresses flooding due to a complex relationship between tide levels and rainfall events. We hypothesize that a data-driven approach whereby patterns of tidal levels and rainfall intensities and durations that cause flooding can be identified. Then forecasted rainfalls and tide levels can be used to forecast periods when roadways may be flooded. From the transportation perspective, we are concerned about two types of drivers: those who are on the road as the flood occurs and those who have not yet entered that particular road and must be re-routed. For the first group, warning and road closures must be provided in time to remove these drivers from the impact area. The amount of time required to clear the link depends on network traffic conditions and potentially other flooded areas. The second group must be re-routed so as not to enter the affected link(s) and place the drivers in danger from flooding.

2001: IDEA grant ROADWAY FLASH FLOODING WARNING DEVICES FEASIBILITY STUDY

<http://onlinepubs.trb.org/onlinepubs/sp/its-idea_79.pdf>

Abstract This investigation by Weather Solutions Group, Chesterfield, MO was completed as part of the Intelligent Transportation Systems (ITS) IDEA program which fosters innovations in development and deployment of intelligent transportation systems. The ITS-IDEA program is one of the five IDEA programs managed by the Transportation Research Board (TRB). The other four IDEA program areas are: Transit-IDEA, which focuses on transit practice in support of the Transit Cooperative Research Program (TCRP), NCHRP-IDEA which focuses on highway systems in support of National Cooperative Highway Research Program, High Speed Rail-IDEA (HSR), which focuses on high speed rail practice, in support of the Federal Railroad Administration, and Transportation Safety Technology (TST), which focuses on motor carrier safety practice, in support of the Federal Motor Carrier Safety Administration and Federal Railroad Administration. The five IDEA program areas are integrated to promote the development and testing of nontraditional and innovative concepts, methods, and technologies for surface transportation systems.

2020 (related) Development of Cost-Effective Sensing Systems and Analytics (CeSSA) to Monitor Roadway Conditions and Mobility Safety

<https://rip.trb.org/Results?txtKeywords=traffic%20monitor&txtTitle=&txtSerial=&ddlSubject=1797&txtReportNum=&recordStatus=&projectStatus=&ddlTrisfile=&txtIndex=&states=&specificTerms=&txtAgency=&sourceagency=&txtAuthor=&ddlResultType=&chkFulltextOnly=0&subjectLogic=or&dateStart=&dateEnd=&rangeType=emptyrange&sortBy=publisheddate&sortOrder=DESC&rpp=50#/View/1683376>

This state-of-the-art Cost-Effective Sensing Systems and Analytics (CeSSA) project will provide an affordable method that will benefit state, city, county governments, as well as local communities who have an immediate need but with limited budgets to evaluate the road quality and prioritize repair needs. The project will specifically strengthen the following two major areas to advance our research competency: (1) advanced vehicle-based sensors using Bluetooth technology and (2) computing algorithms in analyzing vibration data. The sensors developed by the project will be attached on each control arm of a vehicle. The vehicle will travel on different roads to generate a variety of vibration signatures that will allow us to evaluate the efficiency and effectiveness of the sensors and algorithms in identifying road roughness. The analysis results will be used to determine where the potential hazards (cracks, potholes, bumps, etc) on roadways are located in Google maps. We will present four specific contributions in the proposal including: 1) Developing the CeSSA system that can immediately reflect the actual road conditions and transfer data to a mobile application and web server. 2) Assembling and programming a sensing network, integrating accelerometers, rotation sensors, and magnetometers, which can differentiate various road surface conditions from unexpected driver’s behavior due to traffic and weather conditions. 3) Unlike prior solutions, we are suggesting to develop the technology based on low cost componentry and commercially available for all highway agencies and institutions. We see the importance to lower the entry level, to deploy widely the scheme to developing countries, which need to improve their infrastructure. 4) Delivering a friendly user interface that will not require lengthy personnel training, and be easy to analyze. The project outcomes will effectively help the governments better prioritize road repairs and immediately inform drivers of potential hazard locations such that they can adjust their path prior to traveling so as to improve the highway condition monitoring, maintenance activities, as well as mobility safety.