Scalable Modeling and Adaptive Real-time Trust Based Communication

NSF Project ID: 1951745

Khan Iftekharuddin, Old Dominion University

Award Type (SCC-IRG Track 2), Solicitation Year (FY2020)

Principal Research Investigators (Name, Institution)

Principal Investigators

- *Khan Iftekharuddiin, Old Dominion University*

Co-Principal Investigators

- *Jonathan Goodall, University of Virginia*
- *Mecit Cetin, Old Dominion University*
- *Navid Tahvildari, Old Dominion University*
- *Jing Chen, Old Dominion University*

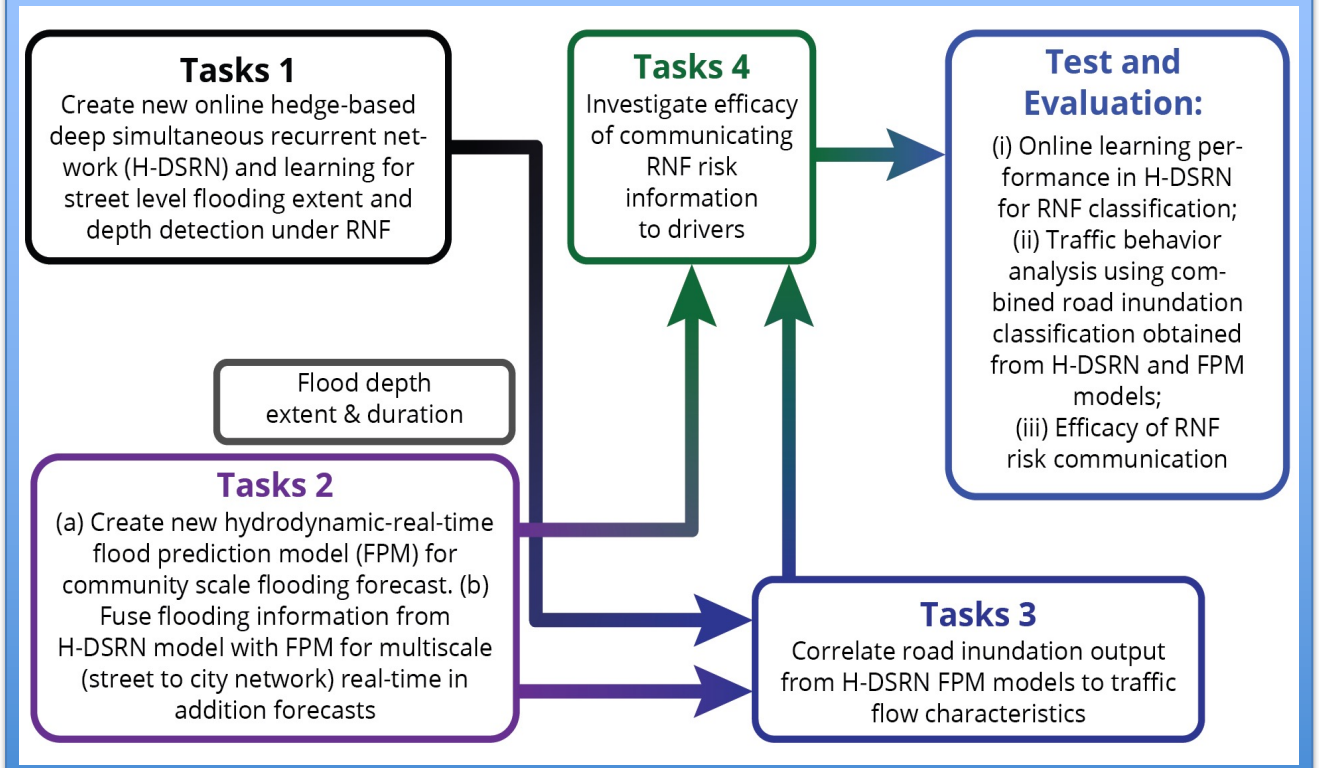
Community Partners (Name, Institution)

Kyle Spencer, Deputy Resilient Officer, City of Norfolk

RISE – a non-profit organization in Norfolk focused on helping businesses develop new solutions for coastal communities to adapt to rising seas and frequent flooding

Project Overview

Visual Schematic



Project Vision

1) **Develop a Scalable Modeling and Adaptive Real-time Trust-based communication (SMARTc) system for roadway inundation detection and monitoring**

2) **Evaluate the system for a flood-prone region in the City of Norfolk, Virginia using data from the City's cameras, tide gauges, and existing and new overland water level sensors in the field**

Project Overview

Use-Inspired Research

The project is Inspired by the needs for a system at street to community level as follows --

(i) Automatic and real-time detection of extent and depth of inundation levels and prediction of duration of RNF, and

(ii) Real time communication of the information to drivers, especially for communities affected by RNF

In collaboration with City of Norfolk, Virginia and non-profit organization RISE that are working to develop new solutions for coastal communities to adapt to SLR and RNF

Fundamental Research Contributions

I. Near real-time learning model for street-scale RNF extent and depth recognition;

II. improved community-scale road network flood prediction model for RNF extent, depth, and flood duration using City camera and other sensor data

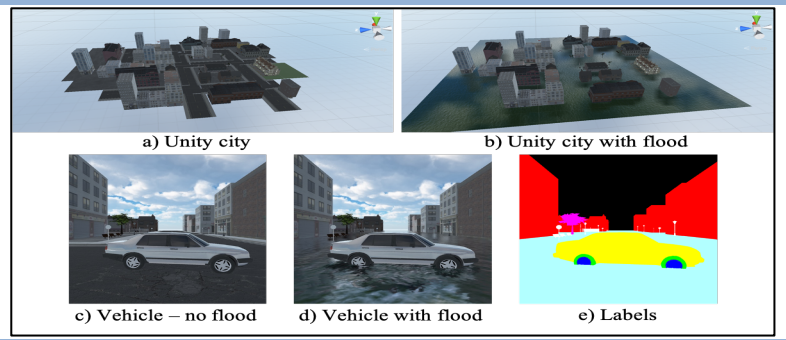
III. improved microscopic car-following models for partially flooded roadway segments so that the capacities and bottlenecks may be estimated and characterized accurately in near real-time

IV. Effective 'risk' communication strategies for drivers using the RNF extent, depth

Project Update

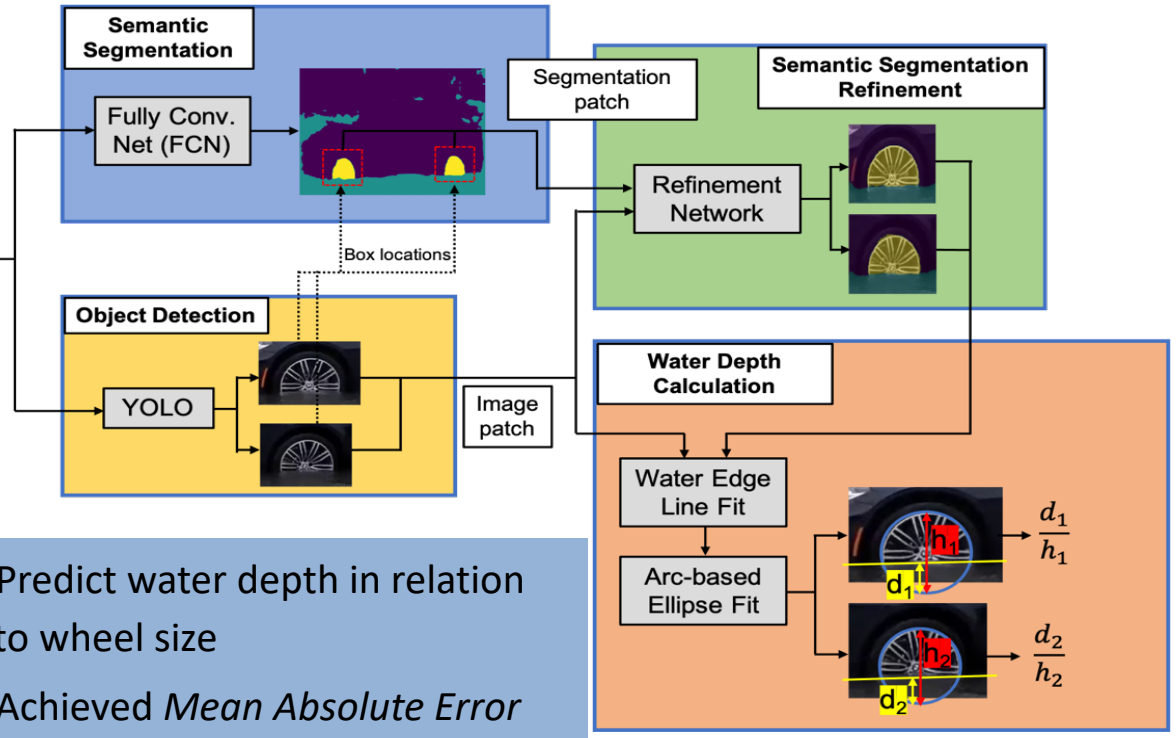
Generating Synthetic Image Data

- Generated flooding scenarios in **Unity**, extracted vehicle images, and labeled them for model training and testing

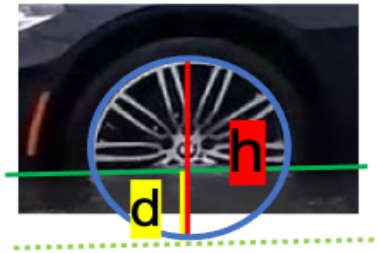


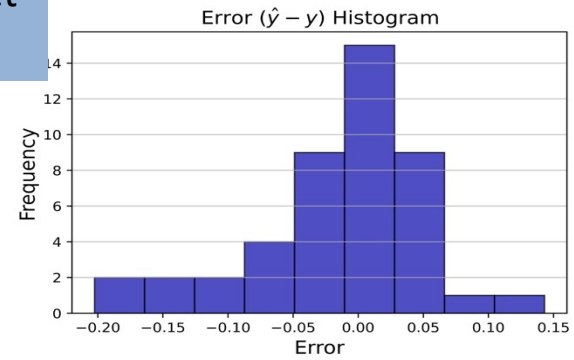
- Exploring **Blender** for more realistic synthetic image generation
  APIC (Affine Particle-in-Cell) solvers within Blender to simulate fluids, a hybrid Lagrangian/Eulerian approximation of Navier-Stokes equations

Flood Depth Prediction



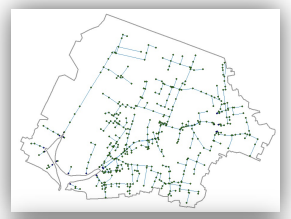
- Predict water depth in relation to wheel size
- Achieved *Mean Absolute Error (MAE)* of 0.051 in water depth to wheel size ratio with our test set of 45 real images.

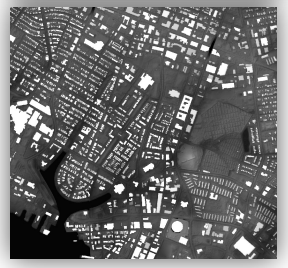




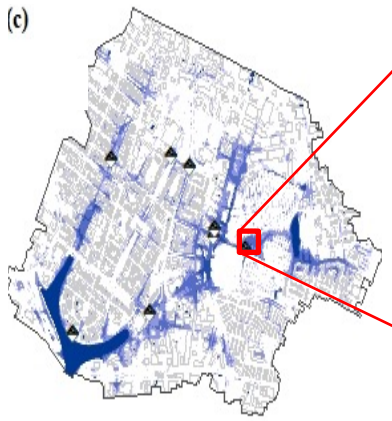
Project Update

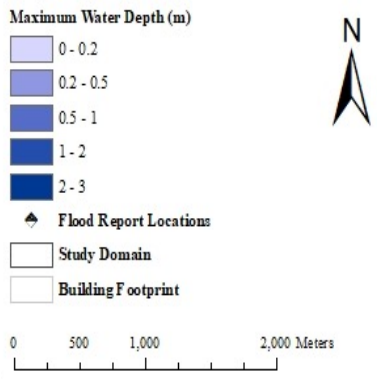
Machine Learning Surrogate Models for Coastal Urban Flooding



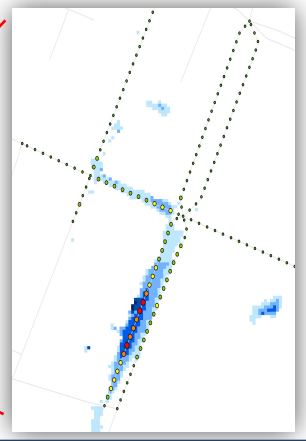


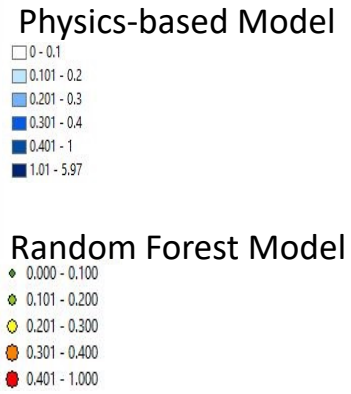
Street-Scale physics-based model for rainfall-driven flooding





Train Random Forest model with the physics- based model output

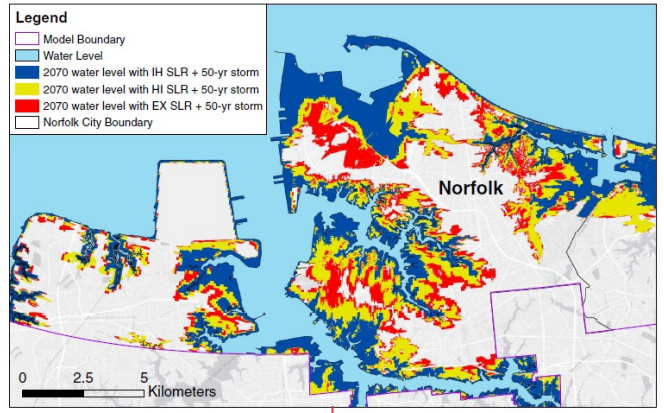




- Random Forest model: 3,000x speedup compared to physics-based rainfall-driven flood model
- Total flood level = rainfall-driven flow+tides+storm surge
- Similar speedup is expected from a ML surrogate model of the physics-based coastal hydrodynamics model, motivating the future work.
- Future work: develop a ML model for total flood level

Future work:

Region-Scale Physics-based Coastal Hydrodynamics Model for Storm Tides



Train

ML Storm Tide Model

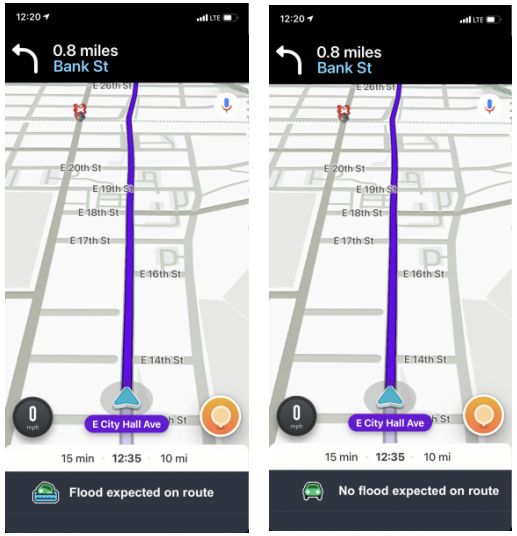
Boundary Conditions

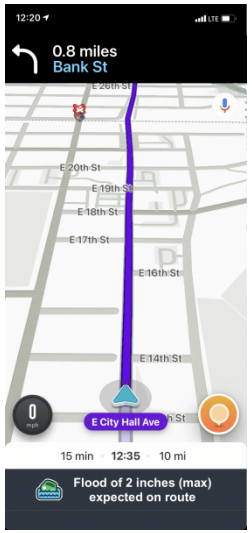
ML Model for Urban Flooding

Real-time Forecast of Total Water Level

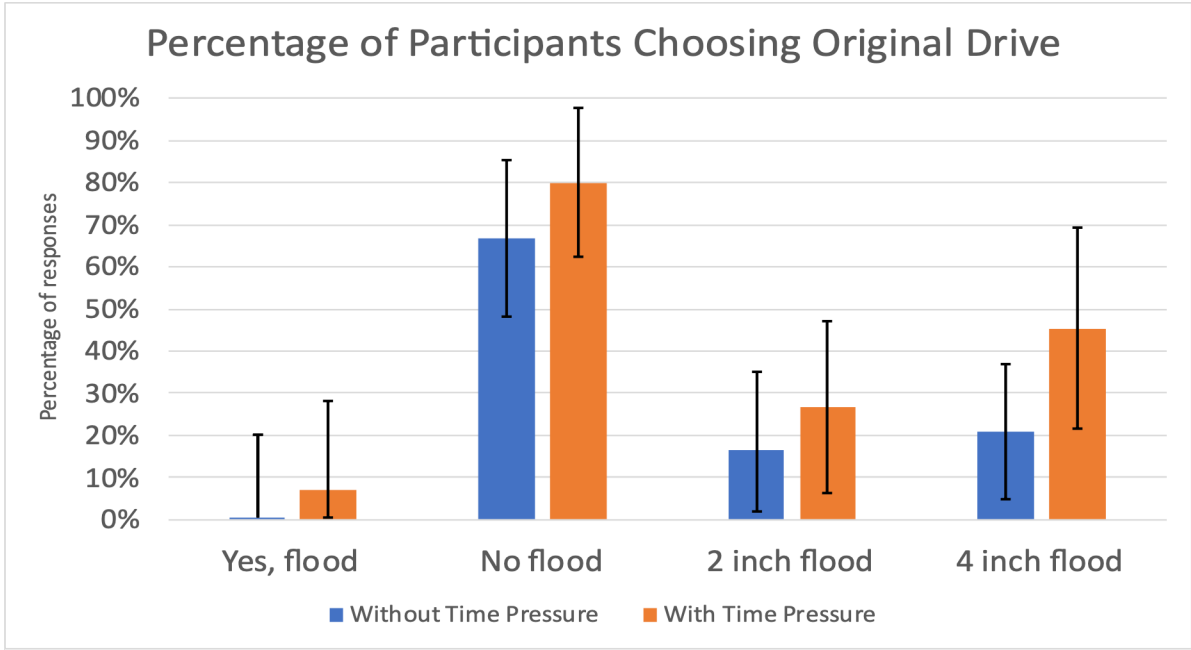
Project Update

Communicating Flood Information to Road Users





- **Purpose:** to examined the effects of time pressure and flood information type on the planned actions of road users
- **Method:** Participants were presented with a short driving scenario and a flood warning given by "Waze". They then were to decide what they would do in their situation.
- **Results:**



Project Evolution

- *We learned that the road-side camara mounted to a major intersection (planned for this study) in Norfolk are not owned by our partner City of Norfolk. Thus, we plan to reach out to Dominion Power to access the roadside electric distribution pole for power and mounting visual camera for this project.*

Anticipated outcomes & success measures for next year

- Collection of vehicle trajectory data on partially inundated roadway segments (needed for studying traffic flow behavior).
- Realistic rendering of the flooding simulation for synthetic data generation.
- Validation of online experiment results through more online and in-person driving-simulator experiments, with behavioral data and eye-tracking metrics.
- Data analysis to compare the effectiveness of different types of flood information and time pressure on road users' decision making and performance.
- Prepare and a journal paper on water depth estimation

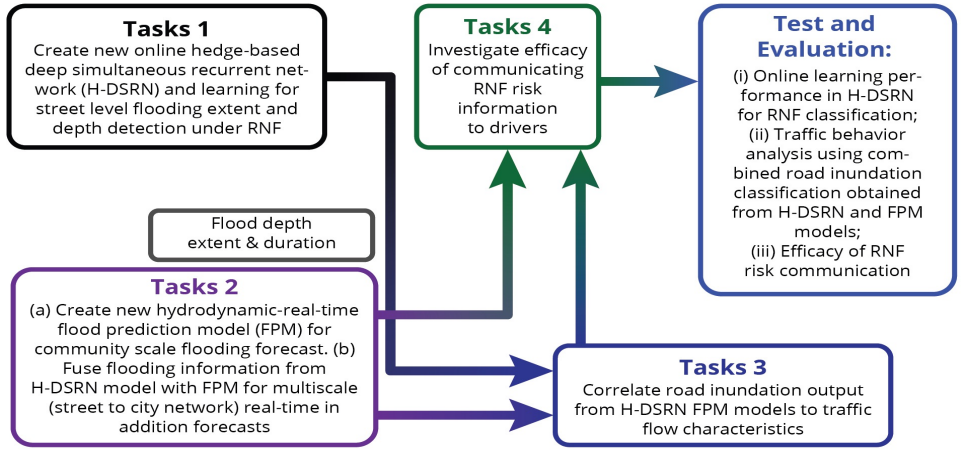
Scalable Modeling and Adaptive Real-time Trust Based Communication

NSF Project ID: 1951745

Khan Iftekharuddin, Old Dominion University

Award Type (SCC-IRG Track 2), Solicitation Year (FY2020)

Visual Schematic



Project Vision

- Develop a Scalable Modeling and Adaptive Real-time Trust-based communication (SMARTc) system for roadway inundation detection and monitoring
- Evaluate the system for a flood-prone region in the City of Norfolk, Virginia using data from the City's cameras, tide gauges, and existing and new overland water level sensors in the field

Use-Inspired Research

Recurrent nuisance flooding on Norfolk's roadways and neighborhoods becoming more frequent yet there is no effective solution to monitor and predict the extent and depth of the floodwater. Kyle Spencer, Deputy Resilient Officer at the City of Norfolk, and RISE – a non-profit organization in Norfolk – are committed to helping the coastal communities adapt to rising seas and frequent flooding through innovation and new technologies.

Fundamental Research Contributions

- Near real-time learning models for street-scale RNF extent and depth recognition from image data
- improved community-scale road network flood prediction model for RNF extent, depth, and flood duration using City camera, other sensor data, and predictions from hydrodynamic models
- improved microscopic car-following models for partially flooded roadway segments so that the capacities and bottlenecks may be estimated and characterized accurately in near real-time
- Effective risk communication strategies for drivers using the RNF extent, and depth