Flood Digital Twin to Measure Risk Perception in Urban Environments

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Introduction

Floods: A Global Threat

- ❖ Most frequent weather hazard worldwide.
- ❖ The natural disaster with the highest economic impact.
- ❖ Increasing frequency:
  - ➢ 223 flood events in 2021, exceeding the annual average of 163.
  - ➢ Nearly 5,000 flood events in the U.S. in the past 20 years
- ❖ Available flood depth estimation tools do not provide real-time and accurate information in urban areas for the general public.

Flood in London, UK(Jul 2021)
Credit: London Fire Bridge/ Twitter

Flood in Lanchyn, Ukraine (Sep 2020)
Credit: Emergency Situation Ministry, Vis Associated press

The Need for Improved Risk Communication

- ❖ Timely and accurate information is crucial for:
  - ➢ Effective response and recovery.
  - ➢ Flood mitigation efforts.
  - ➢ Protecting lives and property.
- ❖ Traditional methods may overlook public perception and concern.

VR Simulation: A Promising Approach

- ❖ Offers a safe and controlled environment to mimic flood risks.
- ❖ Can be used to investigate and improve flood risk perception.

Flood Risk Perception:
More Than Just the Numbers

- ❖ Experts assess real flood risk through hazard, exposure, and community factors.
- ❖ But individual experiences, knowledge, and social influences shape how people perceive that risk.
- ❖ This "perceived risk" of floods is how people understand and react to potential flooding.

Why Perception Matters

- ➢ People's perception of flood risk can affect their behavior and choices.
- ➢ Disaster response and policies are increasingly considering risk perception.

What Shapes Perception?

Rationalism	Constructivism
Focuses on cognitive process Based on situation	Focuses on sociological factors Based on social structure and cultures

Objectives

Our Research Focus on:

❖Understanding how immersive VR experiences influence human perception of flood risk.

❖This research builds upon our existing AI-powered flood water depth estimation tool.

❖By understanding risk perception, we can design better decision-support tools for flood evacuation.

Methodology

VR environment

- ❖ Unity Engine
- ❖ Gaming CPU and GPU
- ❖ VR equipment: VR headset (Oculus Rift)

VR environment perspective view

VR equipment

Participants

❖Participant Recruitment and Criteria:
- ➢ Texas A&M University
- ➢ Aged 18 years or older.

❖Participant Enrollment:
- ➢ 66 interested.
- ➢ 51 participated.

❖Data Collection Timeline:
- ➢ Start: February 2023.
- ➢ End: April 2023.

❖Study Procedure:
- ➢ Participant completed three study parts on the day of their session:
  - ❑ Pre-survey
  - ❑VR Experiment (5 minutes)
  - ❑Post-survey:

User Studies

Building

Fire hydrant

Car

Tree

Stop sign

Acknowledgment

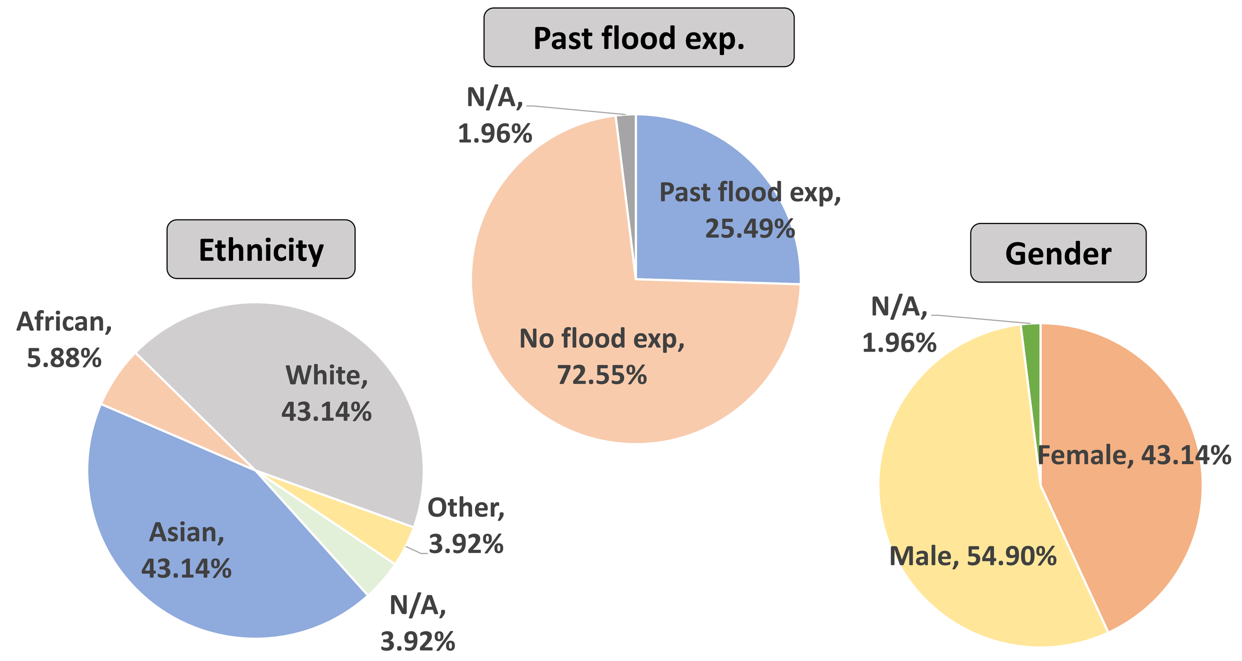
CIBER lab

Blupix app

Analysis and Results

Before the VR experiment: Pre-survey
(10-minutes)

- ❖**Evacuation form:** 55.56% on foot and 33.33% used some type of boat
- ❖**Source of information:** News (37.1%), flood gauges (20%), local measurements (20%), social media (17.1%), and FEMA flood maps (8.6%), no source (14.3%), past experience (2.9%)
- ❖**Mobile data connectivity interruption in floods**: Yes (50%), No (50%)
- ❖**Location**: All reside in College Station, Texas, US



After the VR experiment: Post-Survey
(5-minutes)

- ❖ Rank the urban landmarks based on their frequency of use
- ❖ Rank the urban landmarks based on their visibility

Results based on a 5-point Likert scale

Object	Car	Stop Sign	Fire Hydrant	Building	Tree
Most recognized	4.45	3.37	1.73	2.90	2.55
Most used	4.61	3.22	1.96	2.57	2.65

Statistical Analysis

- ❖ **Testing factors:**
  - ➢ Average flood depth estimation error (Ave FDEE)
  - ➢ Standard deviation flood depth estimation error (St dev FDEE)
- ❖ **Software**: SPSS
- ❖ **Independent variables:**

Age | Gender | Ethnicity | Past flood experience | Most used object | Average flood level

Test	Variable	Groups	N	Significance (One-sided) Ave. FDEE	Significance (One-sided) St dev. FDEE
ANOVA test	Ethnicity	White	22	0.034*	0.048*
		African	3		
		Asian	22		
		Other	2		

*** Indicates $p < 0.05$**

Presented by

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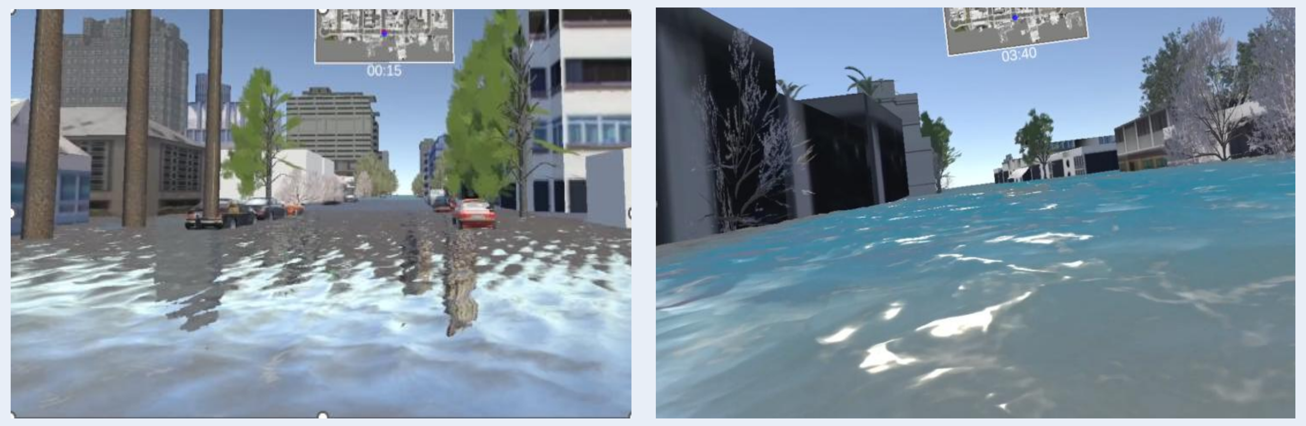

First-person view (as seen through the VR headset) of the flood simulation

Subgroup Analysis:

2 subgroups

- ❖ **Under estimators** (mostly positive FDEE)
- ❖ **Over estimators** (mostly negative FDEE)

❑ **Independent variables:**

Age | Gender | Ethnicity | Past flood experience | Most used object | Average flood level

Test	IV	Groups	N	Significance (One sided) (Under estimators) Ave. FDEE	Significance (One sided) (Under estimators) St dev. FDEE	N	Significance (One sided) (Over estimators) Ave. FDEE	Significance (One sided) (Over estimators) St dev. FDEE
t-test/ Mann-Whitney test	Gender	Male	11	0.041*	0.053	17	0.376	0.101
		Female	10			12		
ANOVA test/Kruskal Wallis test	Ethnicity	White or Caucasian	11	0.668	0.048*	11	0.604	0.599
		Black or African American	3			0		
		Asian or Pacific Islander	6			16		
		Multiethnicity or Other	1			1		

*** Indicates $p < 0.05$**

Conclusion

❖ **Key Findings**
- ➢ Cars were the most commonly used object for depth estimation in VR (may not be ideal in real-world scenarios).
- ➢ No significant difference in FDEE between objects used for estimation.
- ➢ Ethnicity showed a significant difference in FDEE:
  - ✓ Black/African American participants underestimated the most.
  - ✓ White/Caucasian participants underestimated the least.
  - ✓ More research needed for other ethnicity groups due to sample size.

❖**Future Work**
- ➢ Recruit a larger, more diverse sample outside university settings.
- ➢ Analyze the impact of various sociodemographic factors on risk perception.
- ➢ Gain insights into how different populations respond to flood risk.

References

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