Towards Internet of Things (IoT)-supported Mobile Augmented Reality

Maria Gorlatova

November 10, 2021

About the Speaker

- Nortel Networks Assistant Professor, ECE/CS, Duke University
- Previously:
  - Associate Research Scholar, Princeton University, Electrical Engineering
  - Ph.D. Columbia University, Electrical Engineering
  - Industry positions:

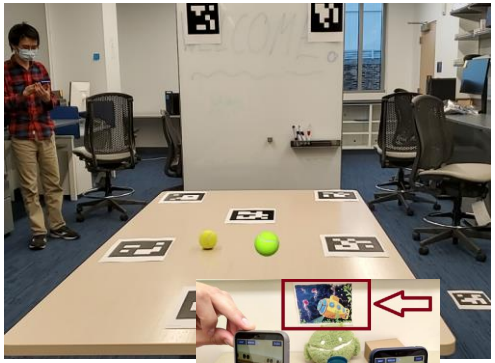
Telcordia Technologies

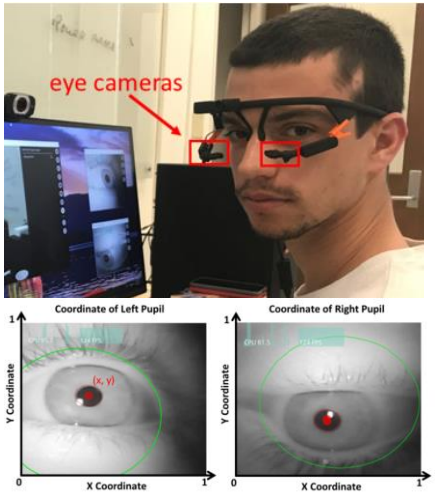
D E Shaw Research

IBM

Duke University Intelligent Interactive Internet of Things (I^3T) Lab

- Core research direction: reliable context-aware mobile AR





NSF

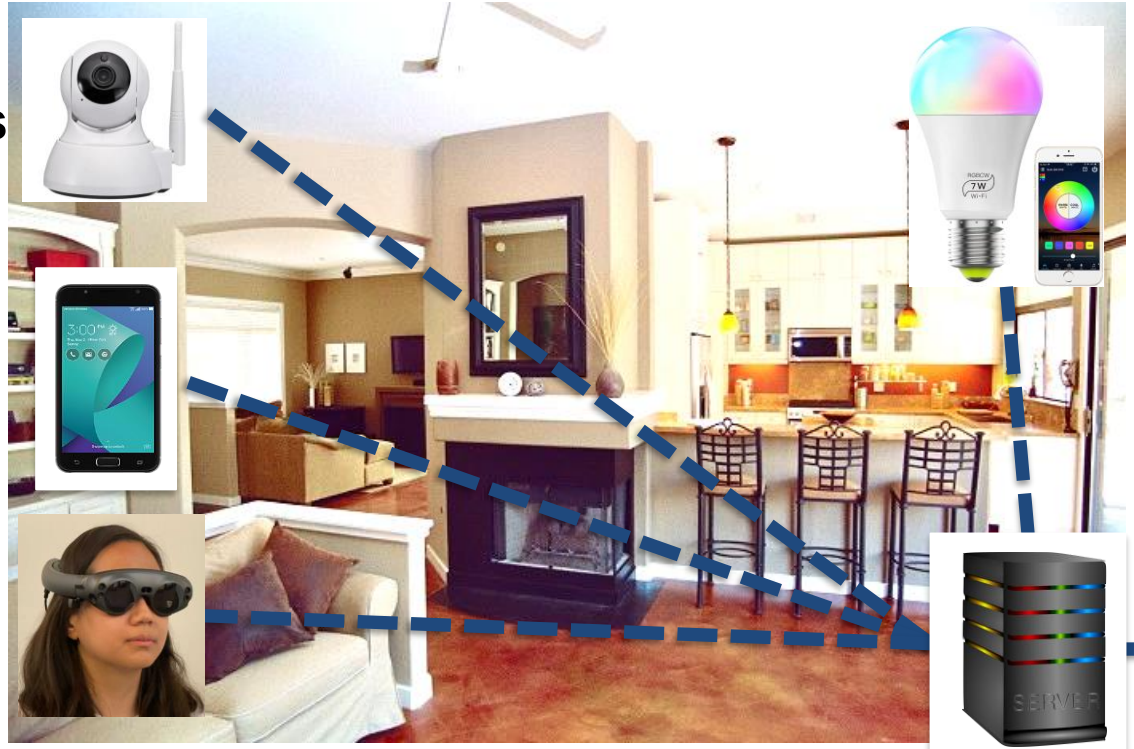
North Carolina Lord Foundation

aws

DARPA

IBM

IoT-supported Mobile AR



Smart cameras

Mobile AR devices

Smart lights, shades, displays

Edge server

Cloud

Mobile AR: Current State and Limitations

Already: impressive capabilities in
merging physical and digital worlds

AR-assisted surgery

AR in an art gallery

Limitations:

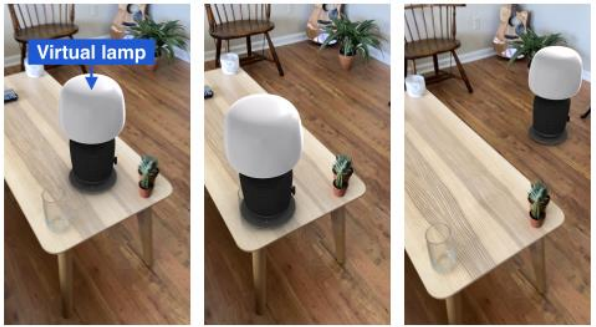
- Resource consumption
- Errors in **semantic and spatial awareness**
- …

❑ Demo video: Cognitive context-adaptive AR in an art gallery: https://sites.duke.edu/timscargill/ar-art-gallery/

Failures in Semantic & Spatial Awareness

- **Semantic errors**: incorrect holograms rendered
- **Spatial errors**: holograms rendered in the wrong place

Incorrect scale

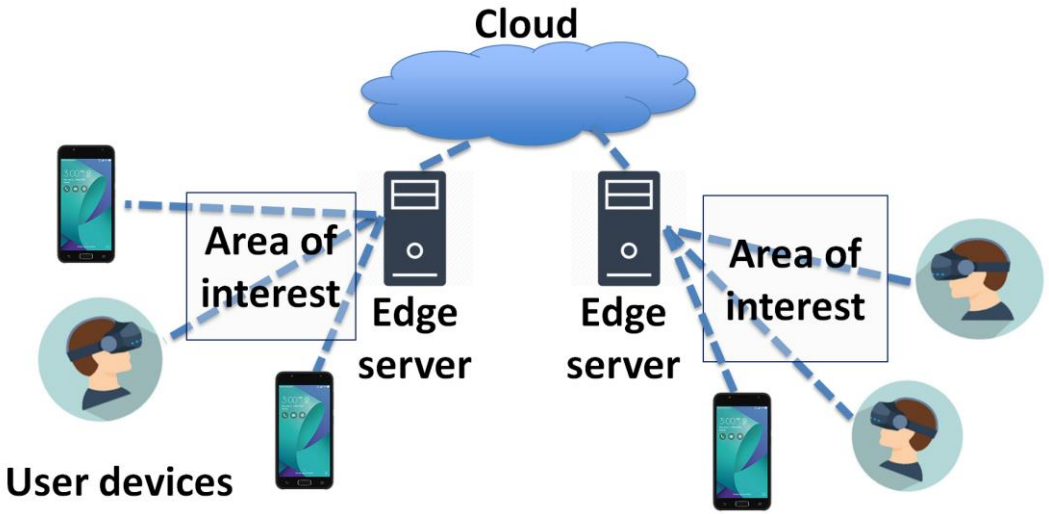


Unintended motion (drift)

Major improvements are required to make mobile AR reliable

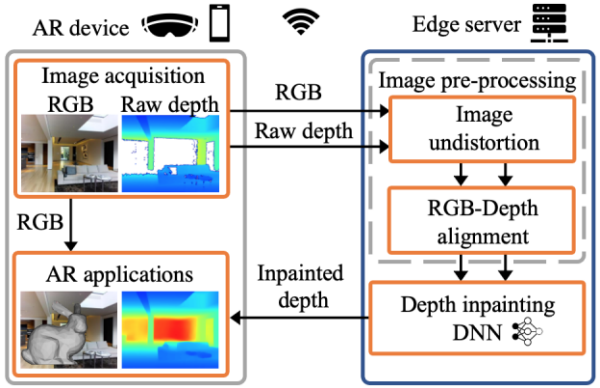
❑ T. Scargill, J. Chen, M. Gorlatova, Here to Stay: Measuring Hologram Stability in Markerless Smartphone Augmented Reality. arXiv: 2109.14757, Sept. 2021.

Edge Computing-supported Mobile AR

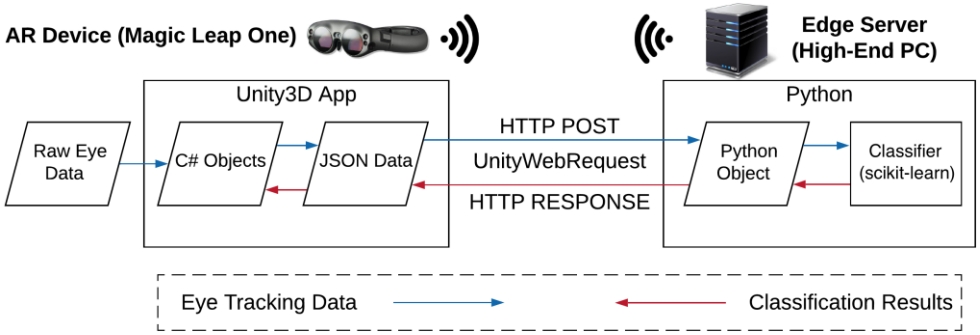


- **Edge computing**: providing computing services close to mobile AR devices

Edge Computing-supported Mobile AR



Edge computing for depth data inpainting



Edge computing for gaze-based cognitive context detection

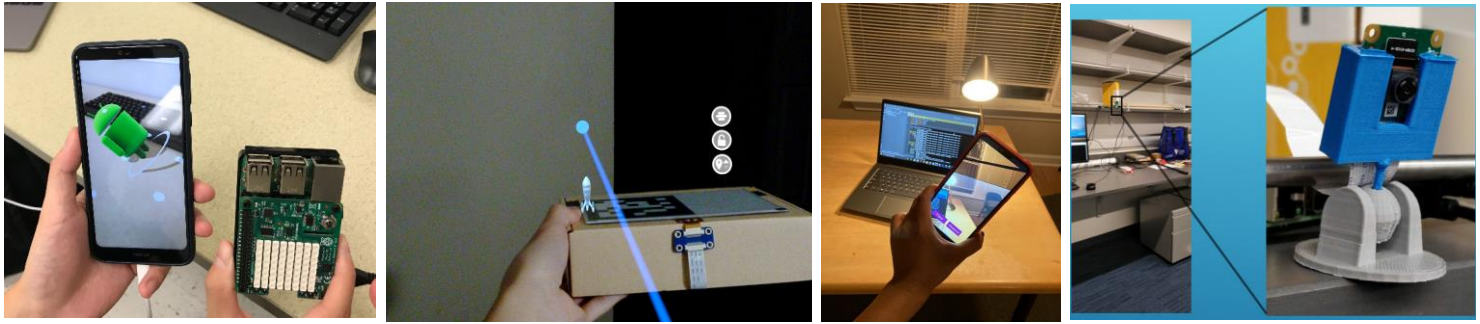
- X. Ran, C. Slocum, Y.-Z. Tsai, K. Apicharttrisorn, M. Gorlatova, J. Chen, Multi-User Augmented Reality with Communication Efficient and Spatially Consistent Virtual Objects, in *Proc. ACM CoNEXT'20*, Dec. 2020.
- G. Lan, B. Heit, T. Scargill, M. Gorlatova, GazeGraph: Graph-based Few-Shot Cognitive Context Sensing from Human Visual Behavior, in *Proc. ACM SenSys'20*, Nov. 2020.

IoT-supported Mobile AR

- Edge computing for interfacing with IoT devices
- IoT **sensors** and **actuators** supporting mobile AR in developing environmental awareness
  - Persistent environmental monitoring
  - Environmental control

Integrated AR+Edge+IoT Platforms

- Mobile AR ↔ Edge ↔ IoT connectivity can be readily established



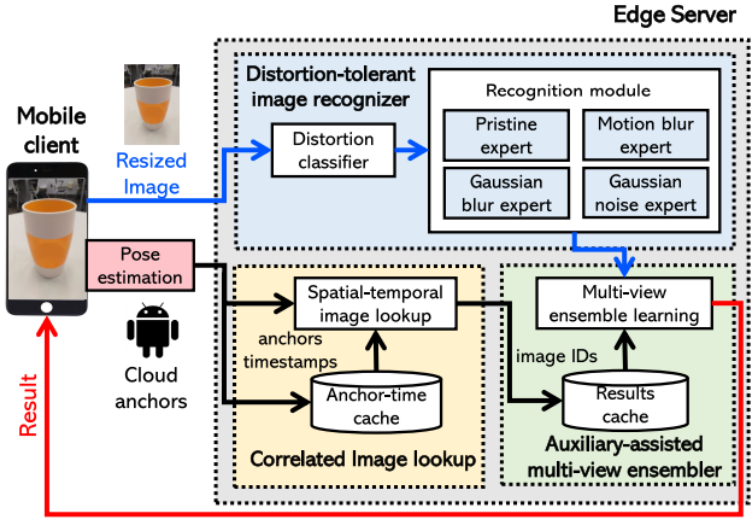
Different IoT sensors and actuators integrated with mobile AR platforms

Challenges include:

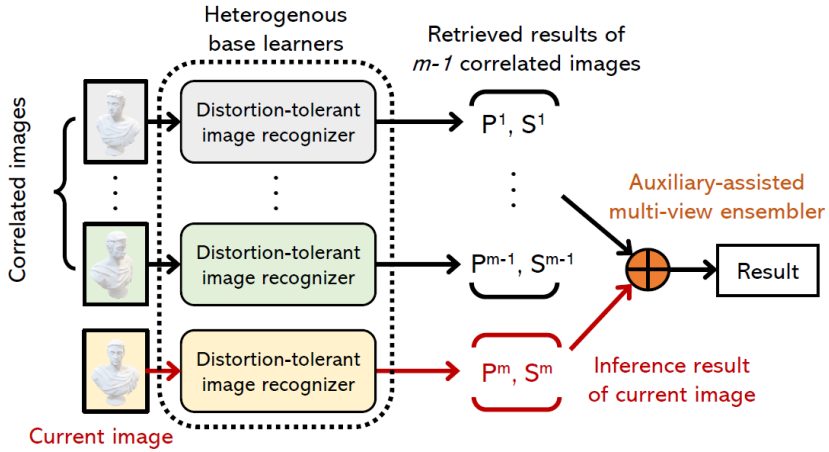
- Low-end IoT devices' spatial awareness
- Learning the extent of environment controllability

New Algorithms: Exploiting Multiple Views of the Same Scene

- DNN-based image recognition enables seamless contextual AR
- Challenge: DNNs make mistakes
  - ➢ Distortions, occlusions, non-standard object poses
- Multiple views of a scene can help



CollabAR: Collaborative Image Recognition for Mobile AR



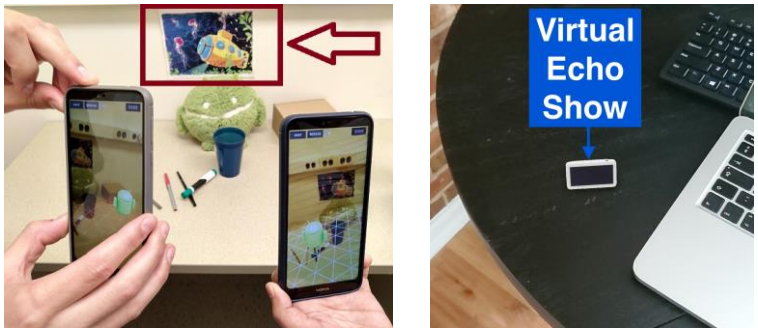
Auxiliary-assisted Multiview Ensemble Learning

- Improves recognition accuracy by 16% to 20% in severe distortions scenario
- Many other opportunities to exploit IoT cameras for semantic awareness

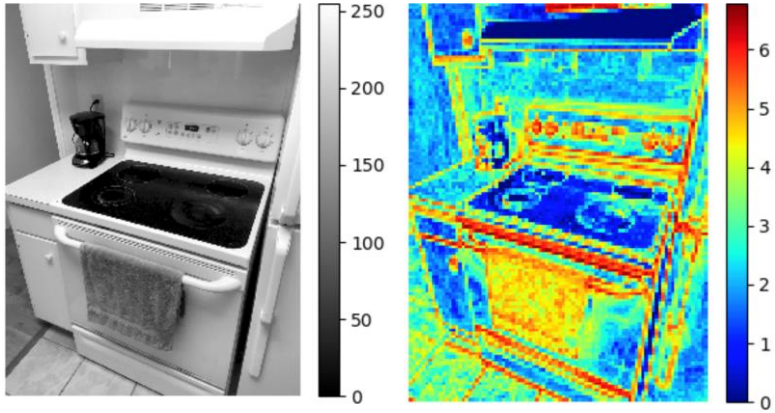
- G. Lan, Z. Liu, Y. Zhang, T. Scargill, J. Stojkovic, C. Joe-Wong, M. Gorlatova, Edge-assisted Collaborative Image Recognition for Mobile Augmented Reality, to appear in the *ACM Transactions on Sensor Networks*, Vol. 18, No 1, Feb. 2022.
- Z. Liu, G. Lan, J. Stojkovic, Y. Zhang, C. Joe-Wong, M. Gorlatova, CollabAR: Edge-assisted Collaborative Image Recognition for Mobile Augmented Reality, in Proc. *IEEE/ACM IPSN'20*, April 2020. **IEEE/ACM IPSN Best Research Artifact Award.**

New Algorithms: Scene Characterization for Spatial Awareness in Mobile AR

- Challenge: automatically detecting and *quantifying* conditions that cause spatial artifacts



Featureless (left) and dark (right) scenes are associated with spatial artifacts



Featureless areas have low entropy

❑ T. Scargill, S. Hurli, J. Chen, M. Gorlatova, Demo: Will it Move? Indoor Scene Characterization for Hologram Stability in Mobile AR, in *Proc. ACM HotMobile'21*, Feb. 2021.

Summary

- Modern mobile AR has limitations in environmental awareness
  - ➢ Semantic, spatial awareness
- IoT sensors and actuators can help

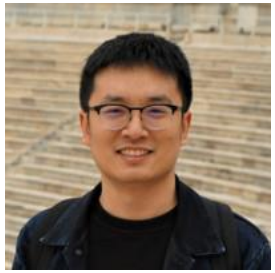
- Developing platforms and algorithms to enable this vision

Acknowledgements

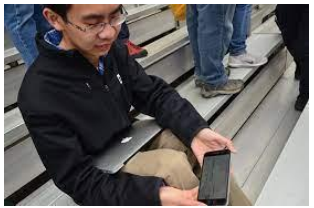








North Carolina Lord Foundation

Questions?

- E-mail the speaker: maria.gorlatova@duke.edu