MAS.S66 Computational Wireless Sensing

Lecture 9: Liquid Sensing





Lecture Outline

- **Overview & Motivation for liquid sensing** ightarrow
- LiquID ightarrow
- CapCam
- RFIQ ightarrow
- Comparison between technologies ightarrow
- Project updates

Liquid Sensing Applications

- Food safety (fake alcohol, baby formula, water)
- Product counterfeiting
- Fake Medicine
- Security (at airports)





The Washington Post Democracy Dies in Darkness

Morning Mix

In Flint, Mich., there's so much lead in children's blood that a state of emergency is declared

By Yanan Wang





The New Hork Times

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ASIA PACIFIC

China's Top Food Quality Official Resigns

By DAVID BARBOZA SEPT. 22, 2008



A baby suffering from kidney stones after drinking tainted formula was treated Monday at a hospital in Chengdu, China. China Photos, via Getty Images

SHANGHAI – The chief of China's food and product quality agency was forced to resign Monday in a growing scandal over the country's tainted milk supply, which has already sickened more than 50,000 infants and killed at least three children_according to the state-run Xinhua news agency.

How is food/liquid safety testing performed today? Electrochemical Tests RF Spectroscopy



•1884, MIT, Chemist Ellen Swallow Richards



<u>Goal:</u> Leverage low-cost, ubiquitous technologies to for liquid sensing (for everyone)

- Low-cost UWB radios: LiquID [MobiSys'18]
- RFID near-field: RFIQ [HotNets'18]
- Sensor fusion (camera+vibrations): CapCam [MobiSys'19]

RFIQ Challenges



Challenge 1: How can we sense the material without even being in contact with it?

Challenge 2: How can we distinguish the impact of the material inside the bottle from that of multipat?

RFID Sticker Spectroscopy

We developed a system that uses the RFID stickers already on hundreds of billions of items



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to sense properties of food in closed containers

We developed a system that uses the RFID stickers already on hundreds of billions of items

Material

Air

RFID wirelessly interacts with material inside the bottle



Challenge: Dielectric sensing requires measuring the response over a large bandwidth

RFIDs are designed to be narrowband (to optimize energy-harvesting)

Build on two-frequency excitation from RFind [MobiCom'17] which can sense a bandwidth 10,000x larger than their communication bandwidth

without any hardware modification to the RFIDs

Prototype Implementation

RFID reader implemented on software radios (USRP)

Off-the-shelf RFID sticker

Two-frequency excitation setup (400-800MHz)

How can we distinguish the impact of the material inside the bottle from that of the environment?

Multipath vs. Near-field coupling

Constructive & destructive interference Multipath across different frequencies

Near-field Coupling



Shifts the center frequency of operation



Train machine learning model to identify adulterants based on these features

Peak @ 950MHZ 1000

Can RFIQ detect tainted alcohol? Pure Prepared alcohol mixtures with different compositions

Actual



- 150 experimental trials
- 10-fold cross-validation



Can RFIQ detect adulterated infant formula? Pure

Actual

Prepared infant formula mixtures with different compositions



- 80 experimental trials
- 5-fold cross-validation



Caveats (aka Open Questions)

- Testing and training were performed on similar compositions • How well would this perform on untrained mixture composition?
- Focused on fixed adulterant and fixed food of interest
 - Would like to generalize to different food and contaminants
- Demonstrated robustness to limited environmental changes
 - Can this really work with significant multipath changes?

