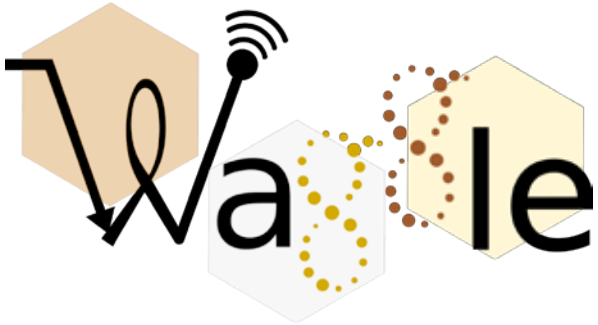


Environmental Sensing at the Edge: Waggle and the Array of Things

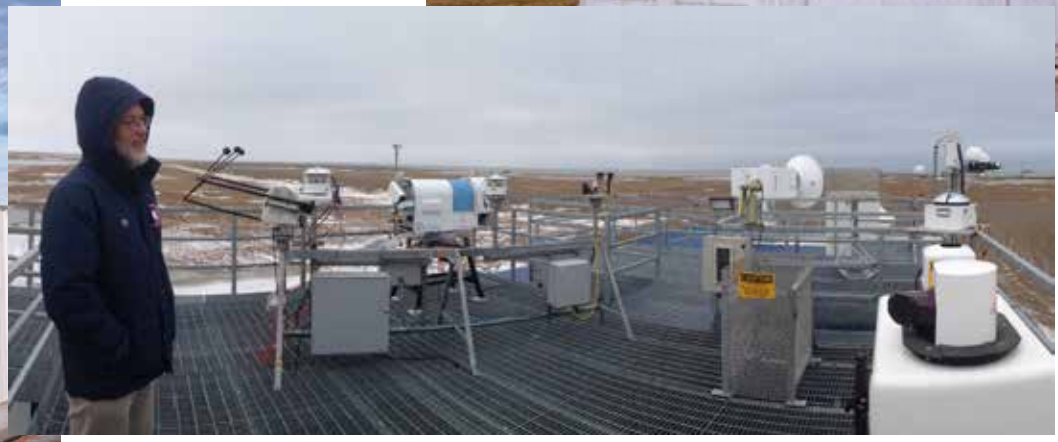
Pete Beckman

Co-Director, Northwestern Univ. / Argonne Institute for Science and Engineering

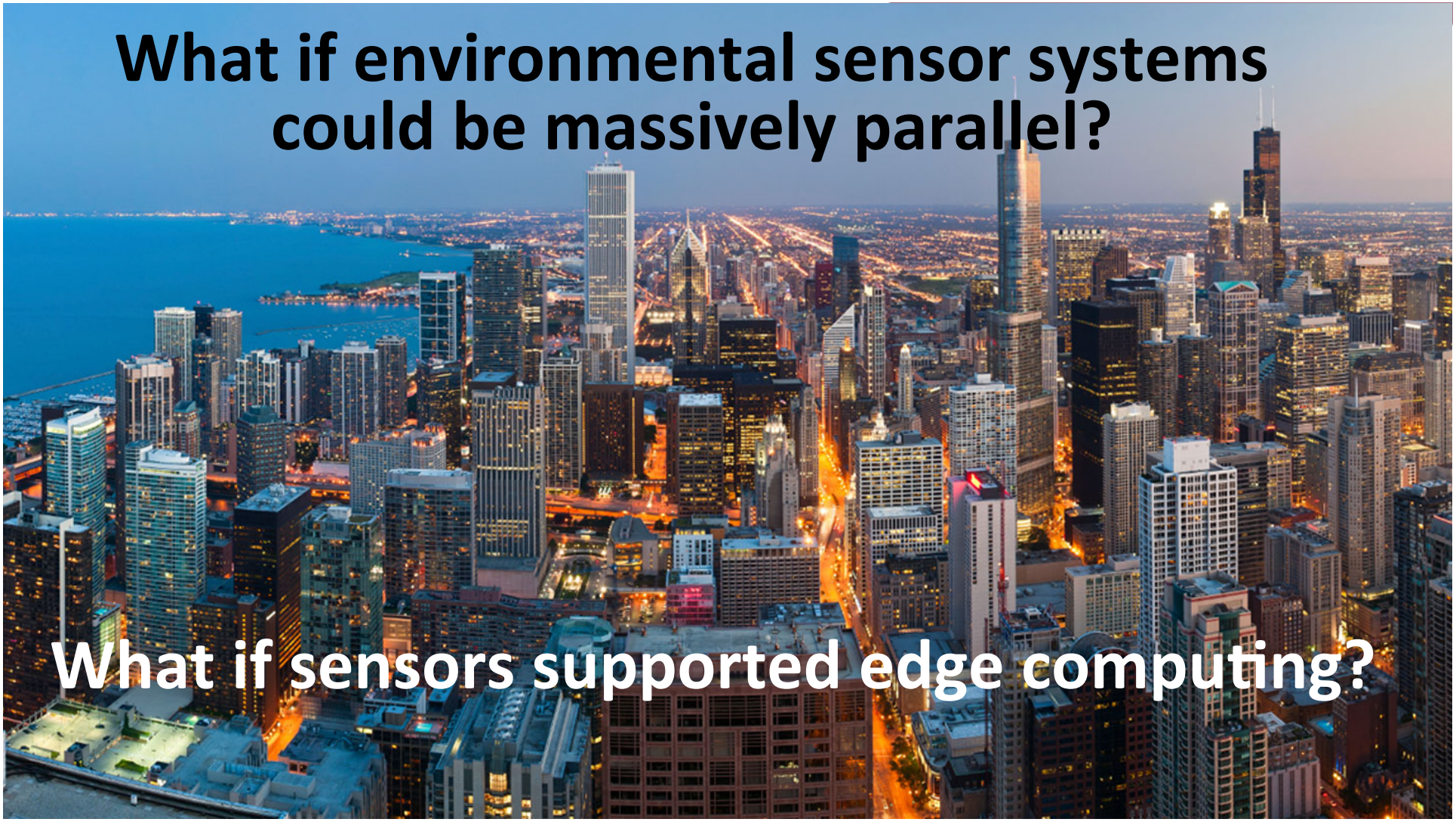
Senior Computer Scientist, Argonne National Laboratory

Collaborators: Charlie Catlett, Rajesh Sankaran, Rob Jacob, and Nicola Ferrier

Big Sensor Science



Big, Expensive, Precise, Sparse


What if environmental sensor systems could be massively parallel?
What if sensors supported edge computing?

Waggle: An Open Platform for ***Intelligent*** Sensors

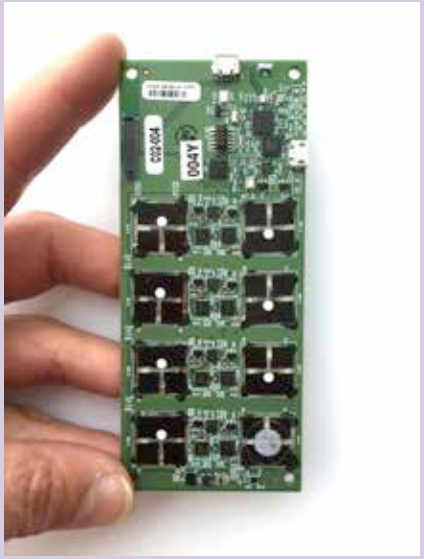
Exploiting Three areas of Disruptive Technology + "Deep Space Probe" design

Machine Learning

Computer Vision

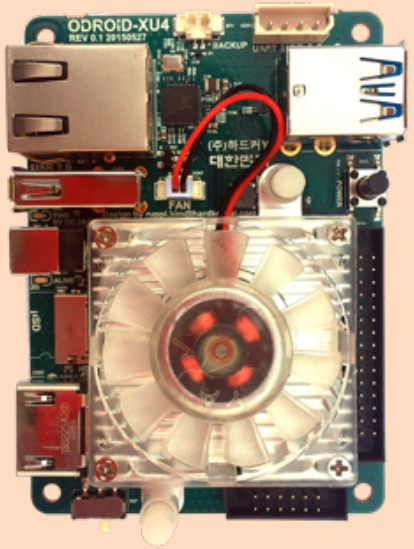
Novel Sensors

Nano / MEMS



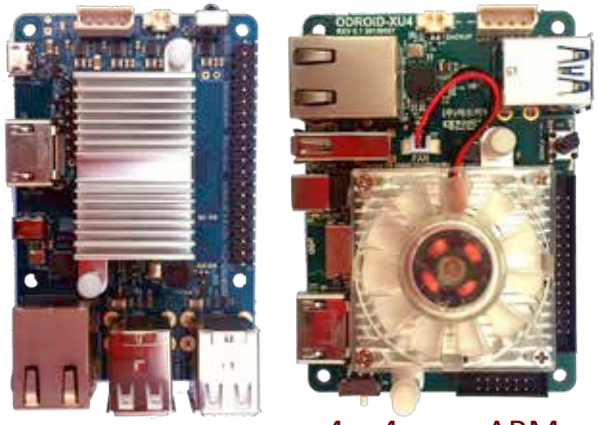
Edge Computing

GPU / Smartphones



Powerful, Resilient & Hackable

Multiple boot media (µSD / eMMC)



4-core ARM

4 + 4-core ARM
8-core GPU

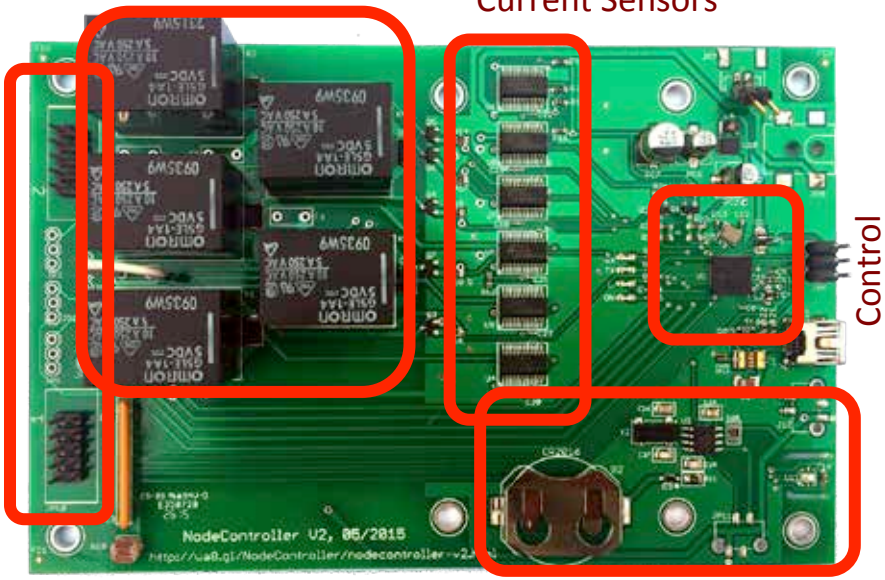
Node Control &
Communications

In-Situ / Edge
Processing

Linux Development Environment

Relays

Current Sensors



Real time clock & Internal sensors

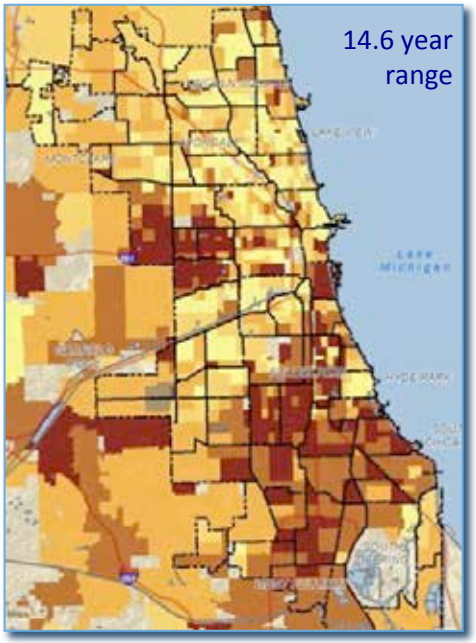
"Deep Space Probe" Design

The Array of Things

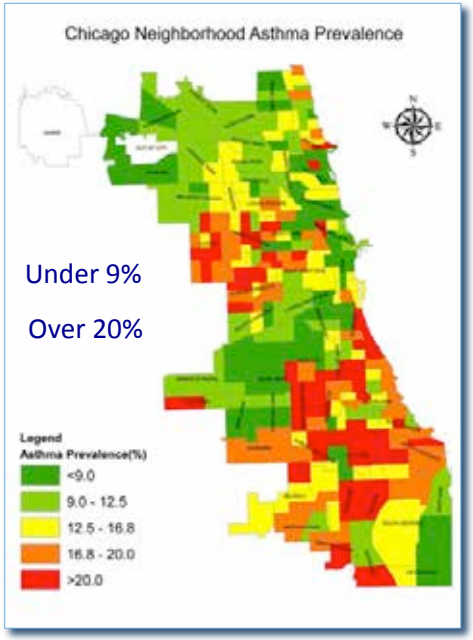
Charlie Catlett, Pete Beckman, Rob Jacob, Nicola Ferrier, Mike Papka, Rajesh Sankaran, et. al.

THE UNIVERSITY OF CHICAGO
Argonne NATIONAL LABORATORY
URBAN CENTER FOR COMPUTATION AND DATA

Urban Challenges are Neighborhood-Specific



Life Expectancy

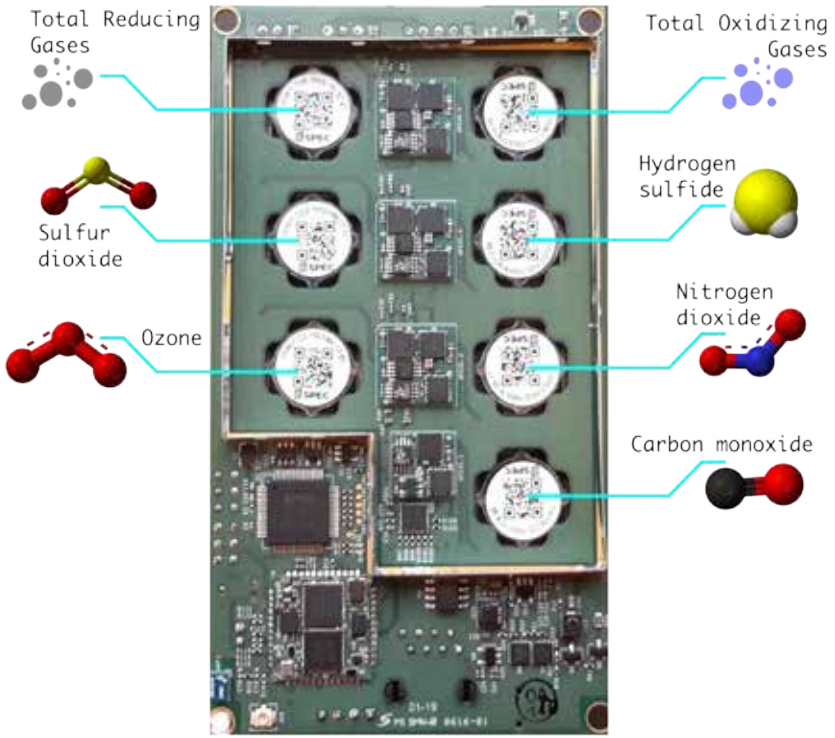


Asthma

Access to services

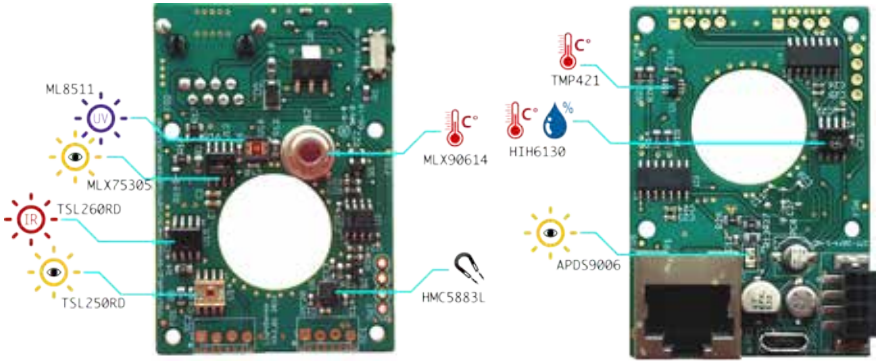
But many city challenges are hyper-local, and to diagnose and address them requires much better measurement strategies.

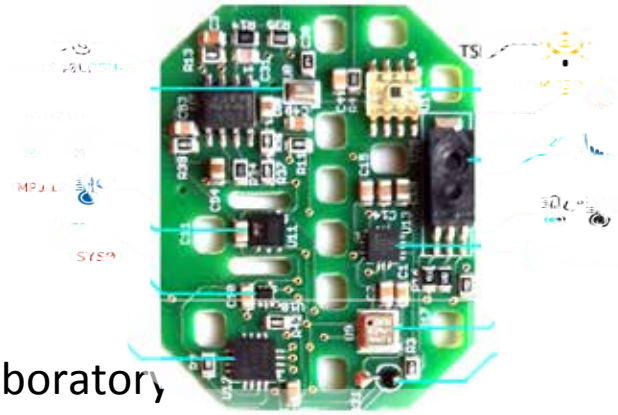
AoT Nodes are going up in Chicago

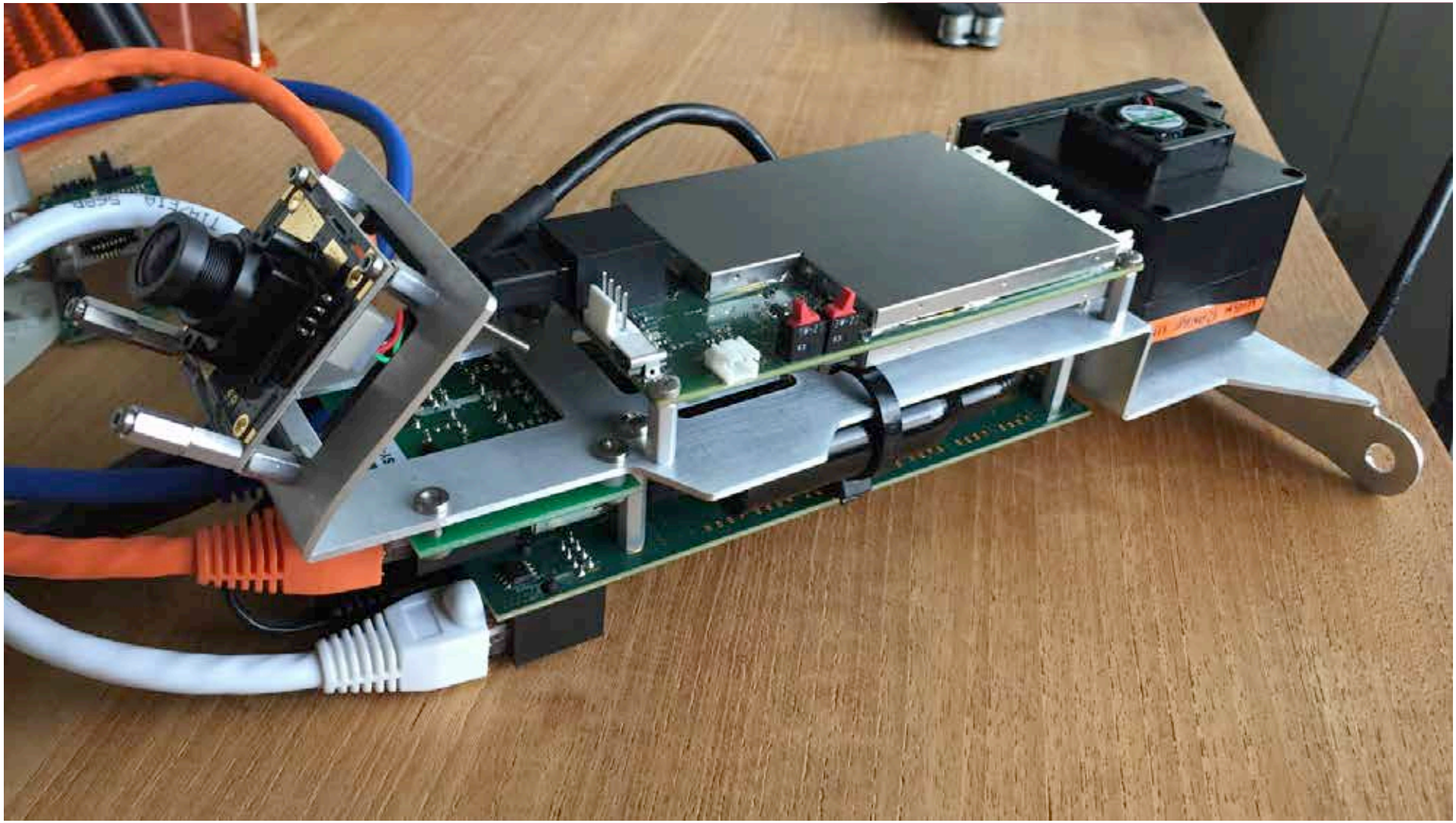


Chemical Sensors

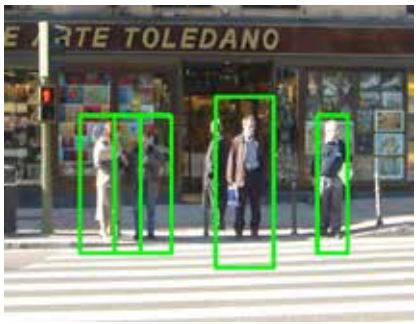
Physical Sensors







Computer Vision Research: Tracking Pedestrians



Detected pedestrians are captured by green bounding boxes

Tracking Experiment

Blue bounding box represents the pedestrian and red dot represents the centroid. The edge processor can send the centroid coordinates.

Research by (* using INRIA public dataset):

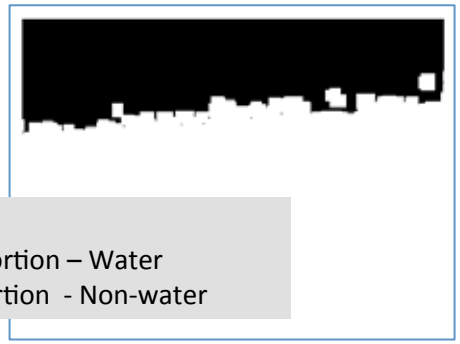
- **Zeeshan Nadir** (Purdue University)
- Ethan Trokie (Northwestern University)
- Nicola J. Ferrier (Argonne National Lab)

Computer Vision Research: Water Detection

Example of flood/pond water

Process 50 frames:

Extract the mode frame. Notice it captures all the reflections and stationary objects.



Legend:
White Portion – Water
Black Portion - Non-water

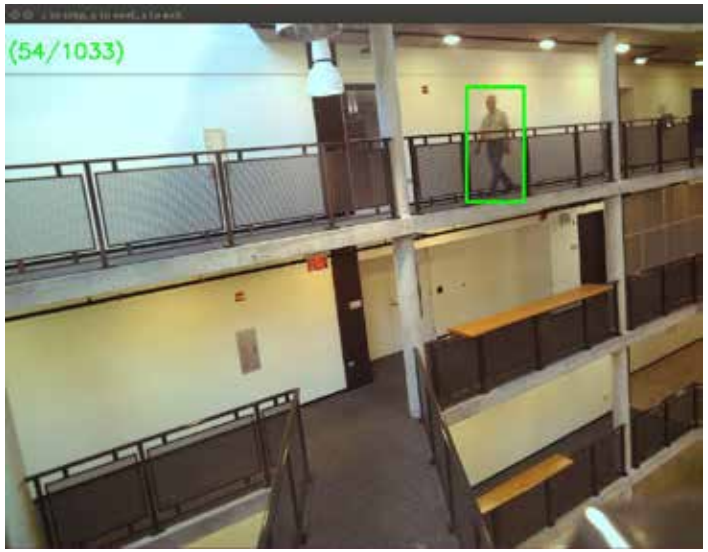
Automated water/non-water segmentation

Ground Truth (human)

Research by:

- Zeeshan Nadir (Purdue University)
- **Ethan Trokie** (Northwestern University)
- Nicola J. Ferrier (Argonne National Lab)

Computer Vision Research: Counting People



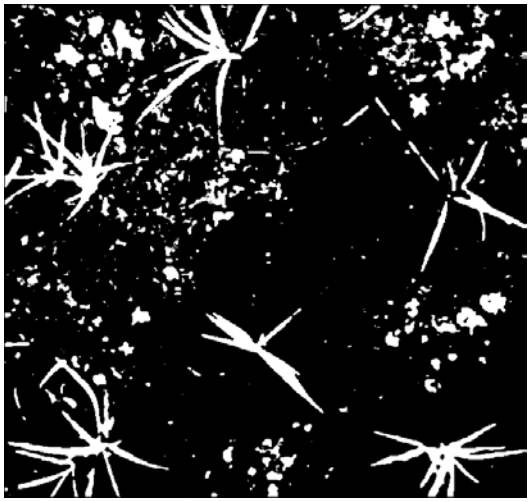
Detection uses OpenCV HOG descriptor and linear SVM. Detection size (window size) is (64, 128). The detector is written in Python and for 640x480 image, performs about 3 images/sec on current Waggle Edge processor.

Research by:

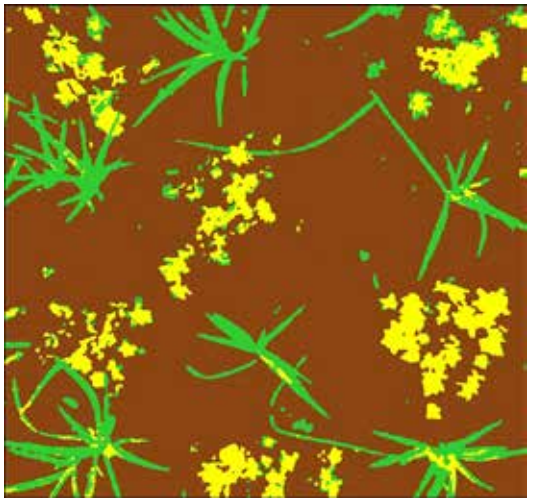
1. **Yongho Kim** (Purdue University)
2. Nicola J. Ferrier (Argonne National Lab)

Computer Vision Research: Vegetation Growth

Original



Single Mean Model

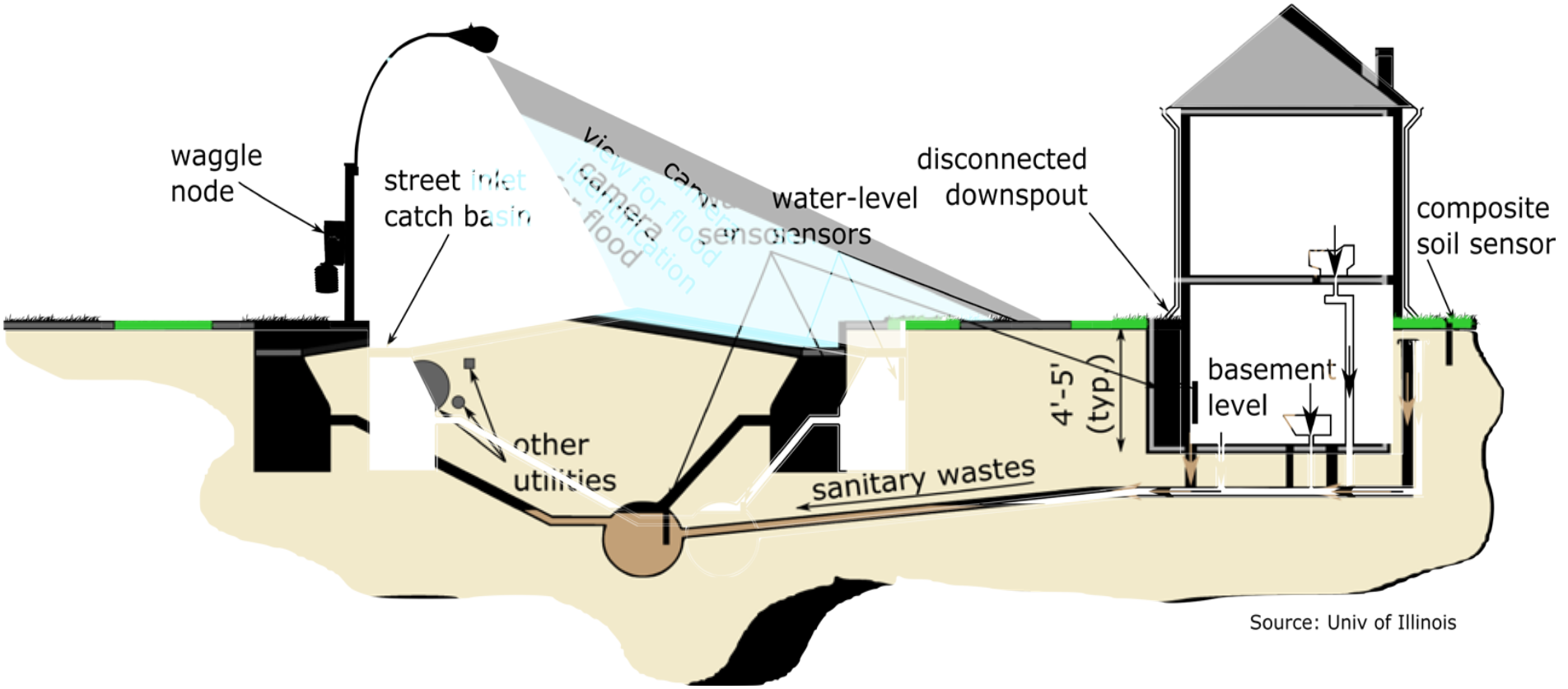


Mixture Model

Research by:

- **Renee Zha** (Northwestern University)
- Zeeshan Nadir (Purdue University)
- Cristina Negri (Argonne National Lab)


When my property flooded
I lost my...
FAMILY ROOM, WATER HEATER
COLLEGE PAPERS, SPARE BEDROOM
FURNITURE, GARAGE SPACE


waggle
node
street inlet
catch basin
camera
water-level
sensors
disconnected
downspout
composite
soil sensor
4'-5'
(typ.)
basement
level
other
utilities
sanitary wastes
Source: Univ of Illinois


Work with David Lary, Udallas
Measure pollen in Chattanooga

Imagine Programmable Infrastructure

Examples from discussions with smart people about cities:

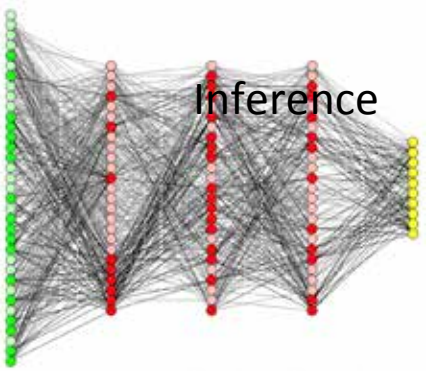
- Interesting Stops
- Diesel Truck Stops
- Bike Helmets
- Wildlife & QoL
- Audio quality of life
- Traffic Crowds
- Street water
- Collisions
- Pedestrian Misses
- Baby Strollers

All based on parallel computing & deep learning, advanced system software

Next Steps:
Edge Processing and Deep Learning With Feedback

Instruments

Parallel Computing



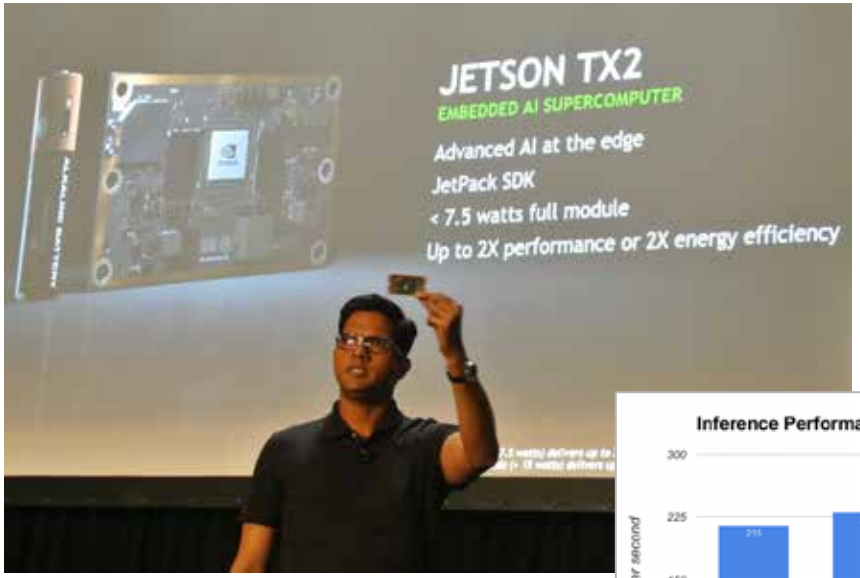
Reduced, Compressed data

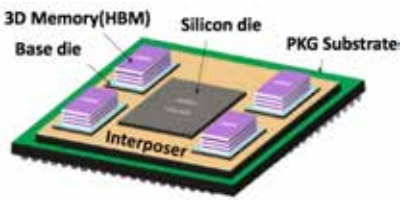
New classifiers (code)

HPC

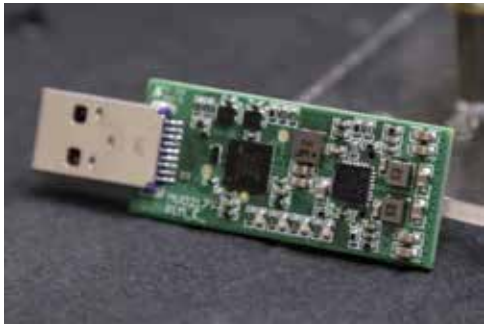
Deep Learning Training

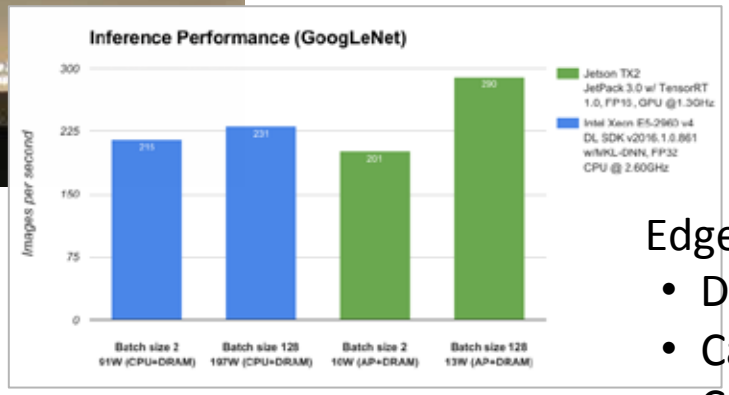
Hardware for Edge Computing is Rapidly Changing





Intel/Nervana





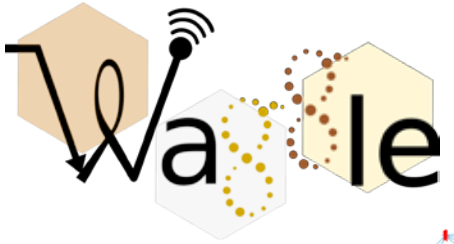
NVIDIA Jetson TX2 example:

- "AI at the edge"
- 256 Pascal cores
- ½ TF SP FLOPS

Edge Processing common:

- Drones
- Car collision detection system
- Camera systems

Questions?



http://www.wa8.gl

http://arrayofthings.github.io