How cities can become smarter: Sensors, Edge Computing, and The Array of Things

Charlie Catlett
Senior Research Scientist, Discovery Partners Institute, University of Illinois
Senior Computer Scientist, Argonne National Laboratory
Senior Fellow, Mansueto Institute, University of Chicago

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Collaborators:
Pete Beckman (ANL/NU)
Nicola Ferrier (ANL/UC)
Jim Olds (GMU)
Dan Reed (Utah)
Ilkay Altintas (UCSD)
Carlton Nolan (Chicago CIO)
Mike Papka (ANL/NIU)
Kathleen Cagney (UC)
Howard Nusbaum (UC)
Marc Berman (UC)
Mark Potosnak (DePaul)
Douglas Pancoast (School of the Art Inst of Chicago)
Daniel Work (Vanderbilt)
...and many more
Cities: Collections of Neighborhoods

Life expectancy
https://www.chicagohealthatlas.org/

Asthma

Access to services

Access to healthy food
Beginning in 2013 we asked scientists, residents, and city department heads and workers…

“What do you want to measure?”

**SENSORS**

**Environment**
- Solar load on buildings
- Traffic safety
- Idling trucks
- Construction effects
- Noise pollution/sources
- Urban heat island
- Mold exposure

**Air Quality**
- Asthma rates
- Traffic impact on AQ
- Industrial air pollutants
- Fossil fuel emissions
- Hydrogen sulfide
- Fuel leaks
- Flammable hazards

**OBSERVATIONS**

**Activity**
- Flooding
- Traffic flow & safety
- Pedestrian flow & safety
- Use patterns of public spaces
- Sources of noise pollution & noise events

Array of Things current sensor configuration includes sensors that were selected and developed based on five years of input from, and collaboration with, city officials, policymakers, residents, scientists, and students.
The “Array of Things” (AoT) was an NSF-funded Major Research Instrumentation project in partnership with the City of Chicago, led by the University of Chicago and Argonne National Laboratory. The underlying hardware and software used is Argonne’s Open WAGGLE platform. (wa8.gl)

Array of Things Measurements
(First units built and deployed in 2016)

Environment
- Ambient, UV, IR light
- Visibility
- Magnetic Field
- Vibration
- Sound pressure
- Temperature
- Relative humidity
- Barometric pressure

Air Quality
- PM 1, 2.5, 10
- Carbon monoxide
- Ozone
- Sulfur dioxide
- Nitrogen dioxide
- Hydrogen sulfide
- Total reducing gases
- Total oxidizing gases

Edge Computing or “AI at the Edge” Research:

Computer Vision: Flooding, traffic flow, safety (bike helmet use, pedestrian patterns…), use patterns of public spaces, cloud cover

Computer Audio: Noise components, sound events
Next steps on AQ – smaller, less expensive, ideally with edge AI


Chicago AoT Deployment

Next: Exploring 1-200 low-cost air quality units to place on bus shelters (JC Decaux operates 2100)

Installation Partners include:
- Chicago Department of Transportation (CDOT)
- Chicago Fleets & Facilities Management
- Crown Castle Communications
- Chicago Park District
- ComEd (Exelon)
- JC Decaux
All Data is Open and Free

- Nodes transmit sensor readings several times per minute.
- Only a limited volume of images and sound samples are transmitted*.
- Results of (pre-approved) image or sound processing (e.g., number of pedestrians or vehicles), done using AI-at-the-edge, are transmitted and published.

- For more information, policies, data tutorials, and data links, go to https://www.arrayofthings.org

*Several times per hour a sample image and sound clip are sent to a protected, controlled-access training library, which is only available to research teams under a data use agreement. See Privacy Policies at www.arrayofthings.org
Array of Things Operating Policies
August 15, 2016

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Proposers

Elissa Tevery
President, School of the Art Inst. of Chicago

Avi Scharg
Partner, Edison

Brenna Berman
CEO, CityTech

Carleton Nolan
COO, City of Chicago

Aaron Koch
Chicago Director, Trust for Public Land

Pete Beckman
Scientist, Northwestern

Don DeLoach
Chair, Midwest IoT Council

Scientific Review Group

Elissa Tevery
President, School of the Art Inst. of Chicago

Avi Scharg
Partner, Edison

Brenna Berman
CEO, CityTech

Carleton Nolan
COO, City of Chicago

Aaron Koch
Chicago Director, Trust for Public Land

Pete Beckman
Scientist, Northwestern

Don DeLoach
Chair, Midwest IoT Council

Technical Security & Privacy Group

Elissa Tevery
President, School of the Art Inst. of Chicago

Avi Scharg
Partner, Edison

Brenna Berman
CEO, CityTech

Carleton Nolan
COO, City of Chicago

Aaron Koch
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Guiding principles:
privacy, transparency, and openness

*How do we ensure that residents are enthusiastic, not just accepting (and certainly not opposed!)?
Edge Vision: Cameras and AoT@Edge

- 8 M Pixel Camera
- 5 M Pixel Camera
- FOV 75 degree
- FOV 170 degree
AI at the Edge

Why AI@Edge?
- Privacy
- Real-time decisions—adaptive and goal-oriented computing
- Latency
- Bandwidth limitations

Edge computing and deep learning with feedback for continuous improvement

Reduced, Compressed data
New inference (model)
Adaptive steering

Sensors
- LIDAR
- Hyperspectral Imaging

Facilities
- Software Defined Radios
- Servos
- Dynamic adaptation

Actuators

HPC

Source: Pete Beckman, Argonne National Laboratory and Northwestern University
Faces in these images are blurred for privacy.
Many Science Problems….
For example, new techniques using AI@edge for privacy, scene characterization (natural/urban; ordered/disordered) and understanding how different urban/natural environments impact health, cognition, crime, and other social and behavioral factors.
Looking To The Future: Programming The Computing Continuum

The Computing Continuum will be the future facility; it needs a run-time system and programming model.

Source: Pete Beckman, Argonne National Laboratory and Northwestern University
What does AI@Edge Cyberinfrastructure need?

A User-Driven, Science Architecture:

- Environmental, Social, & Data Scientists & Students
- Run Experiments at Edge & Modify Instruments
- Develop New Cyberinfrastructure for AI@Edge
- AI Algorithm Scientists

Sage Open Data

Schedule AI@Edge

Run at Edge

Write ML Code (PyTorch, TensorFlow, etc.)

Test on Edge nodes, Chameleon

Edge Code Library
Thank you

- **Discovery Partners Institute**
  - Identifying, Creating, Supporting Interdisciplinary Team Science

- **Beyond Array of Things: SAGE**
  - Building on lessons learned from the Array of Things (AoT) - an NSF-funded experimental instrument to explore the use edge-computing and of lower cost sensors to create new types of urban measurements.
  - SAGE: Software-Defined Sensor Network is an NSF Mid-Scale Research Infrastructure project seeking collaborators interested in AI@edge, programming and runtime environments particularly for AI/ML across the edge-to-cloud continuum, developing new types of AI-based measurements and autonomous/adaptive computing, and other areas.

Charlie Catlett
ccatlett@illinois.edu