Ubicomp and Smart Home/City

Maanya | Jack | Ish | Disha

Agenda

Hydro Sensing

Dynamically measuring water usage throughout the entire household utilizing pressure metrics

Energy Sensing

Pinpointing energy usage by appliance, enabling analysis and mitigation

Surface Sensing

Determining severity of deterioration of surfaces to save shocks, time, and lives

Combine these sensing capabilities (and more) to create happier, healthier, and more efficient homes and cities

HydroSense


waterwaterwater
omomgomgomgo
IHASAHOTDOG.COM BY


HYDROSENSE
Tracking Per Fixture Water Usage from a Single Sensor
HydroSense is a pressure-based technology that tracks water usage at the fixture-level using only one sensor (i.e., itemizes water usage at the dishwasher, shower, kitchen sink).
the home plumbing system
kitchen faucet
toilet
tub faucet
psi
time
Home plumbing is a closed pressure system; when a valve opens or closes, a pressure wave is propagated throughout the home.
Each fixture generates a unique pressure wave. HydroSense monitors these pressure signatures to identify the fixture and uses pressure deltas to calculate flow.

Water Facts!

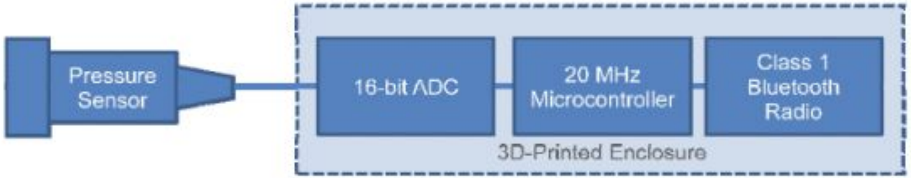
- Nearly 97% of the world's water is salty or otherwise undrinkable. Another 2% is locked in ice caps and glaciers. That leaves just 1% for all of humanity's needs — all its agricultural, residential, manufacturing, community, and personal needs.

- The average family can waste 180 gallons per week, or 9,400 gallons of water annually, from household leaks. That's equivalent to the amount of water needed to wash more than 300 loads of laundry.

What is HydroSense?

HydroSense, a low-cost,single-point solution for activity sensing mediated by a home’s existing water infrastructure. HydroSense is based on continuous analysis of pressure within a home’s water infrastructure.

Consists of a customized stainless steel pressure sensor, an analog-to-digital converter (ADC) and microcontroller, and a Bluetooth wireless radio.



Calculation of water flow

1. Flow rate is related to pressure change via Poiseuille's Law -

$$Q = \frac{\Delta P \, \pi \, r^4}{8 \, \mu \, L}$$

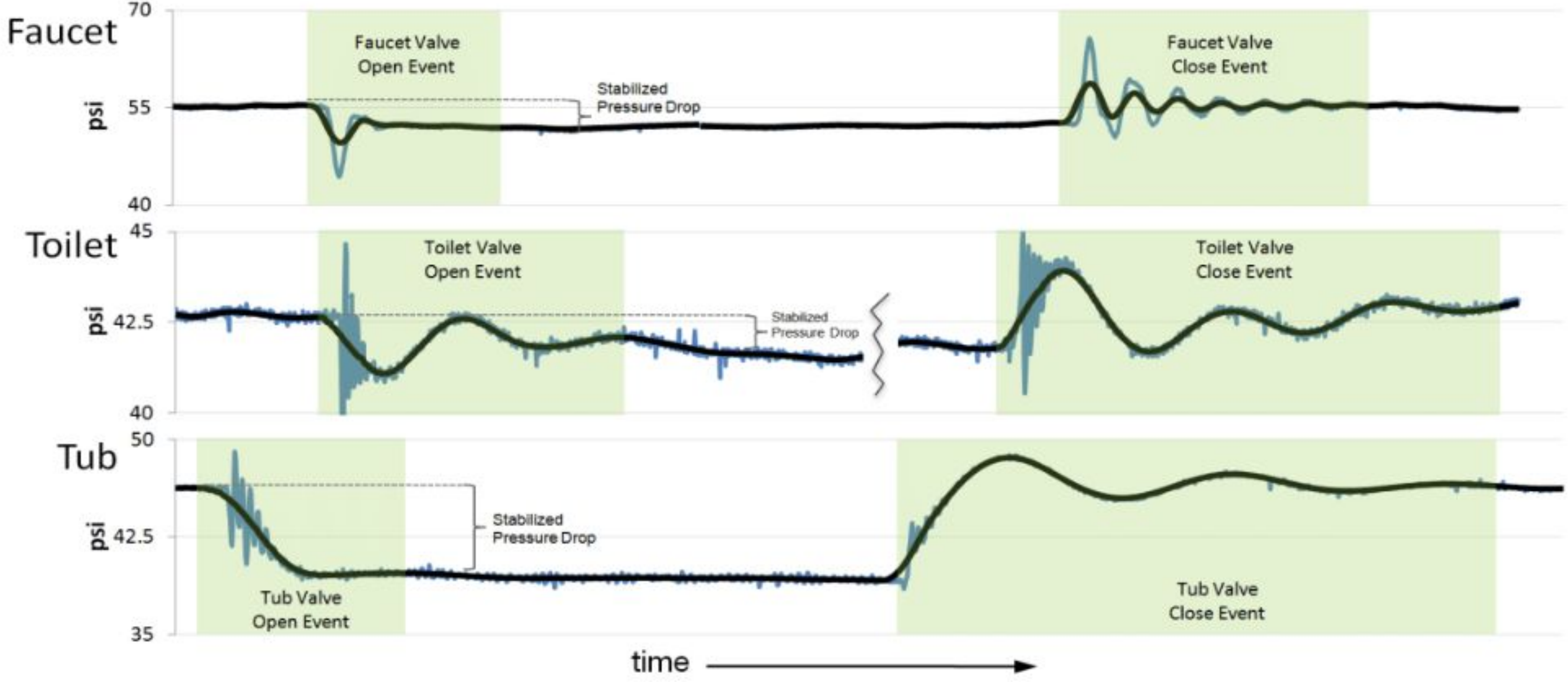
2. This can be simplified by the fluid resistance formulation -

$$R_f = \frac{\Delta P}{Q} \equiv \frac{8 \, \mu \, L}{\pi \, r^4}$$

3. The final formula then is -

$$Q = \frac{\Delta P}{R_f}$$

Open/Close Pressure Waves



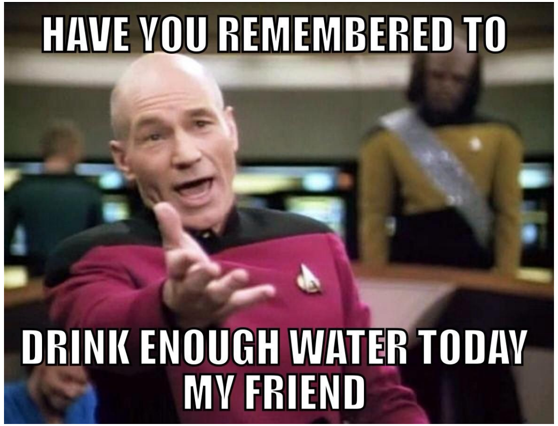
Potential issues with HydroSense

- Events that occur at the exact same instant cannot be distinguished as separate events with the current segmentation algorithm.
- The current sampling is done in a controlled manner
- They do not account for the smoothness of the inner pipe surface, the number of bends, valves, or constrictions in pipes, nor pipe orientation.


Electricity
$46.27 / 329.2
1.05 kW

Discussion Questions

- Is there any scope of using HydroSense by everybody in the world? Why or why not?
- Are there any other potential issues related to the usage of HydroSense other than the ones mentioned earlier?
- Other than measuring the water flow, is there anywhere else this technology can be used?



Electrisense | Single-Point Sensing | Electrical Event Detection & Classification

Sidhant Gupta | Matthew S. Reynolds | Shwetak N. Patel

	32 Save#:5	DineIn
	ggie	Guests:4 T#: B7
[illegible]	.Dry-Fried Eggplant	10.00
1	5.Cilantro Fish Rolls	8.00
1	11.Grandma`s Noodle	7.00
1	24.Szechuan Bang Bang Shrimp	9.00
1	Pinot Blanc(g)	8.00
1	Tsing Tao	4.50
2	Tsing Tao	9.00
1	40c.Basil Chicken	15.00
1	39c.Three Peppers Chicken	15.00
1	35f.Fish in Hot Chili Oil	19.00
1	Customer Design	
	>im a plad a[illegible]e	
1	Customer Design	
	>i have a small p[illegible]	

SubTotal: 104.5

Tax: 10.4

Amount: 114.9

Even Split (4): 28.7

05/07/2016 07:48 PM

EVERSOURCE

Account Number: 0000 000 0000
Customer name key: CUST
Statement Date: 04/05/19
Service Provided To:
JOHN J CUSTOMER

Service Address: ANY STREET
ANY TOWN, MA 00000
Rate: A1 R1 RESIDENTIAL Bill Cycle: 03
Service from 03/07/19 - 04/03/19 27 Days
Next read date on or about: May 06, 2019

Meter Number	Current Read	Previous Read	Current Usage	Reading Type
0000000	30596	30143	453	Actual

Monthly kWh Use

Apr	May	Jun	Jul	Aug	Sep	Oct
463	427	459	439	559	1035	559
Nov	Dec	Jan	Feb	Mar	Apr	
525	562	522	677	520	453	

Contact Information
Emergency: 800-592-2000
www.eversource.com
CustomerServiceMA@eversource.com
Pay by Phone: 800-592-2000
Customer Service: 800-592-2000

Total Amount Due by 04/30/19 **$117.17**

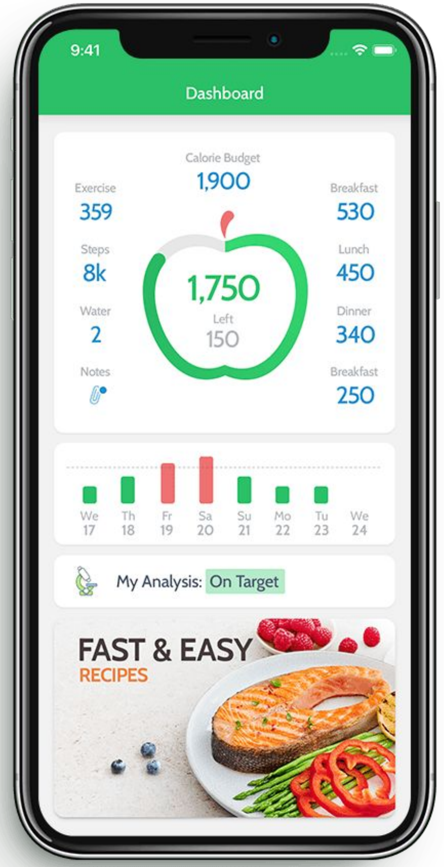
Electric Account Summary	
Amount Due On 04/05/19	$133.48
Last Payment Received On 04/04/19	-$133.48
Balance Forward	$0.00
Current Charges/Credits	
Electric Supply Services	$61.55
Delivery Services	$55.62
Total Current Charges	$117.17
Total Amount Due	$117.17

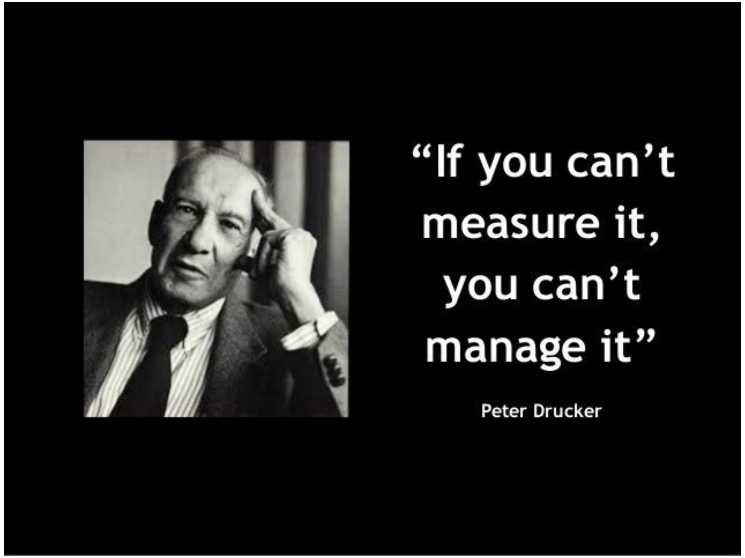
Total Charges for Electricity

Supplier (Eversource) (Basic Svc Fixed)		
Generation Service Charge	453 kWh X .13588	$61.55
Subtotal Supplier Services		$61.55
Delivery (Rate A1 R1 RESIDENTIAL)		
Customer Charge		$7.00
Distribution Charge	453 kWh X .06396	$28.97
Transition Charge	453 kWh X -.00052	-$0.24
Transmission Charge	453 kWh X .02585	$11.71
Revenue Decoupling Charge	453 kWh X -.00057	-$0.26
Distributed Solar Charge	453 kWh X .00088	$0.40
Renewable Energy Charge	453 kWh X .00050	$0.23
Energy Efficiency	453 kWh X .01725	$7.81
Subtotal Delivery Services		$55.62
Total Cost of Electricity		**$117.17**
Total Current Charges		**$117.17**

EM_190403.TXT

Eversource is required to comply with Department of Public Utilities' billing and termination regulations. If you have a dispute please see the bill insert for more information. Visit the "Monthly Customer Communications" page under "My Account" then "Billing & Payment" on Eversource.com for an electronic version of this insert. Eversource offers Payment Plans for customers with overdue bills. Budget Billing is also available to pay a more consistent bill each month. Please see the Customer Rights Supplement for more information.


9:41
Dashboard
Calorie Budget
1,900
Exercise
359
Steps
8k
Water
2
Notes
Breakfast
530
Lunch
450
Dinner
340
Breakfast
250
1,750
Left
150
We 17
Th 18
Fr 19
Sa 20
Su 21
Mo 22
Tu 23
We 24
My Analysis: On Target
FAST & EASY
RECIPES


"If you can't measure it, you can't manage it"
Peter Drucker

Distributed Sensing

- Dedicated sensors for each appliance or area.
- Problems: Costly installation and maintenance.
- Potential Solution: reduce cost by using a single point to sense

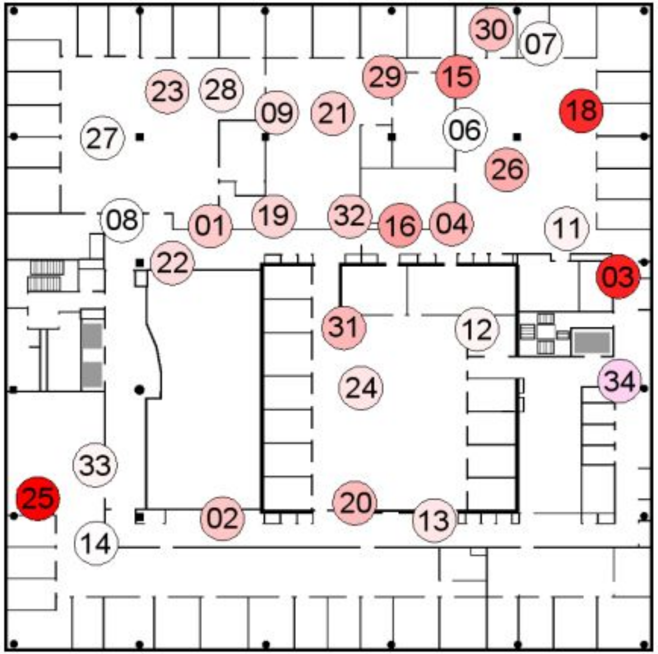


Figure 7: A map of the third floor of the MIT Media Lab. The 31 large circles indicate the location of Plug sensor nodes. The number within each circle is the ID of the Plug at that location. The darker the circle, the more activity occurred at that node over the span of a 20-hour data collection period. Here, "activity" is defined as the sum of the number of motion sensor and vibration sensor activations.

Image Source: Lifton, J., Feldmeier, M., Ono, Y., Lewis, C., and Paradiso, J. A. A platform for ubiquitous sensor deployment in occupational and domestic environments

Single Point Sensing

- Metering technique for whole-house appliance usage via power meter.
- **Problem:** relies on step change activation to identify usage.
- **Potential Solution:** utilize advancing chip technology and shifting macro trends (SMPS systems) to a get high accuracy, low cost solution

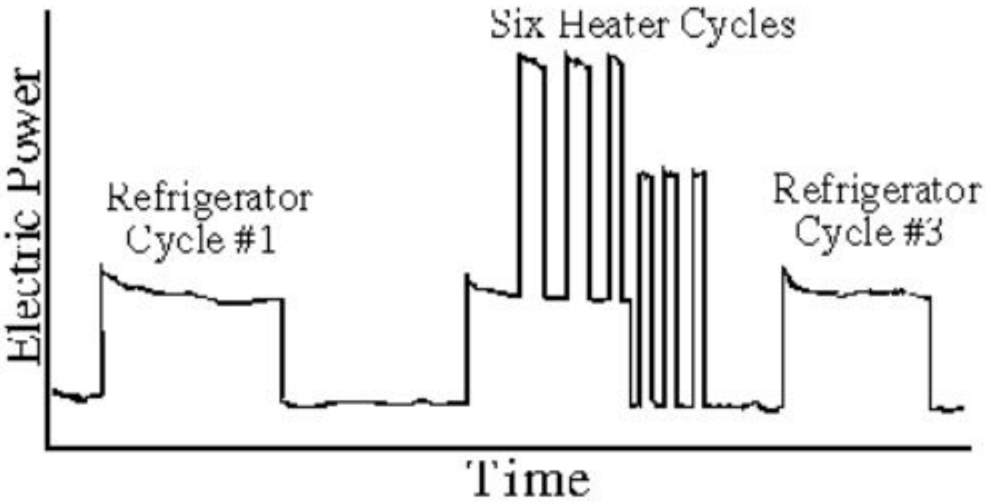


Fig: total (real) power consumption vs. time for a single-family home over a two-hour period

Image Source: http://www.georgehart.com/research/nalm.html

Electrisense (2010)

- A single point system utilizing high frequency EMI signals from each SMPS appliance
- SMPS do not dissipate power as heat, rather store energy in high frequency switches
- Enables high efficiency, and to our benefit, distinct signals to monitor

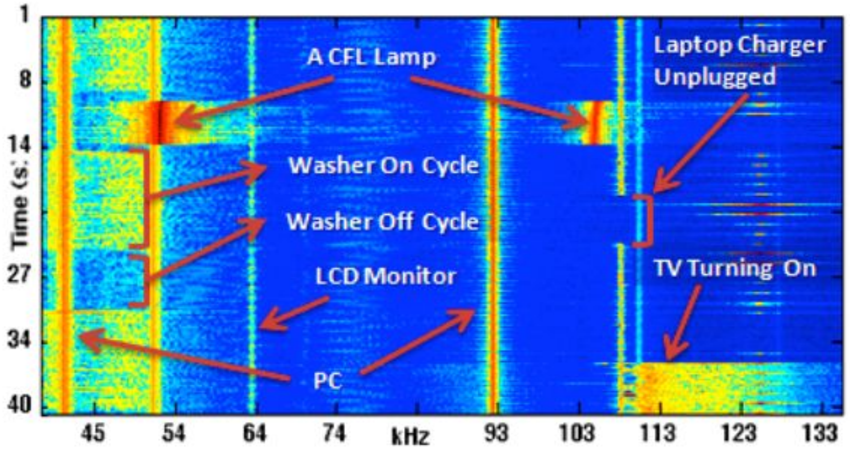


Figure 2: Frequency spectrogram showing device actuation in a home.

Image Source: Reading 1, Electrisense paper

SMPS additional read: https://www.techopedia.com/definition/12378/switched-mode-power-supply-smps

The Experiment

- 7 homes, 6 short term (H1-H6), 1 six month deployment (H7)
- In home devices + 8 20” dell monitors, a camera charger and 2 CFL lamps.

The Setup

- Once configured, just plug into an outlet! So much easier than other systems

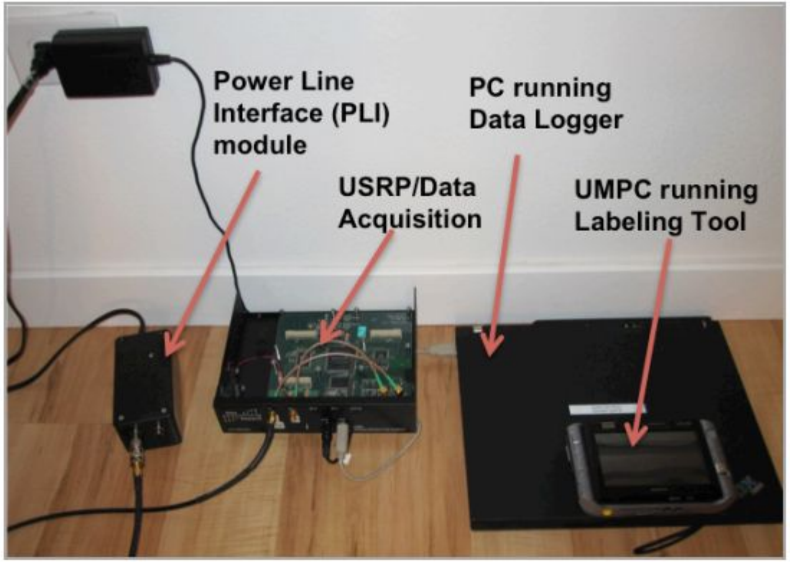
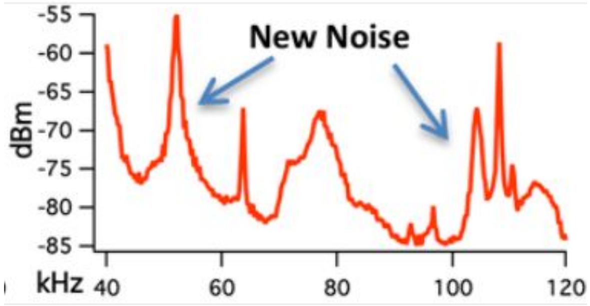


Figure 3: Our prototype system consists of a single plug-in module, acquisition hardware and the supporting software



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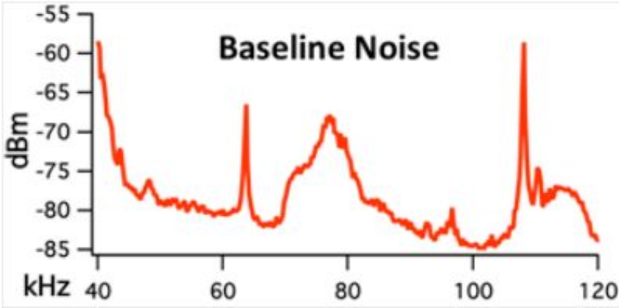

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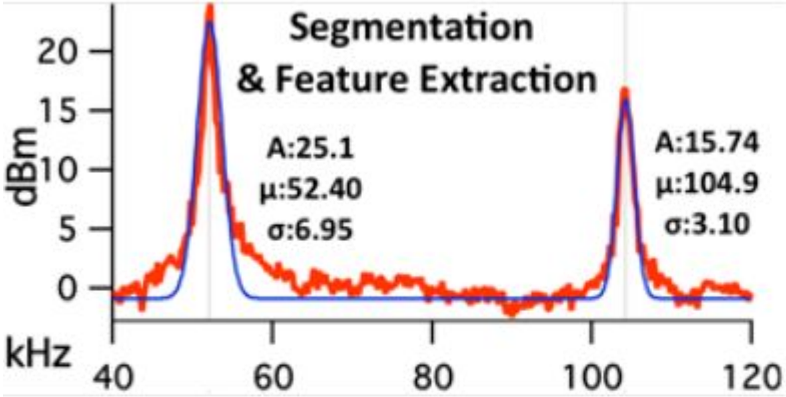


Amplitude, Mean and Variance captured

25?

Device classification using K Nearest Neighbours

Issue with windowing

Device	10 Fold Cross Validation (%)
Camera Charger	100
Laptop	87.5
23W CFL Lamp	100
12W CFL Lamp	100
Aggregate	**96.87**

Issue with same brand, same device model

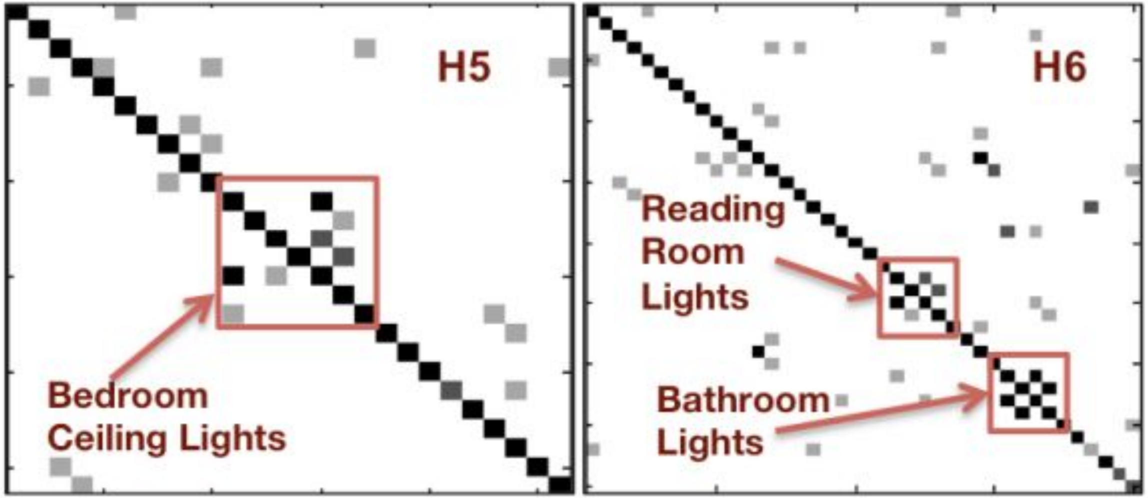


Figure 7: Visual confusion matrix highlighting misclassification due to physical proximity of similar fixtures in H5 and H6.

What’s not right?

KNN can not work if we give some new devices to the system as we only have data for some specific devices.

Needs user to actuate each device atleast once. So it is not a device detection system per se until all devices are used.

The EMI in SMPS is considered to be a disadvantage in these power supplied. Relying on a disadvantage for creating technology can make this obsolete.

💬 Did you find more limitations to this 2010 work?

- Were there some interesting things you learnt while reading this work ? Was there anything you found unique about this paper different from other papers we have read so far? Data collection? Performance calculation?

- What in your opinion got this paper the best paper award? What have the authors done so well?

- How is this work - Electrical device detection relevant to us or to Ubiquitous Computing for Smart Home/Smart City? How and where can we leverage it? Any project ideas you can suggest to the class?

UbiComp Applications ready for use

Roll over image to zoom in

5 VIDEOS

Sense Energy Monitor – Track Electricity Usage in Real Time and Save Money – Meets Rigorous ETL/Intertek Safety Standards

Visit the sense Store

2,220 ratings

2 Price Changes

$299.00

prime One-Day

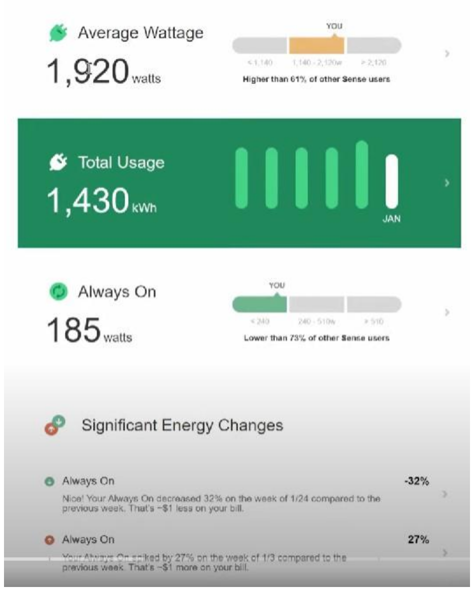
& FREE Returns

Thank you for being a Prime member. Get a $100 Gift Card: Pay $199.00 upon approval for the Amazon Prime Rewards Visa Card.

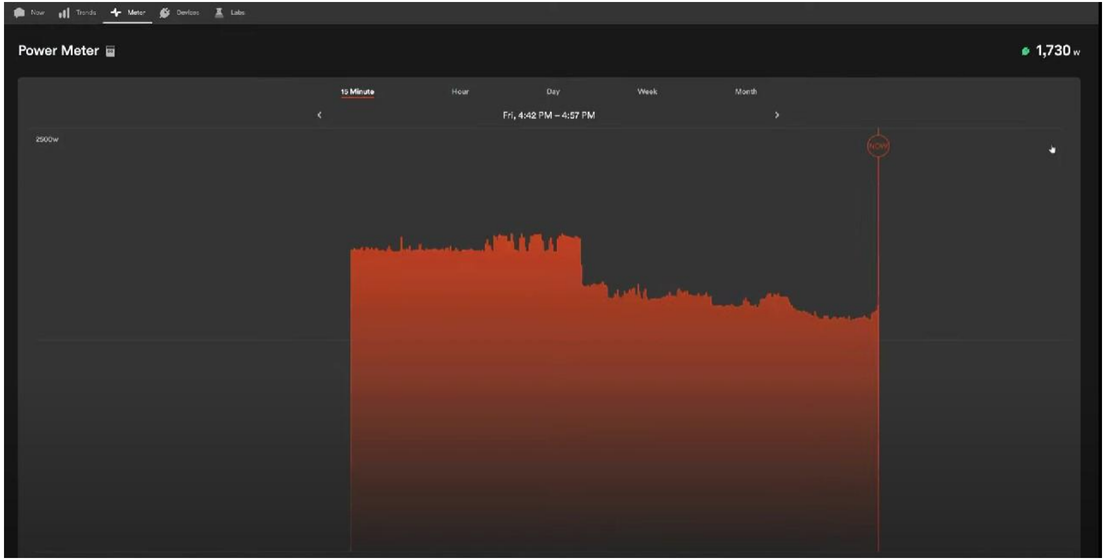
Pattern Name: **Monitor**

Monitor $299.00 prime	Monitor + Amp, Black $310.03 prime

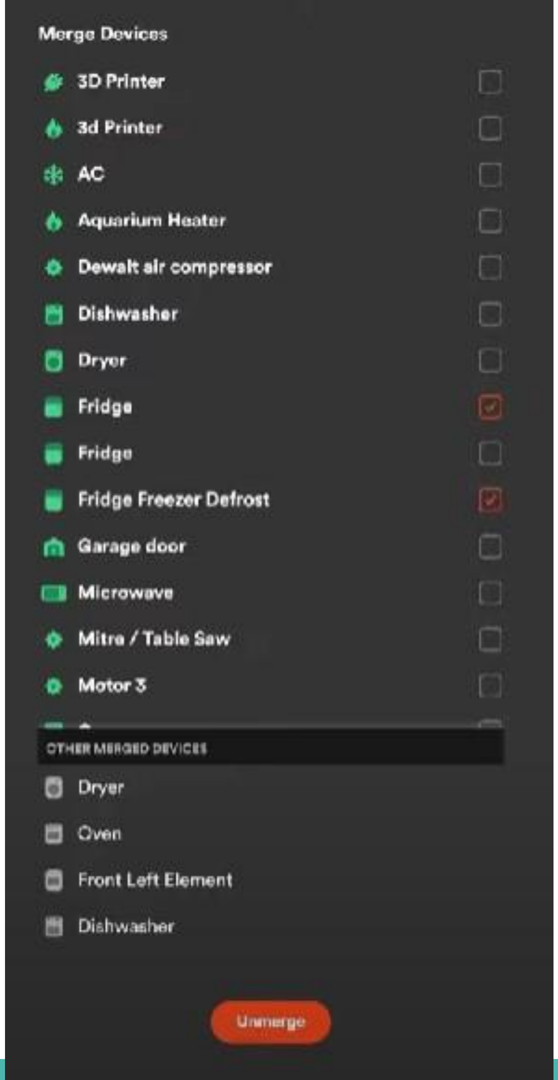
- SENSE SAVES: Sense saves you energy and money by providing insight into your home's energy use and activity. NOW SUPPORTING TIME-OF-USE RATE PLANS.
- SEE WHAT'S UP. KNOW WHAT'S ON: Track how much electricity you're using,


Average Wattage
1,920 watts
YOU
< 1,140
1,140 - 2,120w
> 2,120
Higher than 61% of other Sense users
Total Usage
1,430 kWh
JAN
Always On
185 watts
YOU
< 240
240 - 510w
> 510
Lower than 73% of other Sense users
Significant Energy Changes
Always On
-32%
Nice! Your Always On decreased 32% on the week of 1/24 compared to the previous week. That's ~$1 less on your bill.
Always On
27%
Your Always On spiked by 27% on the week of 1/3 compared to the previous week. That's ~$1 more on your bill.


Computer
Always On: 53 W
330 W
Aquarium Lights
50 W
Aquarium
Always On: 32 W
539 W
Always On
197 W
Hydroponics
Always On: 40 W
286 W
Block Heater
446 W


Now
Trends
Meter
Devices
Labs
Power Meter
1,730 w
15 Minute
Hour
Day
Week
Month
Fri, 4:42 PM – 4:57 PM
2500w

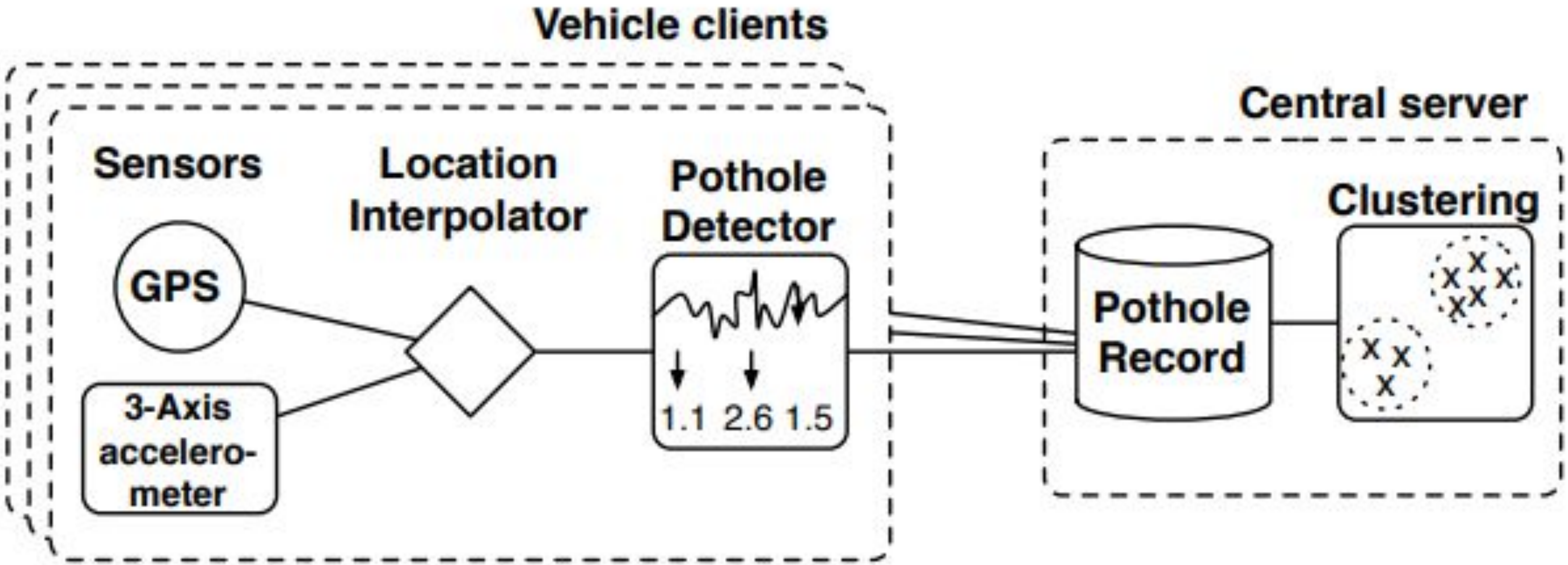

Compare
last 30 days
1924w
YOU
< 1,100
1,100 - 2,140w
> 2,140
Similar homes in your area
Compare me to similar homes
All Sense homes
2053w
Day
Week
Month
Year
Bill
2021
19,784 kWh


Merge Devices
3D Printer
3d Printer
AC
Aquarium Heater
Dewalt air compressor
Dishwasher
Dryer
Fridge
Fridge
Fridge Freezer Defrost
Garage door
Microwave
Mitre / Table Saw
Motor 3
OTHER MERGED DEVICES
Dryer
Oven
Front Left Element
Dishwasher
Unmerge

Pothole Patrol

- Municipalities around the world spend millions of dollars, yet few people are happy with quality of the roads.
- Bad roads
  - Damage vehicles
  - Hazardous to drivers and pedestrians
  - Very annoying to drive or bike on
- The researchers are trying to find out potholes on travelled roads using different sensors in vehicles so that those that are of high severity could be repaired.
- *"Runs on a network of 7 taxis in the Boston metropolitan area"*

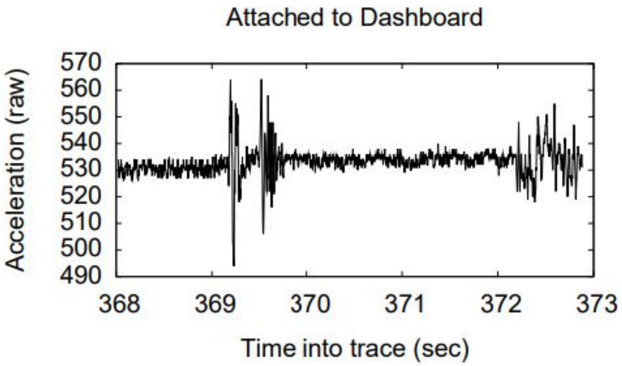
P2 architecture

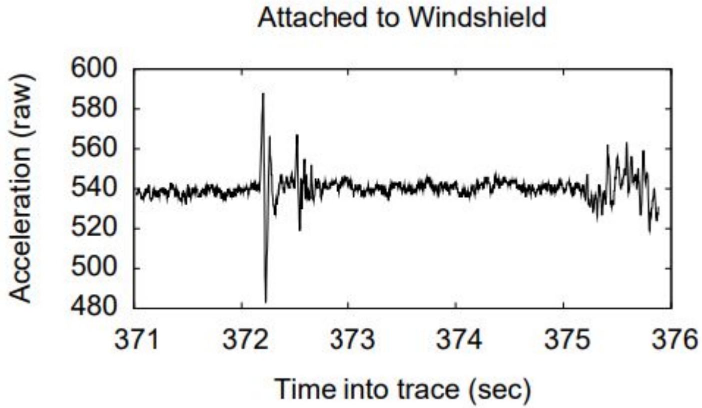


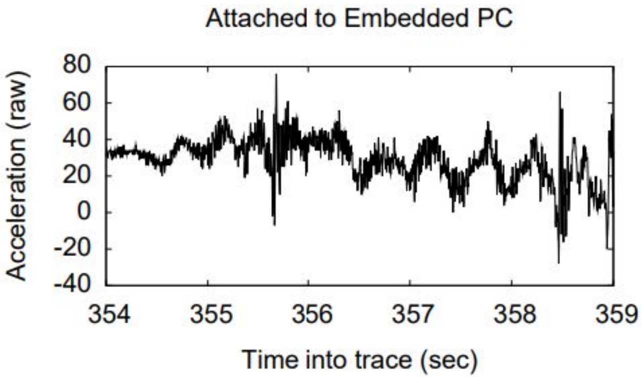
Challenges

- Gathering data is challenging because this would require driving through bad roads. Also, gathering hand-labeled training data would require a lot of effort.
    - Used loosely labeled data as well because completely labeled data is harder to collect.
- Normal events such as fast brakes, speeding, etc. might look similar to some sensors.
    - Different filters are used to resolve this issue (to be continued)

Accelerometer Placement







Different Filters

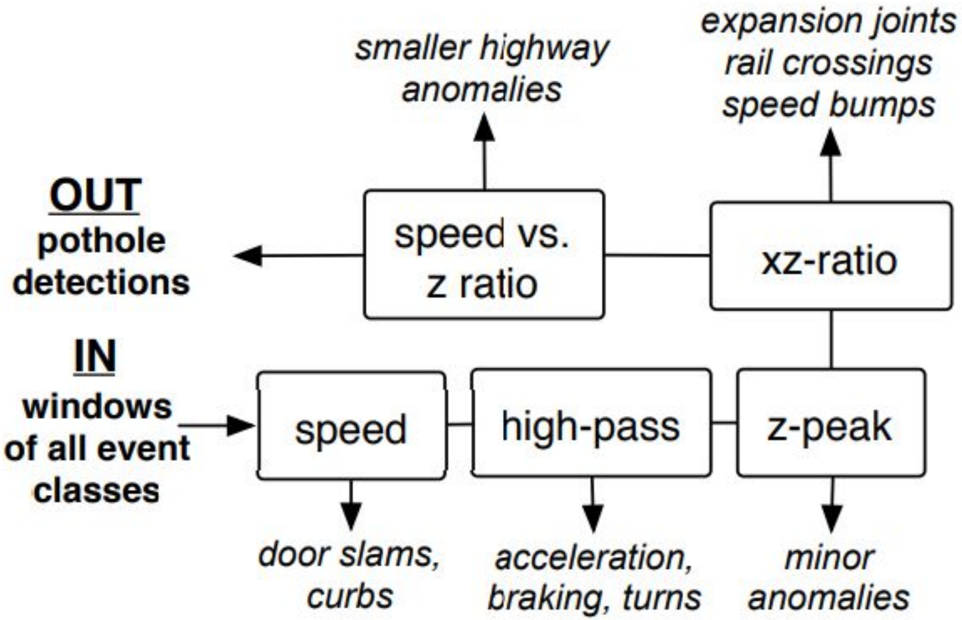
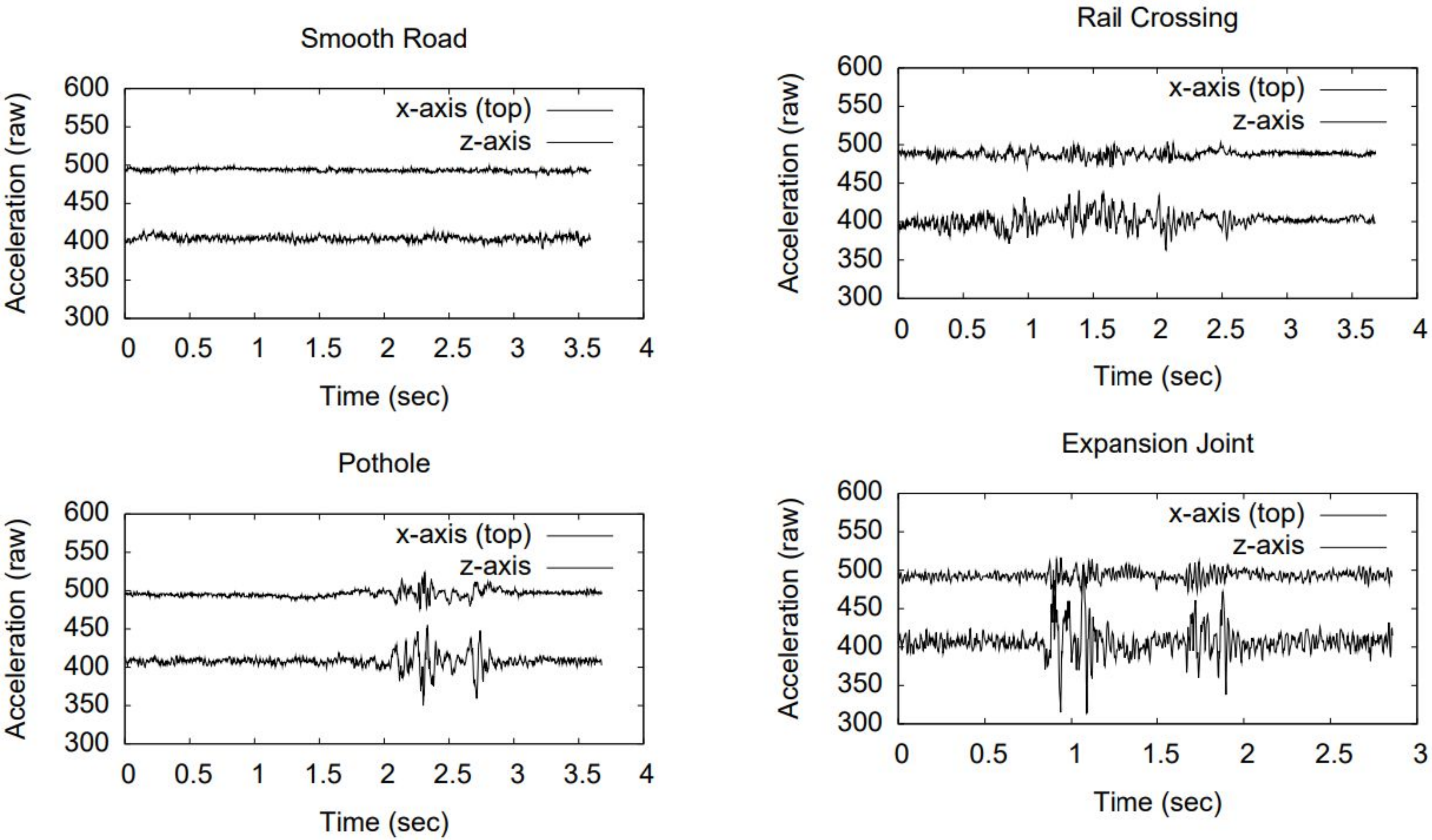


Figure 6: The pothole detector is composed of a number of filters, each separating out a different class of event.


Smooth Road
Acceleration (raw)
Time (sec)
x-axis (top)
z-axis
600
550
500
450
400
350
300
0
0.5
1
1.5
2
2.5
3
3.5
4
Rail Crossing
Acceleration (raw)
Time (sec)
x-axis (top)
z-axis
Pothole
Acceleration (raw)
Time (sec)
x-axis (top)
z-axis
Expansion Joint
Acceleration (raw)
Time (sec)
x-axis (top)
z-axis

Training

$$s(\mathbf{t}) = corr - incorr^2.$$

$$s(\mathbf{t}) = corr - incorr^2_{labeled} - \max(0, incorr_{loose} - count_r).$$

Class	before	after
Pothole	88.9%	92.4%
Manhole	0.3%	0.0%
Exp. Joint	2.7%	0.3%
Railroad Crossing	8.1%	7.3%

Table 3: Test data of listed class that was reported as potholes by our algorithm, before and after training on additional loosely labeled data.

Cyvl.ai

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Contact us

Next-gen infrastructure management with 3D scanning and artificial intelligence

Automated condition assessments of pavements, sidewalks, traffic signs, trees, buildings, and more.

How it works →

Schedule a demo

Step 2. Install

Mount the sensor to your vehicle in seconds with a trailer hitch adaptor that we provide.

Step 3. Drive

Our sensor automatically collects condition data on your infrastructure as you drive.

Discussion questions

- In the P2 architecture, the predictions are processed on car. Could that be limiting the predictions because complex models can't be processed on car?

- Could the research be applicable to wide scale such that every car is reporting potholes? Are there any issues that would need to be fixed to make before making it widespread?

- GPS doesn't give the most precise localization information. Since the sensors are inside a vehicle which is mostly outdoors and most cabs have internet access, could that be used to get a better prediction?


SMART CITY
BUILDING TOMORROW'S CITIES
INDUSTRY
SECURITY
RETAIL
SOCIETY
HEALTHCARE
HOME
ENERGY
MOBILITY
H

Closing thoughts

- What synergies can we identify between these 3 sensing technologies?

- What additional technologies or sensors could be implemented into this system?