Photo by Braydon Anderson on Unsplash

GETTING STARTED WITH TINYML

LESSONS LEARNED FROM BUILDING AN ARTIFICIAL NOSE

Benjamin Cabé
@kartben

LEARNING OBJECTIVES

What is TinyML anyway?

Sensor data + AI = 

TinyML + IoT = 


COFFEE
ESPRESSO

BENJAMIN CABÉ

Principal Program Manager
Azure IoT – Microsoft

Open Source &
Community Advocate

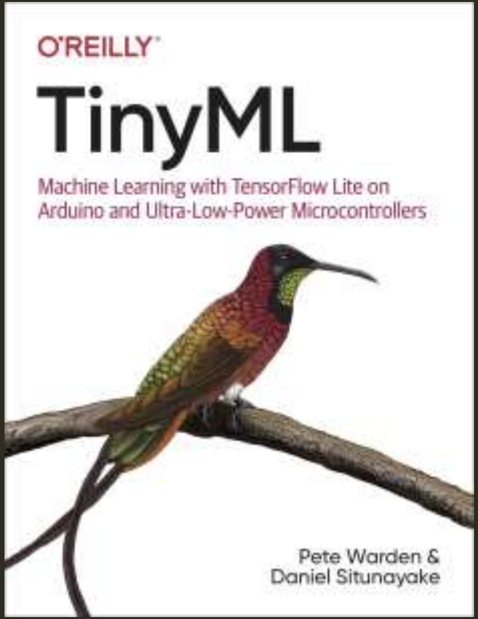
Amateur Potter

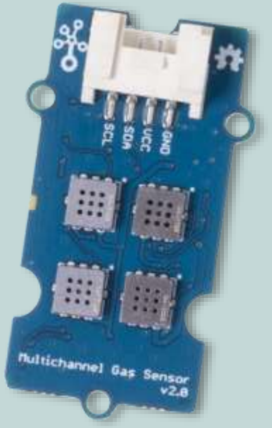
@kartben


BORDEAUX

TINYML?

> The ability to run a neural network model at an energy cost of below 1 mW.





WIO TERMINAL + GAS SENSOR

Carbon monoxide (CO)
Nitrogen dioxide (NO_2)
Ethyl alcohol(C_2H_5OH)
Volatile Organic Compounds (VOC)

COST CONSIDERATIONS

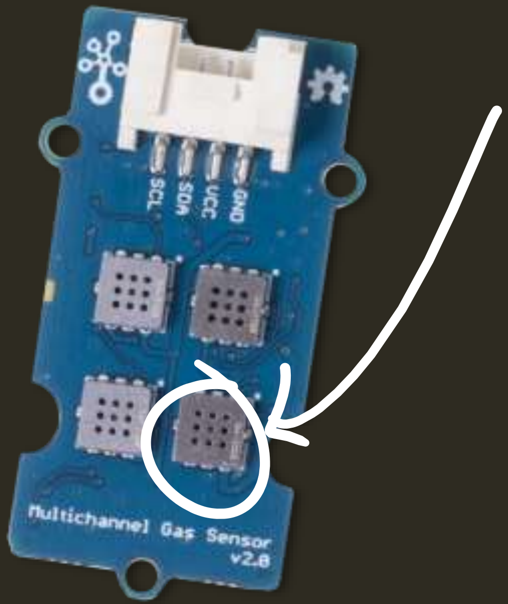
Wio Terminal
~$38

Arm Cortex-M4
512K of Flash
192K of RAM

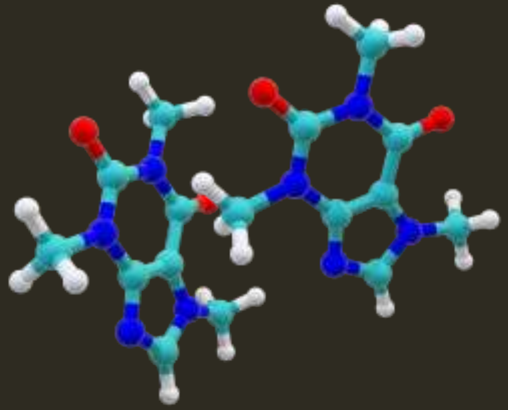
ATSAMD51P19A
~$5 (when ordering 3000+ units)

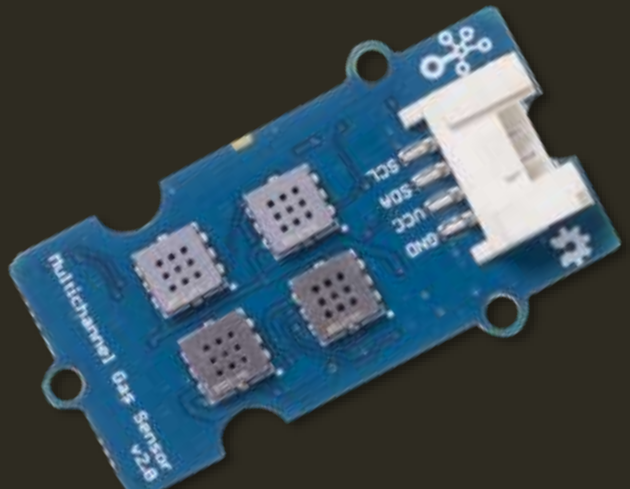
Arm Cortex-M4F
512K of Flash
192K of RAM

BUT HOW CAN A MACHINE SMELL ANYWAYS?



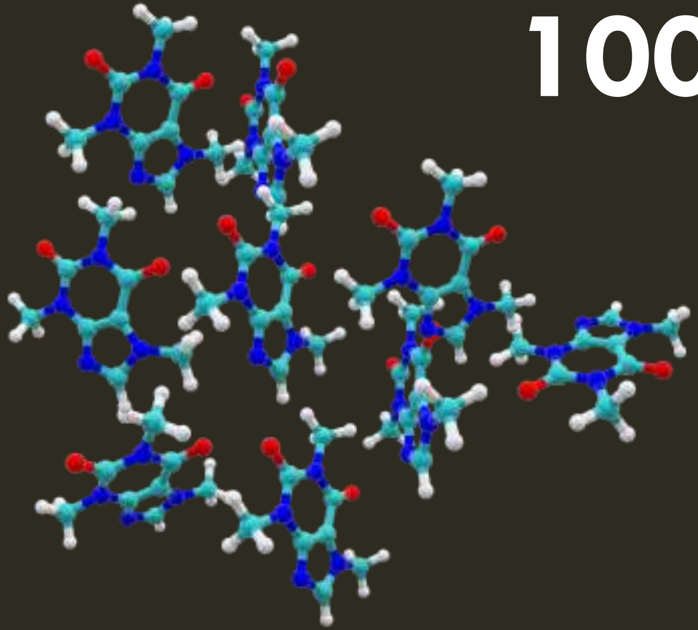
10 ppm



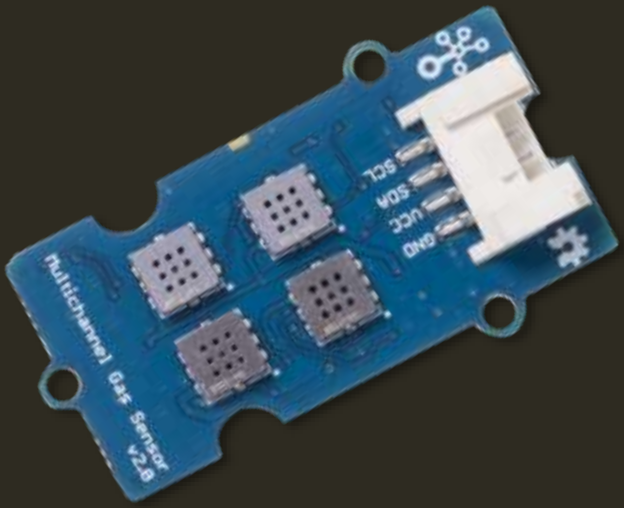


VOC?

100 Ω!



1000 ppm



VOC?

200 Ω!

AI MODEL FOR SMELLS?

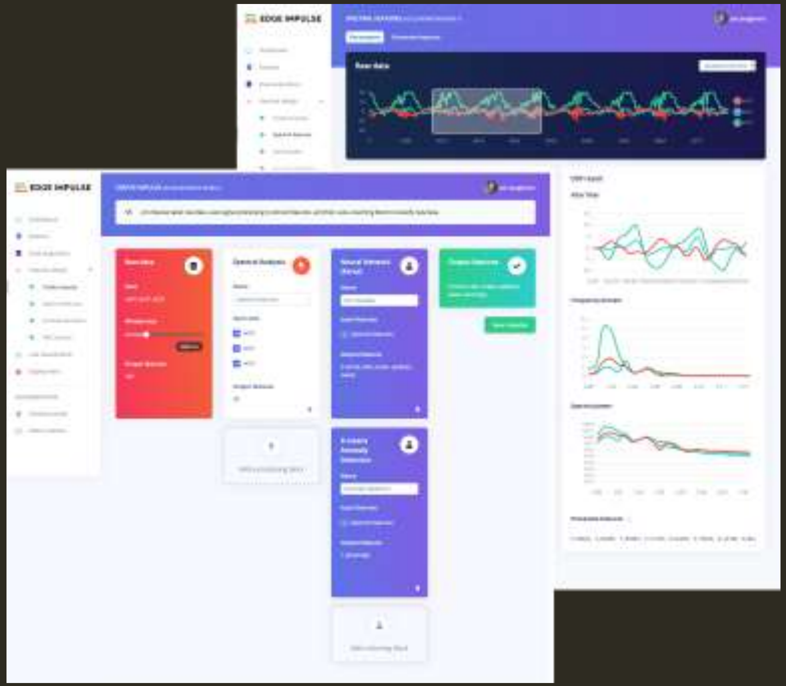
EDGE IMPULSE

Super simple **data acquisition** and **labelling** workflow

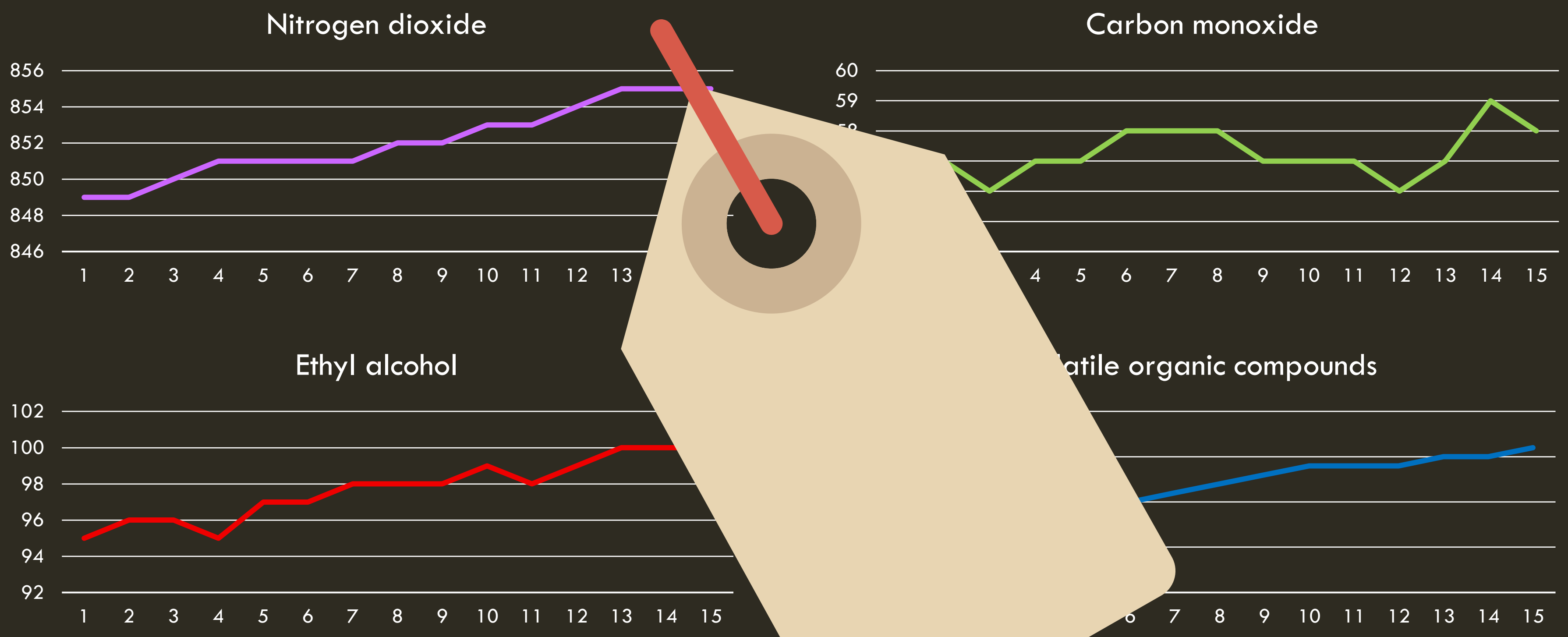
Pre-defined common NN layers, DSP, and anomaly detection "blocks"

Model **training in the cloud**

Runtime based on **TensorFlow Lite**



edgeimpulse.com



	1	2	3	4	5	6	[illegible]	8	9	10	11	12	13	14	15
Nitrogen dioxide	849	849	850	851	851	851	[illegible]	852	852	853	853	854	855	855	855
Carbon monoxide	57	57	56	57	57	58	58	58	57	57	57	56	57	59	58
Ethyl alcohol	95	96	96	95	97	97	98	98	98	99	98	99	100	100	100
Volatile organic compounds	182	183	184	184	185	185	186	187	188	189	189	189	190	190	191

BUT HOW CAN A MACHINE SMELL ANYWAYS?

Raw features (whiskey) – 1.5 s of sensor data, 10 Hz

[849, 57, 95, 182, 849, 57, 96, 183, 850, 56, 96, 184, 851, 57, 95, 184, 851, 57, 97, 185, 851, 58, 97, 185, 851, 58, 98, 186, 852, 58, 98, 187, 852, 57, 98, 188, 853, 57, 99, 189, 853, 57, 98, 189, 854, 56, 99, 189, 855, 57, 100, 190, 855, 59, 100, 190, 855, 58, 100, 191]

BUT HOW CAN A MACHINE really SMELL ANYWAYS?

Flattened features (whiskey) – step 1:

```
[
 [ 849, 57,  95, 182 ],
 [ 849, 57,  96, 183 ],
 …
 [ 855, 58, 100, 191 ]
]
```

BUT HOW CAN A MACHINE really SMELL ANYWAYS?

Flattened features (whiskey) – step 2 (scale axes):

```
[
 [ 0.849, 0.057, 0.095, 0.182 ],
 [ 0.849, 0.057, 0.096, 0.183 ],
 …
 [ 0.855, 0.058, 0.100, 0.191 ]
]
```

BUT HOW CAN A MACHINE really SMELL ANYWAYS?

Flattened features (whiskey) – step 3 (DSP):

[0.8520, 0.849, 0.855, 0.8250, 0.0019, NO_2

0.0572, 0.056, 0.059, 0.0554, 0.0007, CO

0.0977, 0.095, 0.100, 0.0946, 0.0016, C_2H_5OH

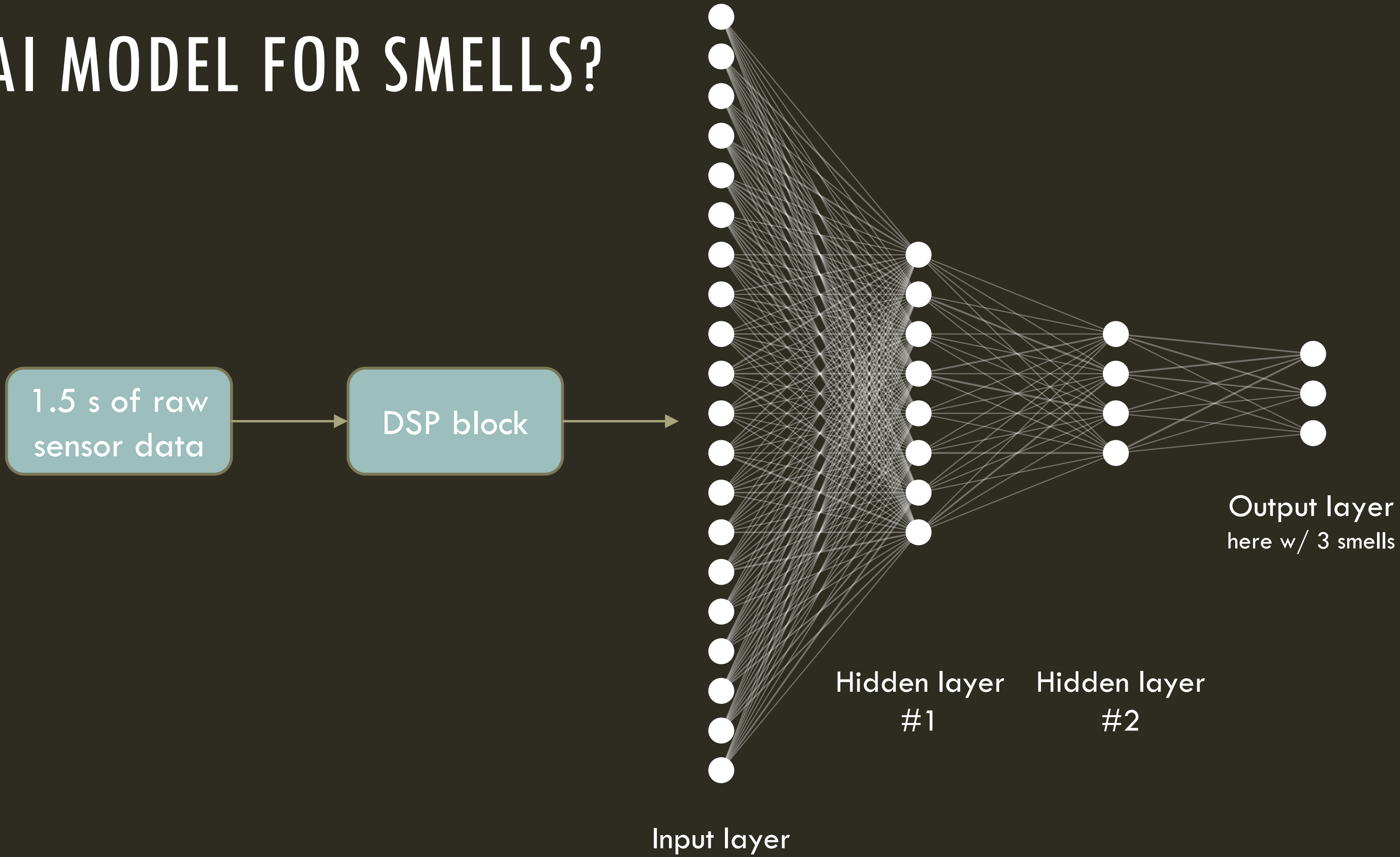
0.1868, 0.182, 0.191, 0.1808, 0.0027] VOC

average | min | max | root-mean square | standard deviation

AI MODEL FOR SMELLS?

AI MODEL FOR SMELLS?

AI MODEL FOR SMELLS?



TENSORFLOW LITE FOR MICROCONTROLLERS

Optimized for on-device machine learning

- **latency** – there's no round-trip to a server
- **privacy** – no personal data leaves the device
- **connectivity** – Internet connectivity is not required
- **size** – reduced model and binary size
- **power consumption** – efficient inference & a lack of network connections

High performance (hardware acceleration and model optimization)

Available as **Arduino library**

RE: PERFORMANCE AND CODE SIZE

Classifying 3-5 smells:

- ~4KB of RAM, ~27KB of ROM (the actual TFLite model is ~3KB)
- Inference is ~1ms on an 80MHz 32-bit MCU

IMPROVING ACCURACY?

Better model (ex. RNN)

Better gas sensors

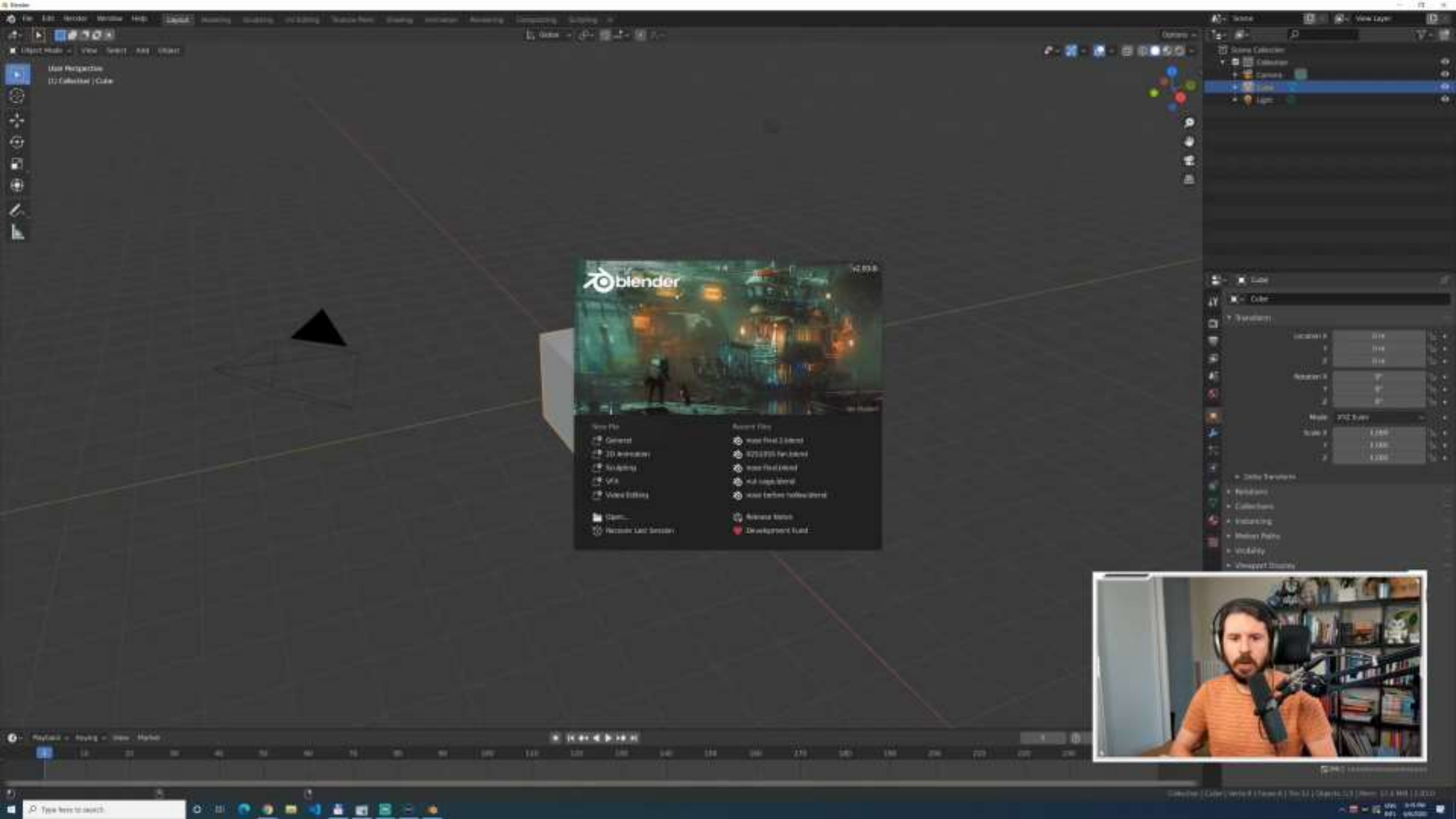
<u>More</u> gas sensors

Sensor fusion

- Humidity
- Temperature
- Color
- …

“GREAT… SO… YOU’VE BEEN TINKERING, EH?”

Photo by Jametlene Reskp on Unsplash


File Edit Render Window Help
User Perspective
(1) Collection | Cube
blender
Type here to search

THINGIVERSE.COM/THING:4493907

Benjamin Cabé @kartben · Feb 12

I realized I **never quite published** the instructions to replicate my #TinyML and #IoT artificial **nose** project, powered by awesome tech from @EdgeImpulse and hardware from @seeedstudio. Working on getting this fixed asap while sipping my espresso! 👃☕

8 22 97

PREMIUM

Pascal BORNET

Intelligent Automation Global Expert | Chief Data Officer | Author | Forbes Tech Council | Ex-McKinsey | Top Voice in Tech | 300K+ followers

+ Follow

View full profile

Pascal BORNET • 2nd

Intelligent Automation Global Expert | Chief Data Officer | Aut...

2mo •

+ Follow

Identifying smells with machine learning!

Built by Benjamin Cabé, this artificial nose has been trained to recognize accurately hundreds of smells. Read more here: https://lnkd.in/gdPKx9Z

This could power so many wonderful use cases: cooking assistant, alerts in case of dangerous gases, perfumes design, support to people who can't smell well... What else would you think of?

Code available here: https://lnkd.in/gSXdiah

If you like my posts, you will enjoy my new book: https://lnkd.in/g4uCcg4

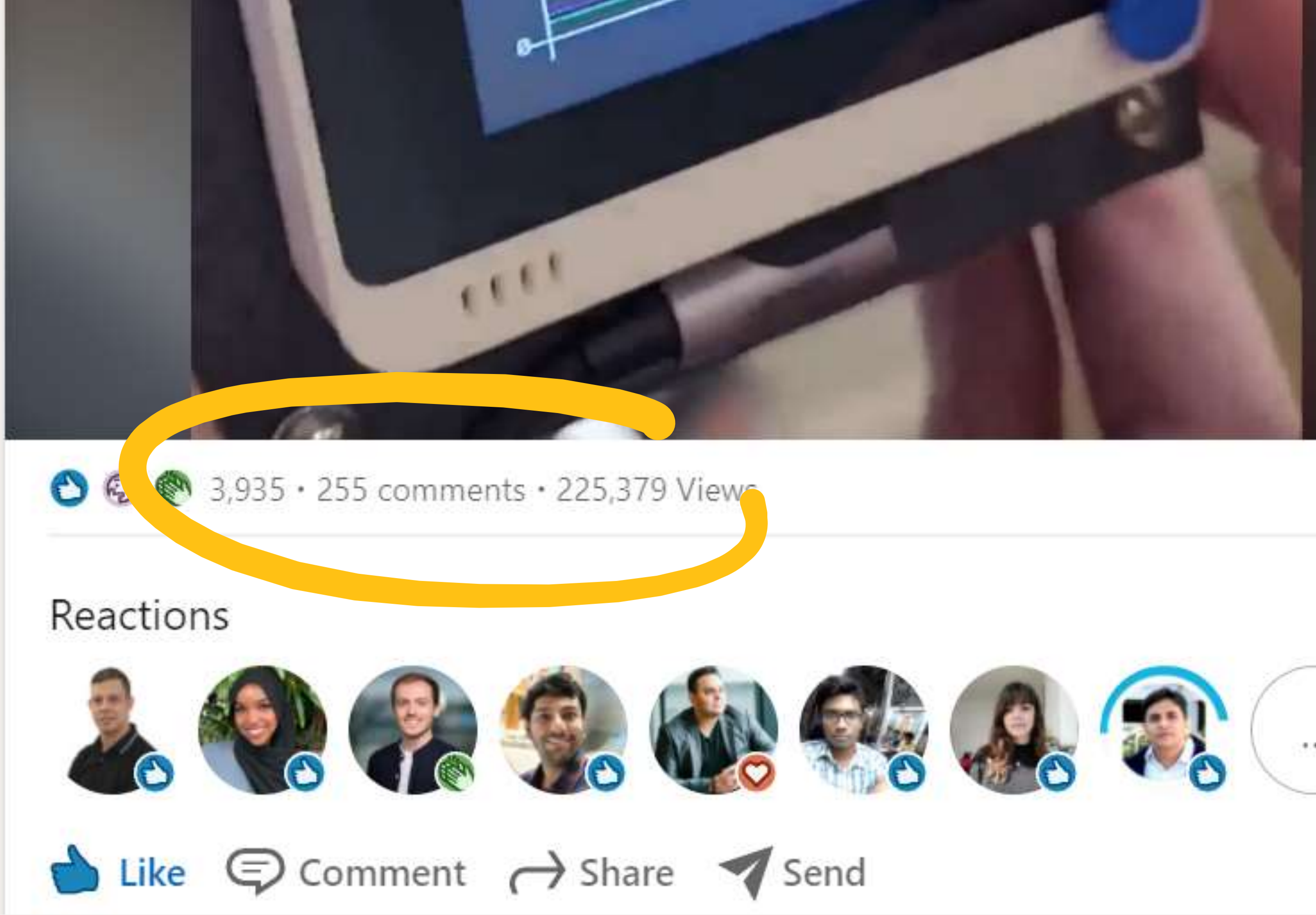
Click "Follow" for more #technology insights https://lnkd.in/gFhhNg9 and https://lnkd.in/fjddMYP

3,935 • 255 comments • 225,379 Views

Reactions

...

Like Comment Share Send


3,935 · 255 comments · 225,379 Views
Reactions
Like
Comment
Share
Send

Make:

MOTORIZED SELF SOLVING RUBIK'S CUBE

MACHINE LEARNING

Swear Bear... Trash Sorter... Easy AI Trainers

Teach your project to think for itself

BENJAMIN CABÉ'S "NOSE" KNOWS!

Build this smell-identifying AI sniffer

BAGUETTE: 99%

23 PROJECTS!

- Raspberry Pi Meteor Camera
- Digital String Art Portraits
- Animated LED Skirt
- Arduino Borealis Lights

SKILL BUILDERS

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- Hack a Knitting Machine

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VOLUME 77

SECOND SENSE

MAKE A SMART SNIFFER THAT CAN SORT COFFEE FROM TEA, CHOOSE YOUR FAVORITE BOOZE, OR WHATEVER ELSE YOU TRAIN IT TO SMELL!

Written and photographed by Benjamin Cabé

BENJAMIN CABÉ
is a software engineer and IoT jack of all trades at Microsoft, living in Toulouse, France. Find him on Twitter

It was a long weekend of May 2020. Like many of my human siblings stuck at home with time on their hands due to an ongoing pandemic, I was busy trying to perfect my bread recipe. In fact, just a few days before, I had ordered a gas sensor (Figure A) that I thought would be ideal to help me monitor my sourdough starter and bake my bread at just the right moment.

And then I thought about it some more. "Surely this is the perfect excuse for me to finally start learning this machine learning thing that everyone's talking about. But … do I really want to bake dozens of baguettes before I have a training set large enough to teach an AI the relationship between the olfactory fingerprint of the sourdough starter and the yumminess of the final loaf? Plus, flour is pretty scarce these days!"

That's how, over the course of the next few days, I ended up building a DIY, general-purpose, artificial nose — one that can smell virtually anything you teach it to recognize! The artificial nose is powered by artificial intelligence — a TinyML neural network that I trained using the free online tool Edge Impulse and then uploaded onto an Arduino-compatible microcontroller.

I learned a lot along the way, and not just about machine learning. From designing my first 3D enclosure to rudimentary fluid dynamics (the airflow within the nose is not exactly optimal), it was the first time I built my own "thing" from scratch, so I'm excited to share it with the Make: community. Here are the steps for replicating the build for yourself.

BUILD YOUR ARTIFICIAL NOSE

1. GET YOUR PARTS READY

You can 3D print the nose enclosure from thingiverse.com/thing:4493907 (Figure B). Alternatively, grab your Miniaturizer 3000™, fly to Easter Island, and capture your own 1:100 copy of a moai!

Note that you don't need the handsome enclosure to build the artificial nose, but you certainly need all the electronic components (Figure C on the following page). They're easy to put together; there's no soldering involved at all, just plugging in some jumper wires and connectors.

TIME REQUIRED: A Few Hours

DIFFICULTY: Intermediate

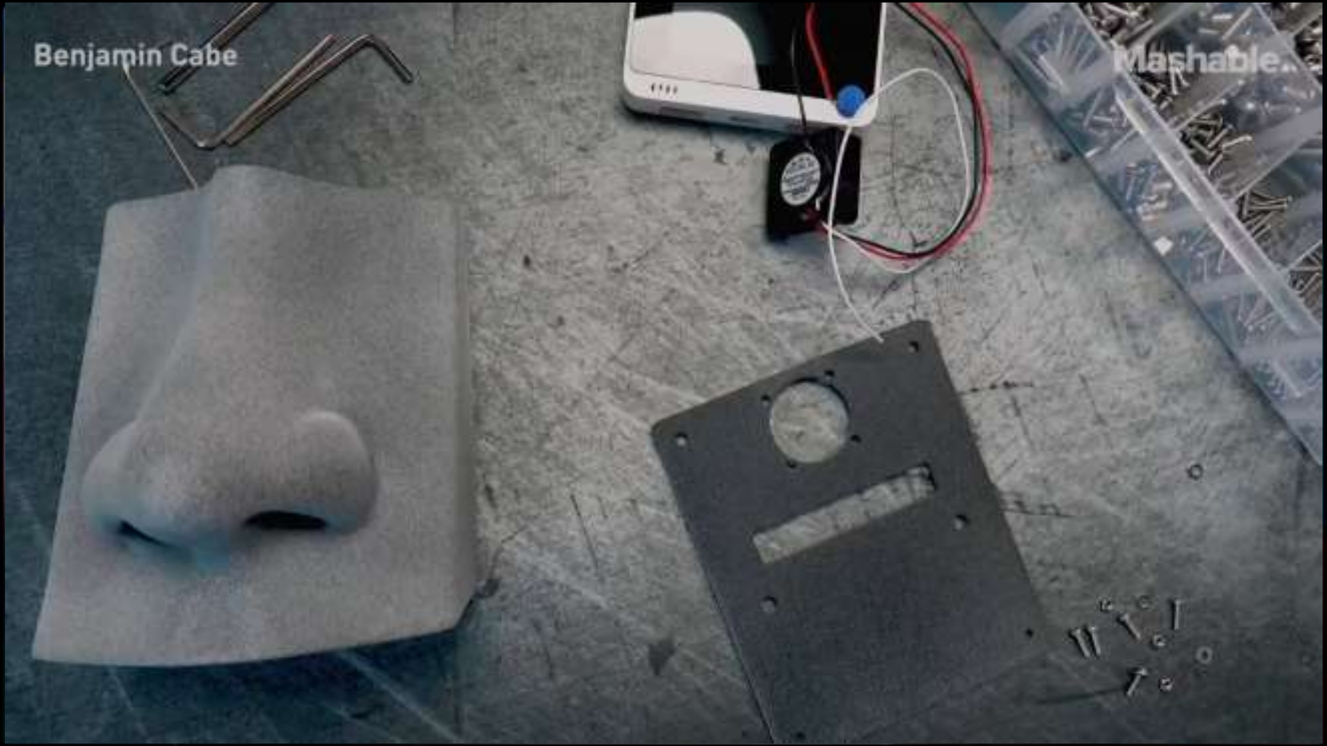
COST: $80–$100

MATERIALS
- Wio Terminal microcontroller board with LCD display
- Grove Multichannel Gas Sensor v2
- 3D printed nose enclosure
- Grove MOSFET board
- Cable, 4-pin Grove connector to male jumper wires
- Fan, 5V DC, 25×25×10mm
- Fan finger guard, 25×25mm
- USB-C right-angle cable (optional)
- Wio Terminal Battery Chassis (optional)
- M2 and M3 screws, nuts, and washers
- Breadboard jumper wires, 100mm (3)

TOOLS
- 3D printer
- Computer with internet connection


A


B



Umm, this AI tool can...smell for you — Future Blink

JORDAN AARON / MAY 07, 2021

Next Up

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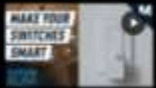

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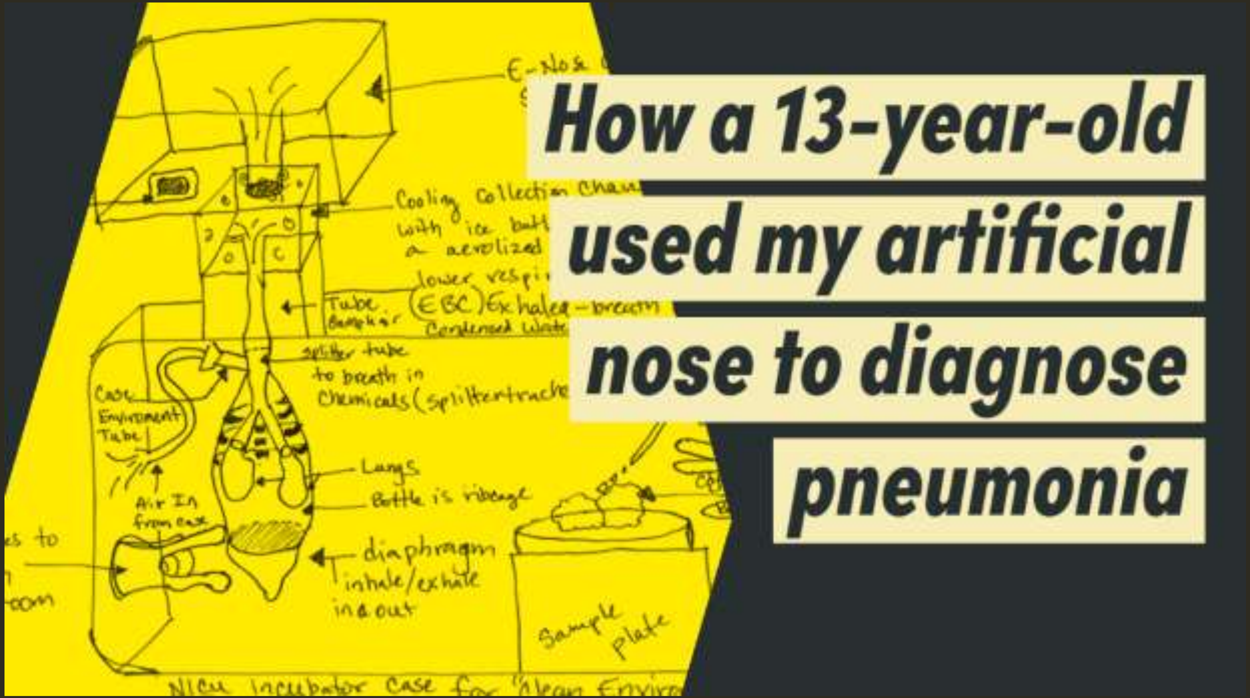


news.ycombinator.com

Y **Hacker News** new | threads | past | comments | ask | show | jobs | submit

1. A 13-year-old used my artificial nose to diagnose pneumonia (benjamin-cabe.com)
229 points by kartben_ 5 hours ago | hide | 128 comments

2. ▲ My smart home 2021: A Home Assistant love story (jorisroovers.com)

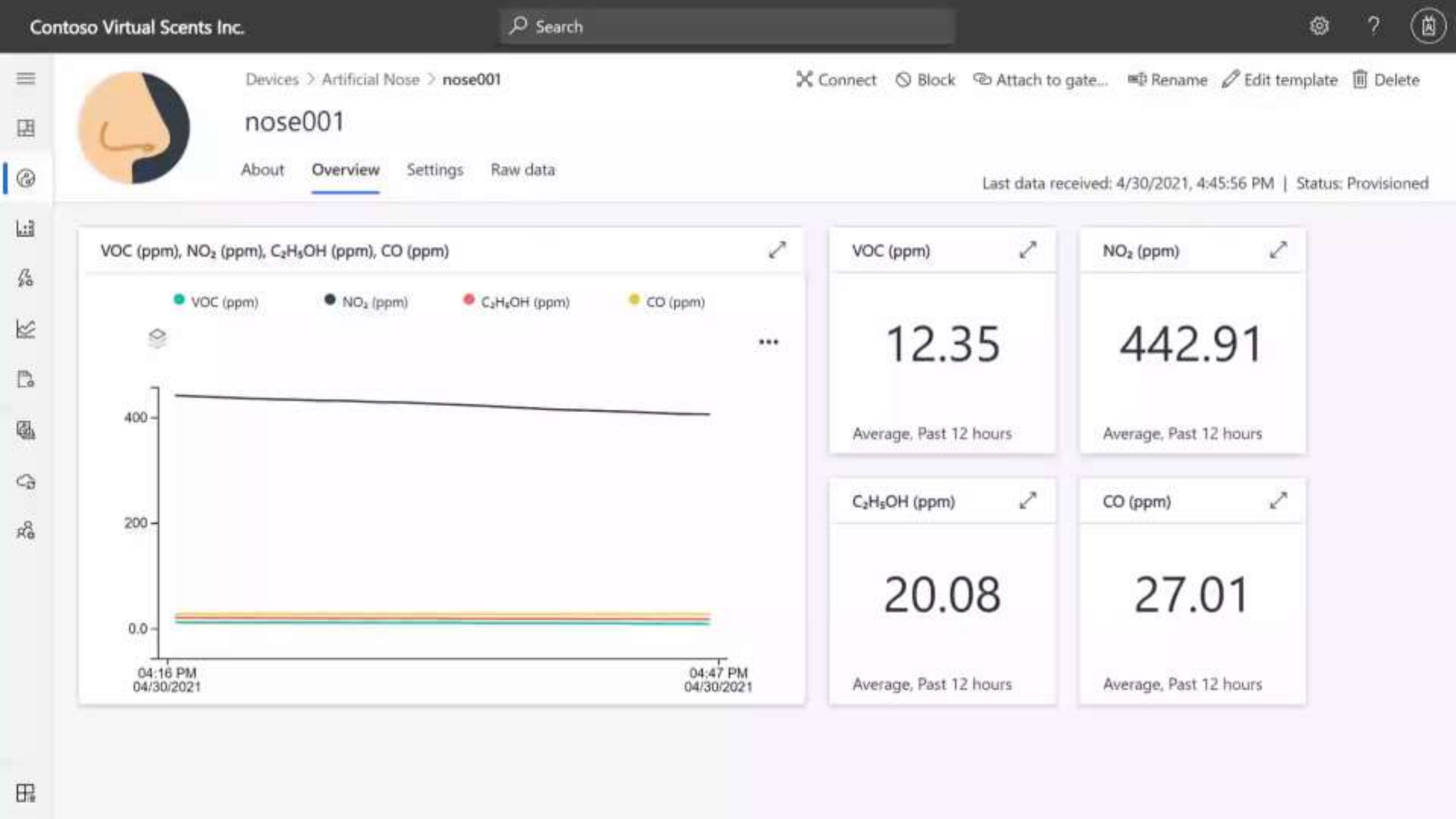

whiskey (73%)

Photo by Wilhelm Gunkel on Unsplash

“INTELLIGENCE AT THE EDGE” + INTERNET = ♥ *

* a.k.a. AIoT

FROM AN "ARTIFICIAL NOSE"…
TO A "CONNECTED ARTIFICIAL NOSE"


Contoso Virtual Scents Inc.
Search
Devices > Artificial Nose > nose001
Connect
Block
Attach to gate...
Rename
Edit template
Delete
nose001
About
Overview
Settings
Raw data
Last data received: 4/30/2021, 4:45:56 PM | Status: Provisioned
VOC (ppm), NO₂ (ppm), C₂H₅OH (ppm), CO (ppm)
VOC (ppm)
NO₂ (ppm)
C₂H₅OH (ppm)
CO (ppm)
400
200
0.0
04:16 PM 04/30/2021
04:47 PM 04/30/2021
VOC (ppm)
12.35
Average, Past 12 hours
NO₂ (ppm)
442.91
Average, Past 12 hours
C₂H₅OH (ppm)
20.08
Average, Past 12 hours
CO (ppm)
27.01
Average, Past 12 hours

"CONNECTING" AN IOT DEVICE IS ONLY THE 1ST STEP

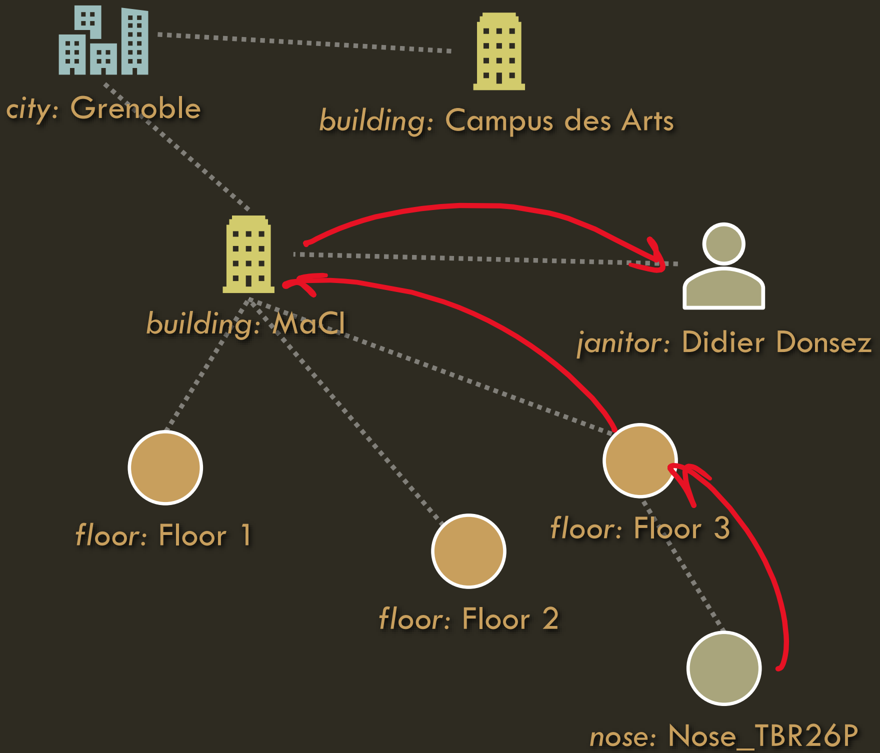
Visualize data in real time

Store telemetry history

Implement **rules**

Integrate with **enterprise systems**

FROM CONNECTED THINGS TO CONNECTED ENVIRONMENTS*



* a.k.a. Digital Twins

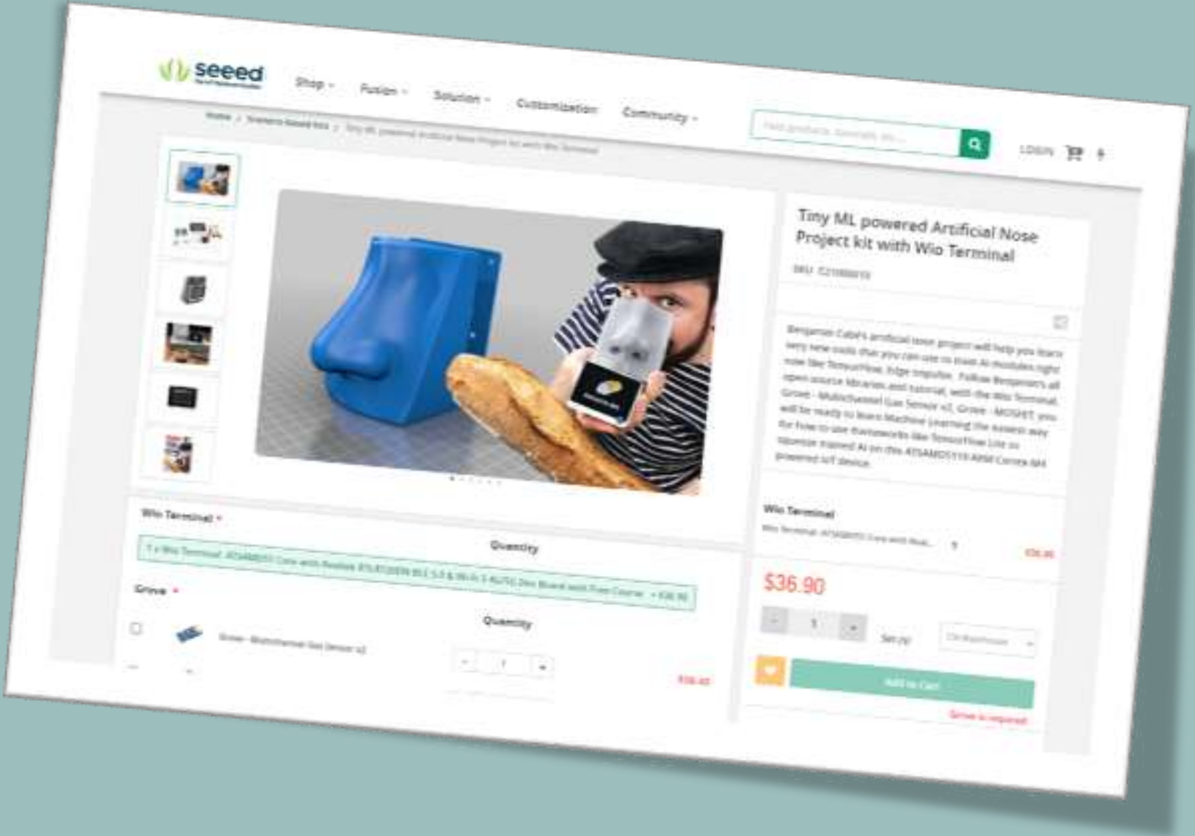
IN A NUTSHELL

TinyML enables an **Internet of Signals**

(Tiny) Edge & **Cloud** each have their strengths

GITHUB.COM/KARTBEN/ARTIFICIAL-NOSE

Bill of materials, source code, schemaitcs, …



AKA.MS/SEEED-TINYML-NOSE-KIT

Wio Terminal + Gas sensors + Fan controller

AKA.MS/AINOSE

Interactive demo,
learning resources, …

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benjamin.cabe@microsoft.com

https://blog.benjamin-cabe.com

THANKS!