tinyML® EMEA
Enabling Ultra-low Power Machine Learning at the Edge

October 10-12, 2022
Limassol, Cyprus

www.tinyML.org
1 Million TinyML developers

*lessons learned from Arduino*
“Enabling anyone to innovate by making complex technologies simple to use.”
30M Estimated Active Developers

41M Arduino IDE Downloads/Year
Computing power
<table>
<thead>
<tr>
<th>Computer</th>
<th>IBM 704</th>
<th>Apollo Guidance Computer</th>
<th>Arduino Nano 33 BLE Sense</th>
</tr>
</thead>
<tbody>
<tr>
<td>Announced</td>
<td>1954</td>
<td>1966</td>
<td>2019</td>
</tr>
<tr>
<td>Processor</td>
<td>Vacuum Tubes</td>
<td>RTL Chips</td>
<td>ARM Cortex M4f</td>
</tr>
<tr>
<td>Bits</td>
<td>36</td>
<td>15+1</td>
<td>32</td>
</tr>
<tr>
<td>Clock</td>
<td>8MHz</td>
<td>2.048 MHz</td>
<td>64MHz</td>
</tr>
<tr>
<td>FLOPs</td>
<td>12,000</td>
<td>~40,000</td>
<td>(Est) 16,000,000</td>
</tr>
<tr>
<td>MIPs</td>
<td>0.04</td>
<td>~1</td>
<td>81.28 DMIPS</td>
</tr>
<tr>
<td>Cost</td>
<td>$338,888/month</td>
<td>$121M</td>
<td>$31.10</td>
</tr>
<tr>
<td>Power</td>
<td>70W</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Notes: Values are obviously a simplification/estimation. Cost of IBM 704 based on quote received by CERN in 1959. Prices adjusted for inflation to 2021 dollars. AGC FLOPs reported as "Arithmetic Operations"
- Self Improving products
- Privacy
- Low Power
- Simpler Hardware
- Latency
- Bandwidth
The beginning (Circa 2014)
Intel Pattern Matching Engine (General Vision)
PLUG+
Reuben Jerome Dsilva, Varenya Raj, Yuxi Liu
Responsible Window
Ubaldo Andrea Desiato, Chaeri Bong, Mantas Lilis
Neighbor-ly
Abhishek Kumar Fahmida Azad Rina Shumylo
Some things I have learned
Easy to replicate examples
Open Source HW

Open Source SW

Teaching Methods

Design & UX

Build a platform if you can
Don’t be afraid to illustrate very simply
Not all your users know advanced math
btw these large scary math symbols are just for-loops

**Summation (capital sigma)**

\[
\sum_{n=0}^{4} 3n
\]

```c
sum = 0;
for( n=0; n<=4; n++ )
    sum += 3*n;
```

**Product (capital pi)**

\[
\prod_{n=1}^{4} 2n
\]

```c
prod = 1;
for( n=1; n<=4; n++ )
    prod *= 2*n;
```
The ability to understand mathematical processes is widespread, but the ability to parse mathematical notation isn't. Insisting on teaching deep learning (which is fundamentally software engineering, not mathematics) with equations is like insisting on teaching Hegel in German.
sometimes what you know gets in the way of what you need to learn explain

Imagine different ways of teaching
Build tools to teach the principles
<table>
<thead>
<tr>
<th>Arduino serial input</th>
<th>ColorKNN.ino visualization</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Color examples seen</td>
</tr>
<tr>
<td></td>
<td>Color sensor viewer</td>
</tr>
</tbody>
</table>
User experience is central
# Digits v4

**Parameters**

- **Generate features**

**Training set**

- **Data in training set**: 30 items
- **Classes**: 10 (0, 1, 2, 3, 4, 5, 6, 7, 8, 9)

**Feature generation output**

- **Thu Sep 16 22:56:12 2021** Construct embedding
- **Still running...**
  - completed 0 / 500 epochs
  - completed 50 / 500 epochs
  - completed 150 / 500 epochs
  - completed 200 / 500 epochs
  - completed 250 / 500 epochs
  - completed 300 / 500 epochs
  - completed 350 / 500 epochs
  - completed 400 / 500 epochs
  - completed 450 / 500 epochs
- **Thu Sep 16 22:56:30 2021** Finished embedding
  - Reducing dimensions for visualizations OK
  - **Job completed**

**Feature explorer (30 samples)**

- **X Axis**
  - Visualization layer 1
- **Y Axis**
  - Visualization layer 2
- **Z Axis**
  - Visualization layer 3

**On-device performance**

- **PROCESSING TIME**
- **PEAK RAM USAGE**
APIs are part of the User Experience
Build layered system that can be discovered progressively
Simple but not too simple
TinyML Dog Bark Stopper

A fun and simple project that uses TinyML to detect and respond to dog barks.

Intermediate  🗂️ Full instructions provided  ⏰️ 2 hours  ⭐️ 8,849

Build meaningful real life examples
Epilepsy seizure detection

Team Epilet
Intelligent Insect Trap
Arduino / Sebastian Romero
Early detection of respiratory diseases

Clinton Oduor
LET THIS CRYING DETECTING CLASSIFIER OFFER SOME MUCH NEEDED REPRIEVE

by: Orlando Hoilett

September 15, 2020
Powerful building blocks / Immediately usable
TinyML on Arduino with Tensorflow Lite Micro
Bring in people from the outside of your obvious space
Engage with people outside your world
“It takes only a tiny group of engineers to create technology that can shape the entire future of human experience with incredible speed.”

Jaron Lanier
Thank you!

Massimo Banzi
askmassimo@arduino.cc
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