tinyML® Summit

Miniature dreams can come true…

March 28-30, 2022 | San Francisco Bay Area

TINY ML

www.tinyML.org

SYNTIANT®

Making Edge AI a Reality

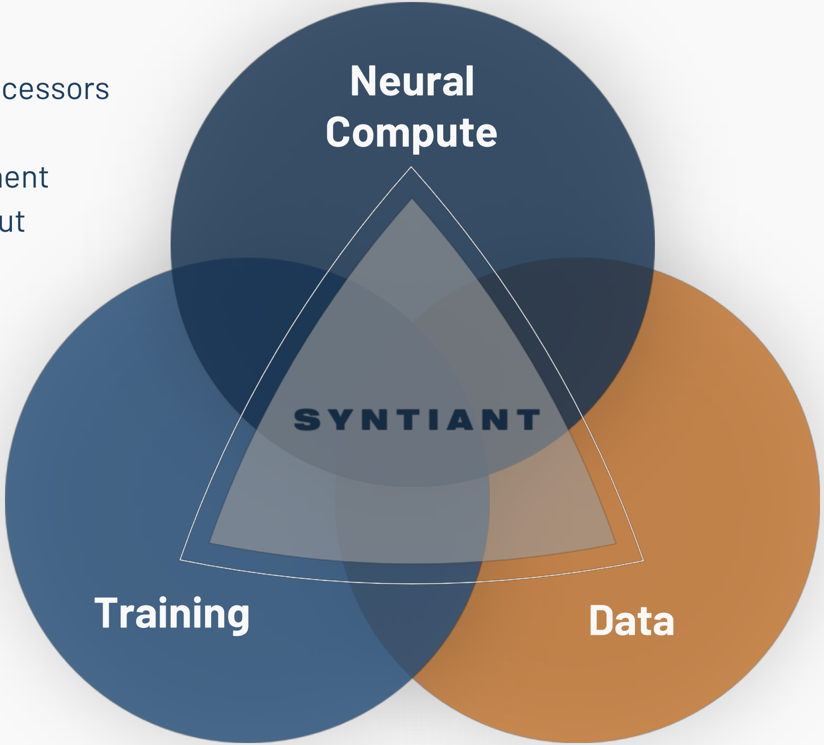
A Complete Edge ML Company
Delivering **Deep Learning** Solutions for
Always-On Devices

Syntiant Complete ML solution

Neural Compute

Syntiant Neural Decision Processors vs. current MCUs:

- ✓ 100x efficiency improvement
- ✓ 30x increase in throughput
- ✓ ½ the die size



Easy to use

All the elements are required to go to market

Training

Syntiant Training Pipeline delivers turn-key models for the mass market

Data

Syntiant Data Platform automates the ingestion, labelling, aligning, cleaning, and synthetic data generation to turn raw data into training data sets

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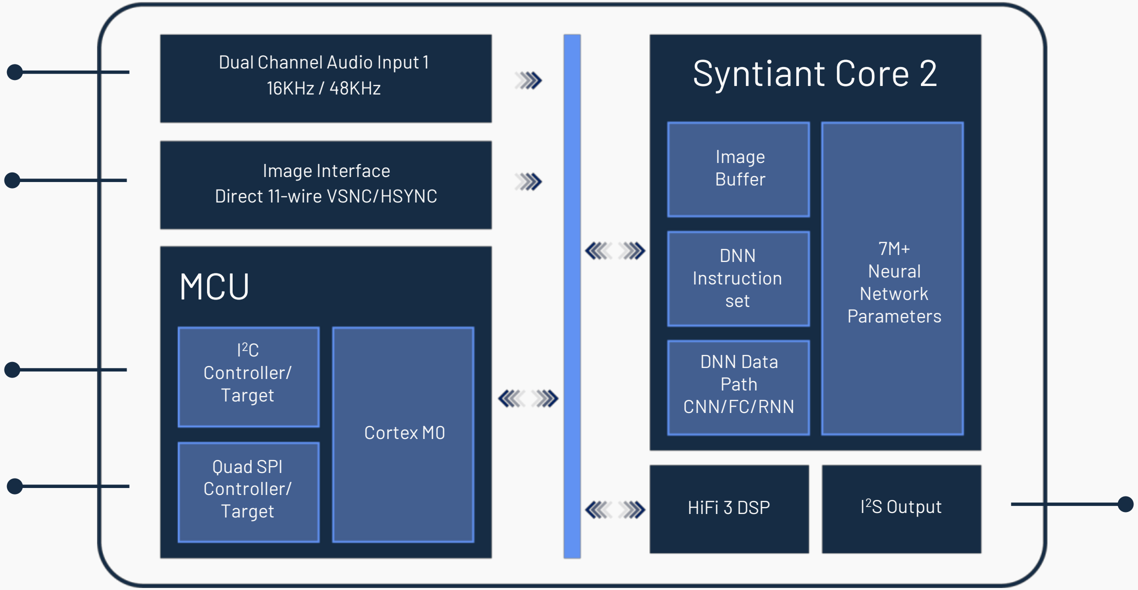
NDP200 Image, Voice & Sensor Neural Decision Processor



Dual Channel Audio Input 1
16KHz / 48KHz

Image Interface
Direct 11-wire VSNC/HSYNC

MCU

I^2C Controller/ Target

Quad SPI Controller/ Target

Cortex M0

Syntiant Core 2

Image Buffer

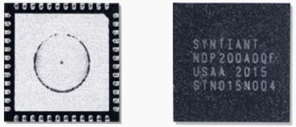
DNN Instruction set

DNN Data Path CNN/FC/RNN

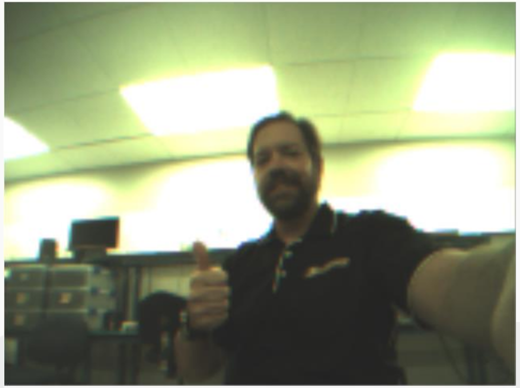
7M+ Neural Network Parameters

HiFi 3 DSP

I^2S Output



5mm x 5mm
QFN40



QQVGA (160x120) color image

Phones / Tablets

Laptops

Smart Speakers

Robotics

Security

Always-on Image processing

MobileNet + sensor in < 1 mW

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Syntiant Silicon: Neural Decision Processor (NDP)

At-Memory Compute

Tightly coupled memory and MAC functions to minimize data movement

Sustained High MAC Utilization

- Syntiant architecture executes NN every clock cycle achieving over 80% utilization for common NN
- Assures maximum usage of operations per second

Native Neural Network Processing

- No need for intermediary compilers
- Networks trained in TensorFlow, etc are deployed directly to the NDPs.

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Performance Comparison

	Syntiant Core 2	Arm A53	Syntiant Advantage
Inferences per Million Cycles	1.346	0.0471	~30x
μJ per Inference	166	16131	~100X

Identical MobileNet V1 0.25 int8 network on A53 & NDP200 (Syntiant Core 2)

tinyMLPerf- style test mechanics - - single, identical input vector

Syntiant Core 2 @ 32MHz

=

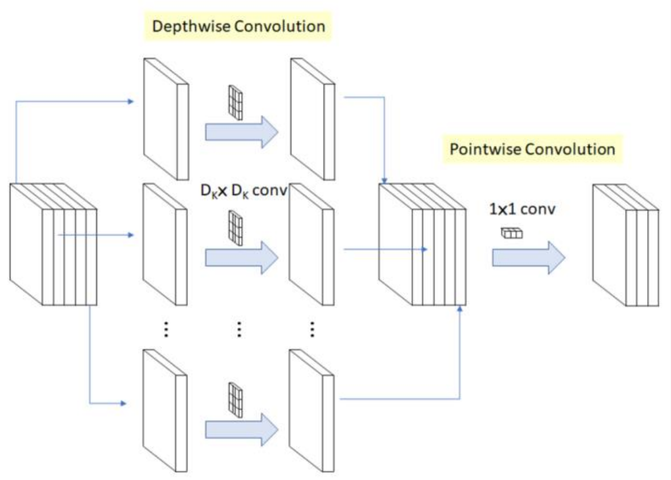
Arm A53 @ 1 GHz

at **1%**

of the energy

If an ARM A53 powered device has a battery life of 3.5 days, the NDP200 powered device has a 1-year battery life running the same neural network.

MobileNetV1



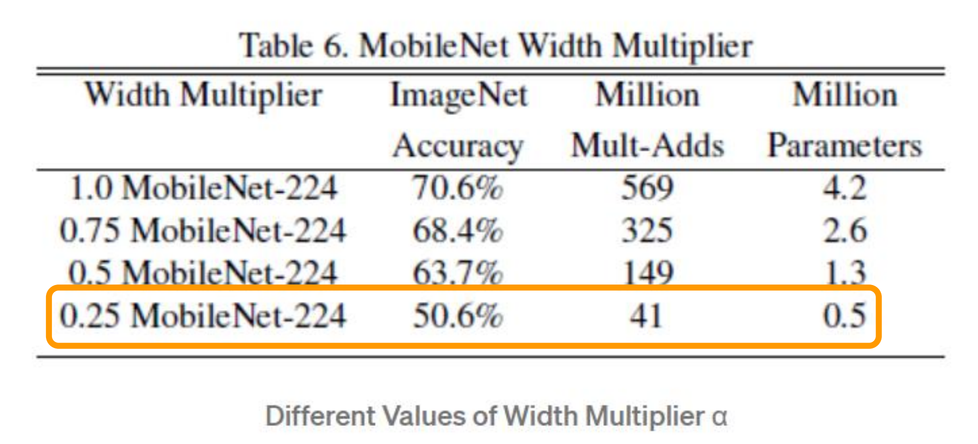


Table 6. MobileNet Width Multiplier

Width Multiplier	ImageNet Accuracy	Million Mult-Adds	Million Parameters
1.0 MobileNet-224	70.6%	569	4.2
0.75 MobileNet-224	68.4%	325	2.6
0.5 MobileNet-224	63.7%	149	1.3
0.25 MobileNet-224	50.6%	41	0.5

Different Values of Width Multiplier α

- Scalable image network architecture for reducing model complexity
  - Depthwise convolutions break complexity
  - Width Multiplier α, resolution Multiplier ρ

- 0.25 MobileNetV1 can easily fit in NDP200
- Under the 640 kB params support
  - Depthwise convolutions break complexity
  - Width Multiplier α, resolution Multiplier ρ

https://towardsdatascience.com/review-mobilenetv1-depthwise-separable-convolution-light-weight-model-a382df364b69
https://arxiv.org/pdf/1704.04861.pdf

MobileNetV1 Style Optimizations

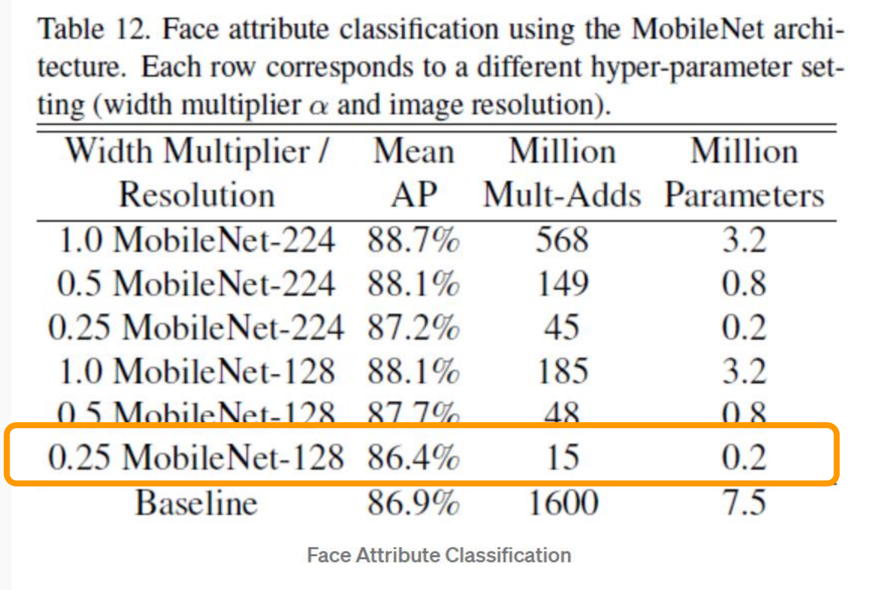


Table 12. Face attribute classification using the MobileNet architecture. Each row corresponds to a different hyper-parameter setting (width multiplier α and image resolution).

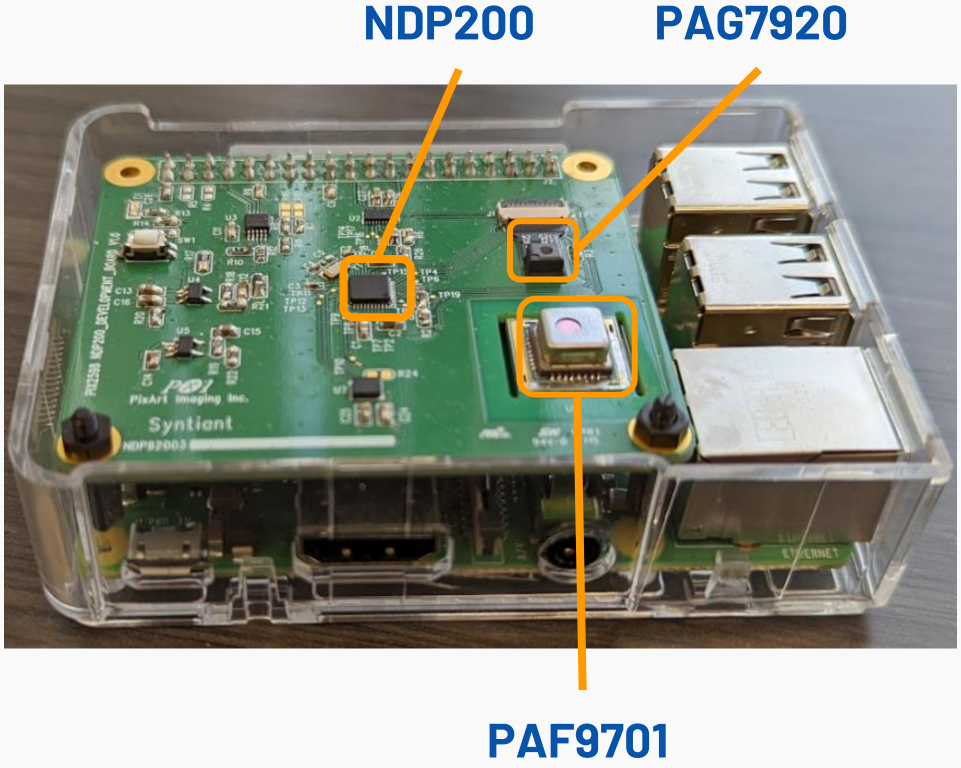
Width Multiplier / Resolution	Mean AP	Million Mult-Adds	Million Parameters
1.0 MobileNet-224	88.7%	568	3.2
0.5 MobileNet-224	88.1%	149	0.8
0.25 MobileNet-224	87.2%	45	0.2
1.0 MobileNet-128	88.1%	185	3.2
0.5 MobileNet-128	87.7%	48	0.8
0.25 MobileNet-128	86.4%	15	0.2
Baseline	86.9%	1600	7.5

Face Attribute Classification

- NDP200 is a flexible architecture that can support tuning the networks
- Example of aggressive model compression in Google's Mobilenet paper - Face attribute classification
  - Shrink to 200k params still with good performance
- Tons of work to tailor optimal solutions for the NDP200 platform
  - MobileNet V2
  - Single-shot multibox detection (SSD)

NDP200 Development Platform

- Jointly developed image development platform with PixArt
  - Raspberry Pi form factor
  - NDP200 for ML solutions
  - 320x240 image sensor (PAG7920)
  - 8x8 thermal sensor (PAF9701)
  - 6-axis accel/gyro BMI sensor (BMI160)
- Enables both capture and model development for Computer Vision (CV) ML model solutions



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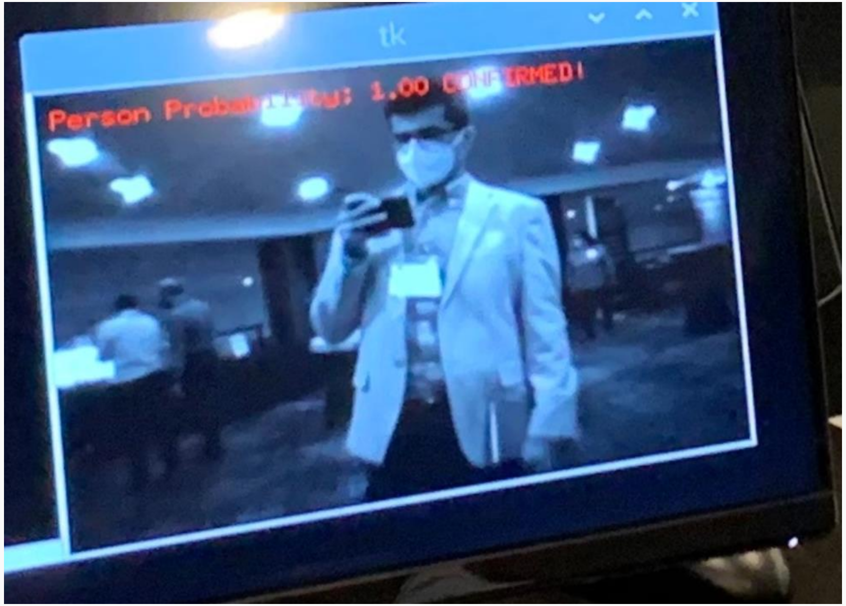
NDP200 Person Detection Demo

- Trained up a MobileNetV1 0.25 person detection
  - Input size 320x240 grayscale
  - First layer was additional decimation to 240x120 image
  - 59-layer Neural network on Core 2
- Used person/non-person images from MS COCO for demo network
  - OpenCV to decimate + grayscale images to match image sensor
- Seeing 90% accuracy on the demo model
  - 4-5 hours of training



Person Probability: 1.00 CONFIRMED!

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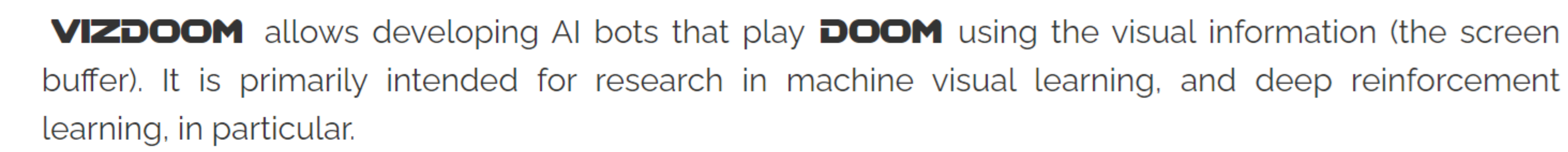
NDP200 - More than just Object detection

- Can NDP200 do more than just object detection?
- Can it observe and act on the images presented to it?
- **Goal: teach NDP200 to play DOOM!**

Doom-based AI Research Platform for Reinforcement Learning from Raw Visual Information



VIZDOOM allows developing AI bots that play **DOOM** using the visual information (the screen buffer). It is primarily intended for research in machine visual learning, and deep reinforcement learning, in particular.

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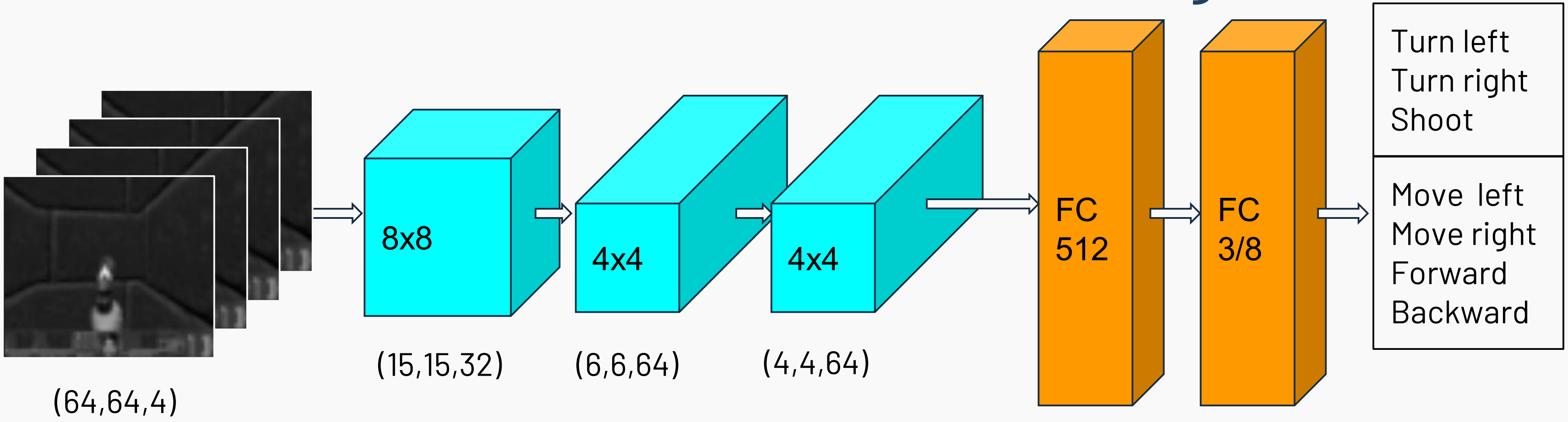
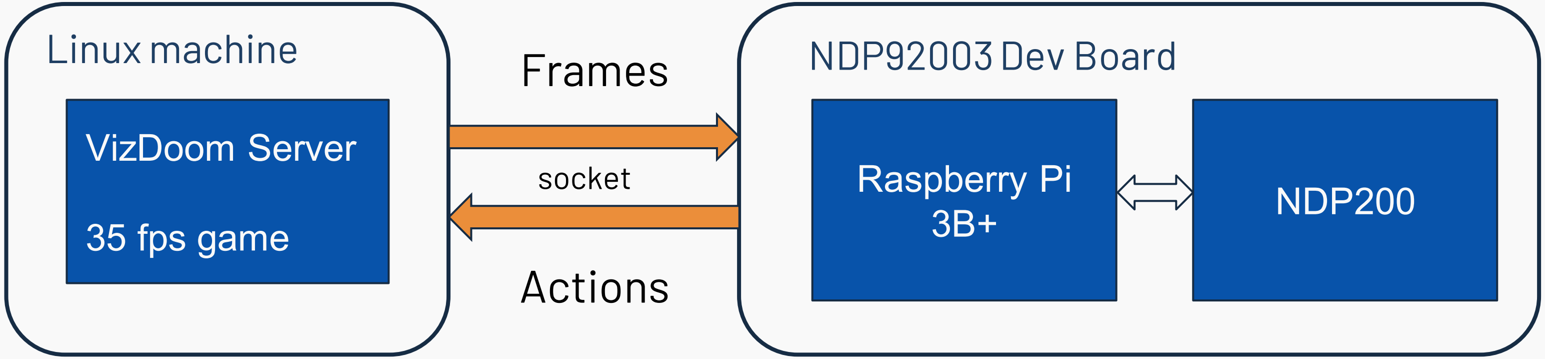
http://vizdoom.cs.put.edu.pl/

NDP200 Platform - Reinforcement Learning



- Using the VizDoom platform, able to train an NDP200 using reinforcement learning to play "DOOM"
  - Reward is killing a monster, only limited time + ammo
  - Training on Syntiant's TDK environment (Linux), inference running on the NDP200
- Convert frames into 64x64 grayscale (4 frames in time series) to the network
  - 3 Convolutional layers into 2 Dense – 606k params

Running VizDoom on the NDP200



Linux machine

VizDoom Server

35 fps game

Frames

socket

Actions

NDP92003 Dev Board

Raspberry Pi 3B+

NDP200

5 layer Deep Neural Network
606k params
1 mW @ 35 fps

15,000x improvement over my 15W brain

NDP200 Platform - Reinforcement Learning

- Start with no knowledge of the game mechanics
- Play thousands of games with rewards for killing monsters
- Learns to shoot and turn around 360 looking for approaching monsters

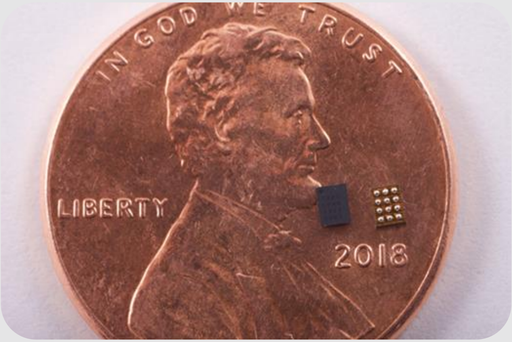
NDP200 Platform - Reinforcement Learning

- Deadly corridor expands to 7 actions (motion)
- CANNOT get past without killing all the monsters
- Roughly 3-days of training, almost the same network
  - 8 output classes

Conclusion

- NDP200 is ready for Computer Vision (CV) applications at the edge in < 1 mW
  - Always-on domain
- NDP200 Development platform is ready to explore CV and sensor-fusion applications
  - Supports data collection (to help calibrate images), and real inference for development
- More than just simple object-detection, NDP200 can use ML to observe and control in the real world

Thank you



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