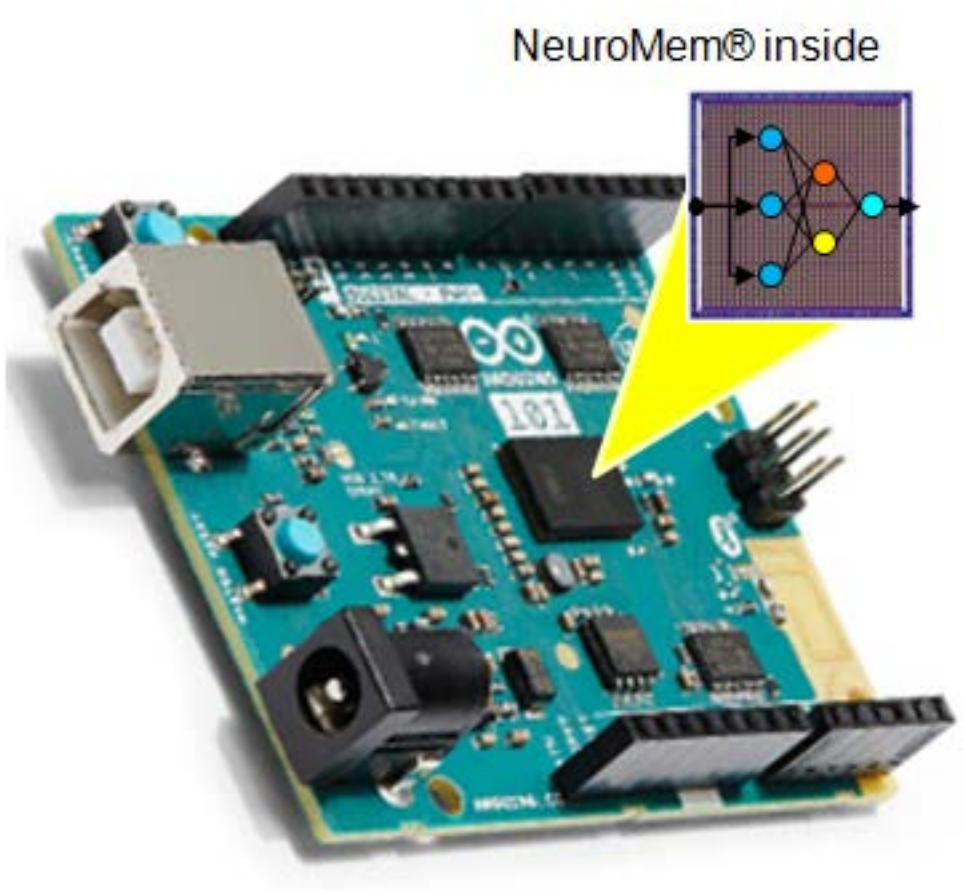
Unleashing the neurons of the Intel® Curie module on the Arduino/Genuino 101 platform

Teach the neurons with the push of a button or else, and immediately start recognizing

Monitor signals and act only when significant events occur.



What is NeuroMem?

NeuroMem

= Neuromorphic Memories

= Digital neurons

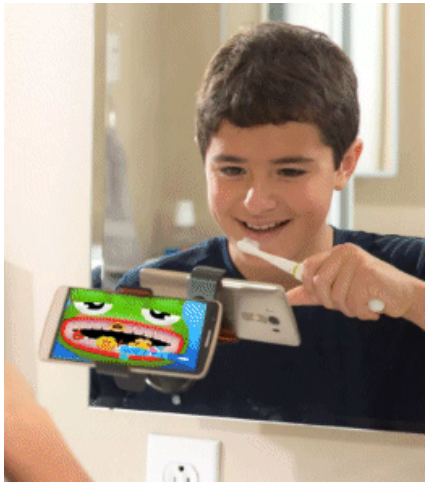
= Trainable

= Parallel architecture

- 2015: Intel rolls out the QuarkSE, 1st SOC with NeuroMem inside (128 neurons with 128 bytes of memory per neuron)
- 2011: General Vision licenses its NeuroMem technology to Intel®
- 2007: General Vision introduces its NeuroMem CM1K chip (1024 neurons with 256 bytes of memory per neuron)
- 1993: IBM introduces the ZISC chip, ancestor of the NeuroMem chips (36 and 79 neurons of 64 bytes of memory per neuron)

What can I do with the Curie neurons?

Grush, the gaming toothbrush making sure the kids brush their teeth properly



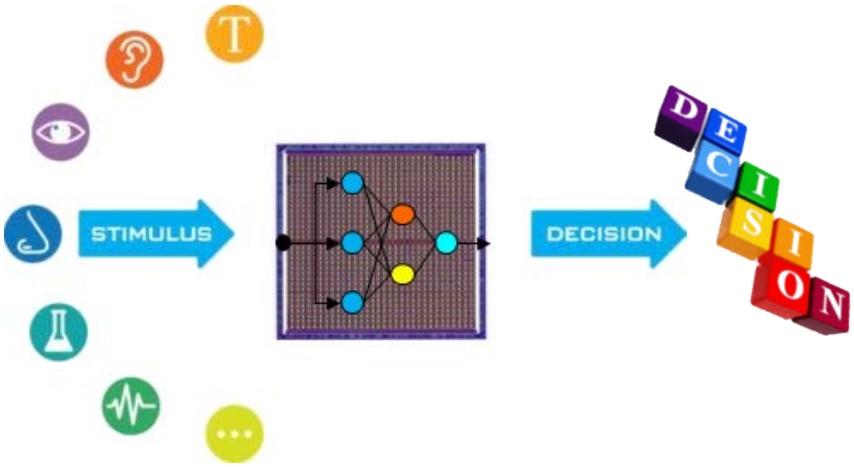
ShapeHeart, arm band with heart monitoring

Jagger & Lewis, smart collar monitoring well-being of dogs

Benefits of the neurons

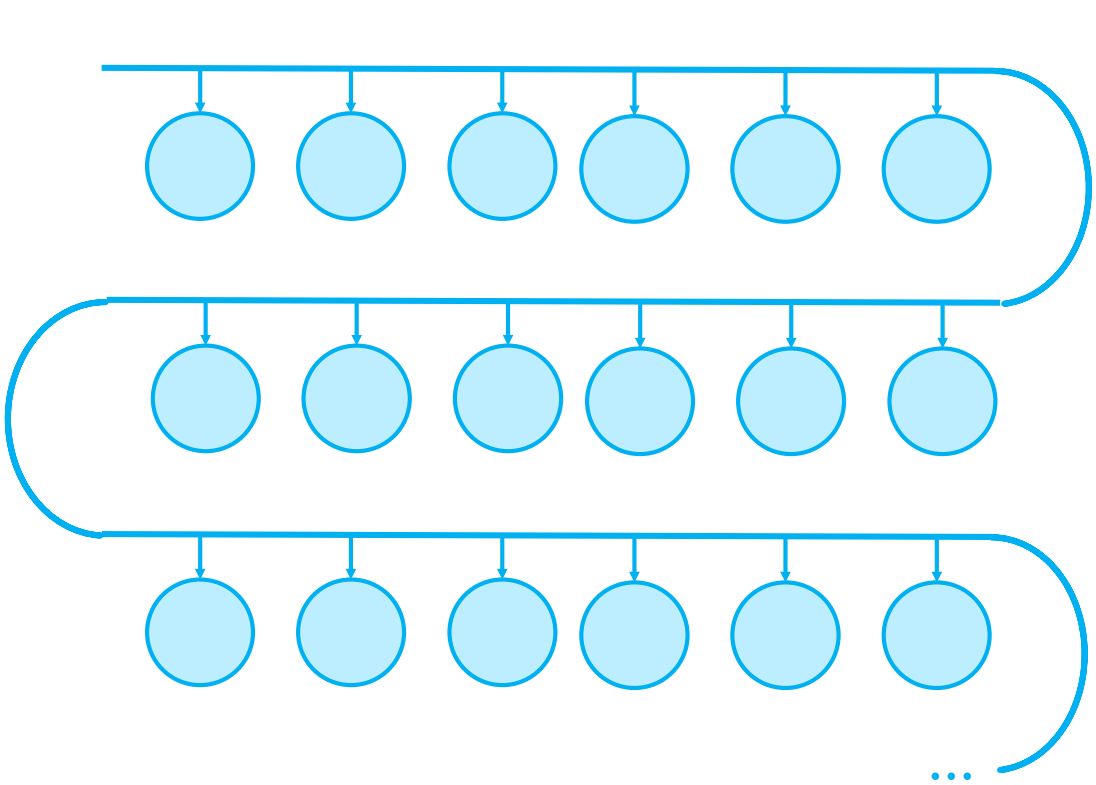
- The neurons learn by examples
  - No programming
  - Training can be done off-line or the fly
- Continuous monitoring at low-power
- Can detect novelty or anomaly
- Knowledge portability
- Knowledge expandability

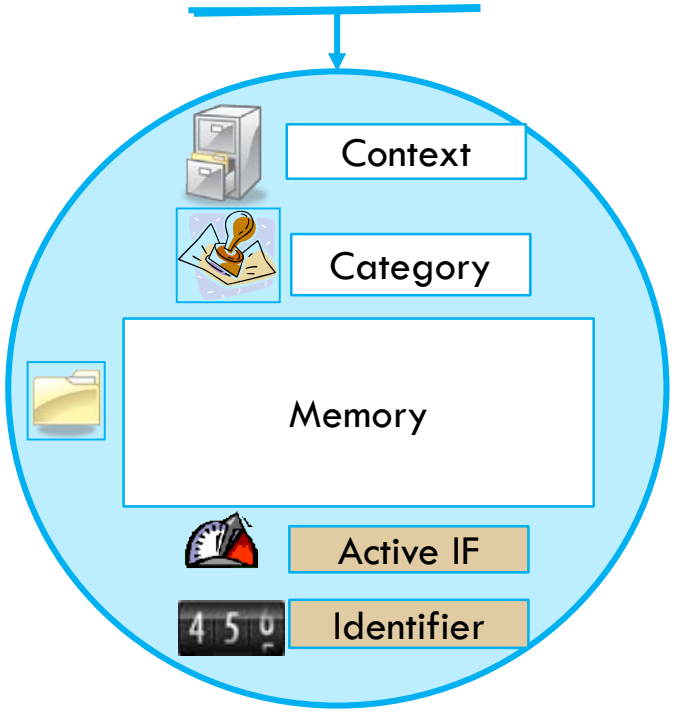
- Input= Stimuli
- Output=Decision



About the neurons

Chain of identical neuron cells, no supervisor, low clock, low power





Curie Neurons attributes

ANN Attributes	Quark SE
Neuron capacity	128
Neuron memory size	128 bytes
Categories	15 bits
Distances	16 bits
Contexts	7 bits
Recognition status	Identified, Uncertain or Unknown
Classifiers	Radial Basis Function (RBF) K-Nearest Neighbor (KNN)
Distance Norms	L1 (Manhattan) Lsup

A simple API

Learn pattern

Recognize pattern

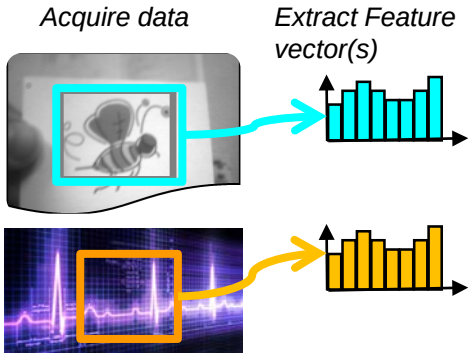
Save Knowledge

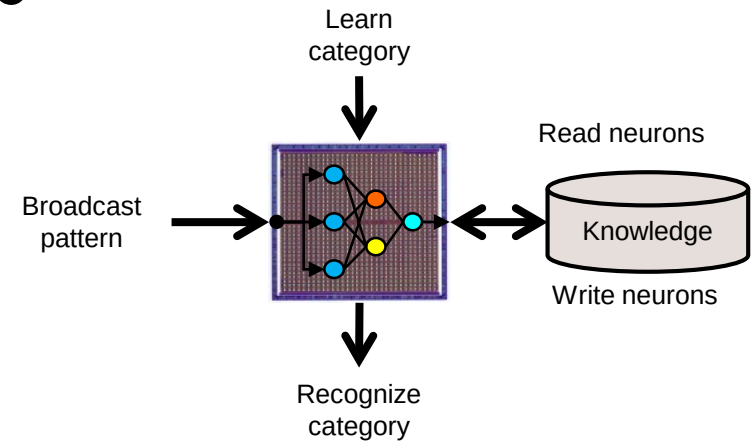
Load Knowledge

RBF or KNN classifier

Context segmentation

- 4 basic functions
  - Learn/Recognize patterns (<=128 bytes)
  - Save / Restore knowledge
- Additional settings



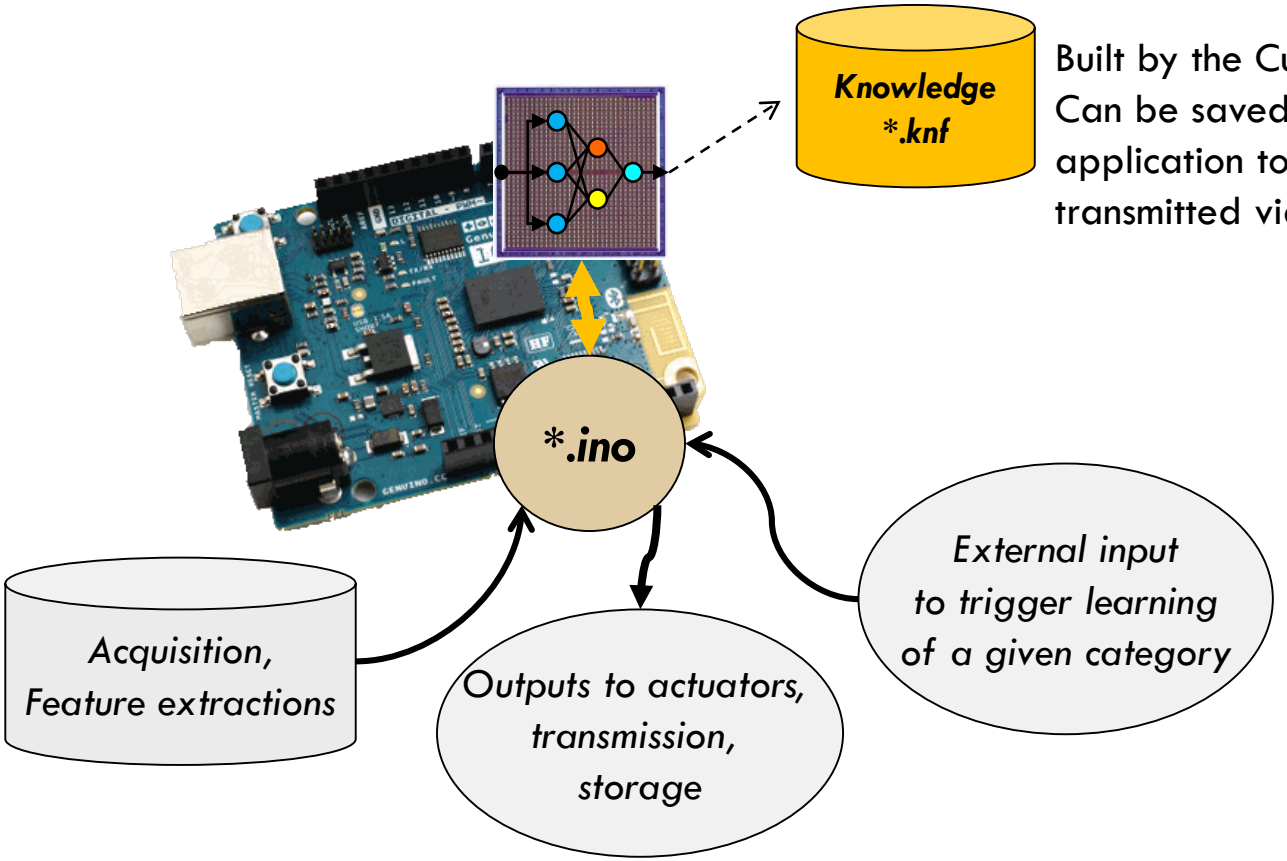


How to teach the neurons

- CurieNeurons libraries for real-time training
  - Data acquisition
  - Feature extraction
  - Broadcast to neurons for continuous recognition
  - User input to trigger a broadcast to neurons for learning, along with a category
  - The neurons build the knowledge autonomously
- Soon…Knowledge Builder apps for off-line training
  - Data collection and annotation
  - Learning of training sets, validation on testing sets
  - Export of the knowledge built by the neurons

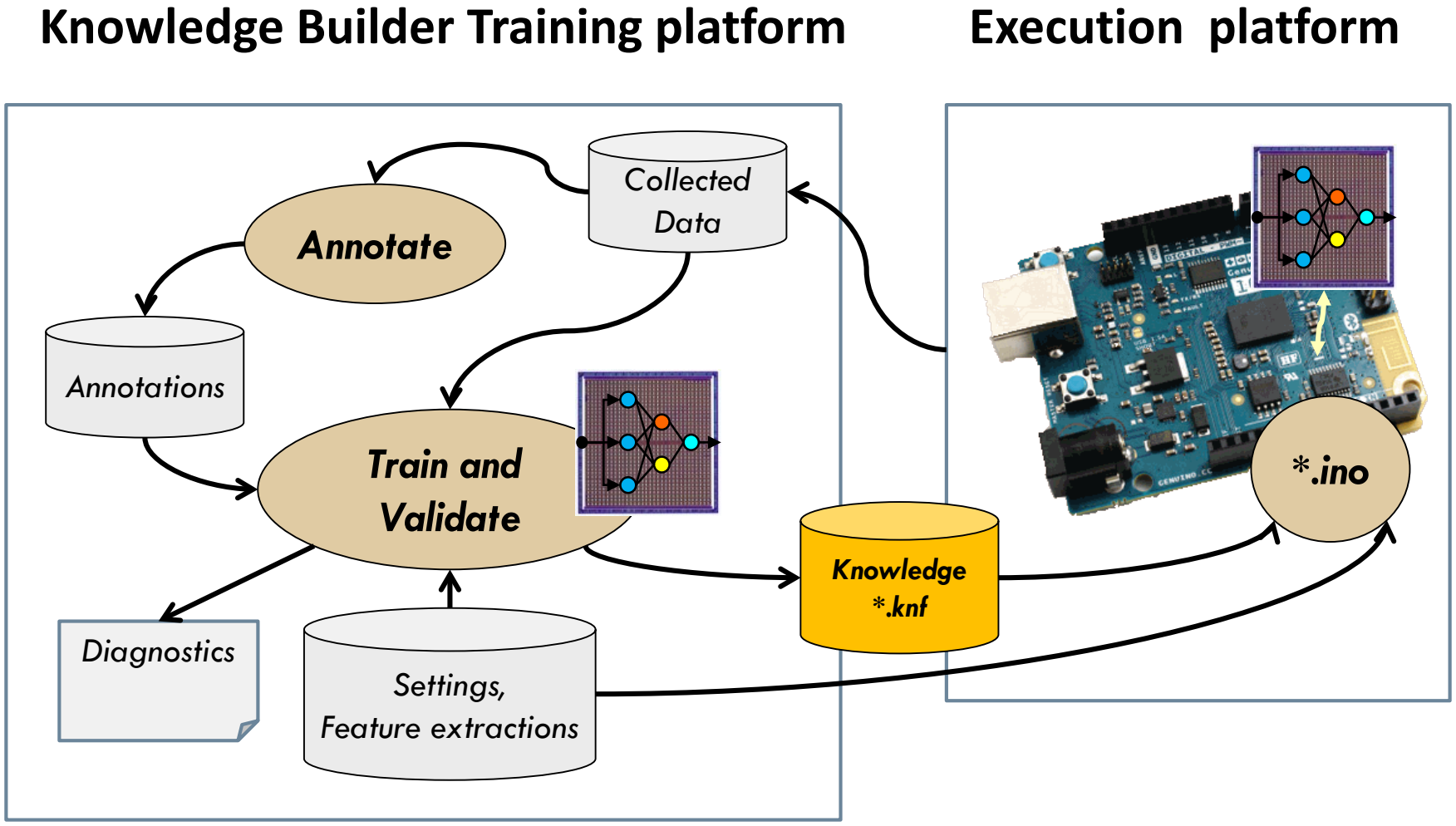
Application deployment w/ live training

Training & Execution on Curie



Built by the Curie neurons.
Can be saved by the application to Flash, SD card, transmitted via BlueTooth, etc

Application deployment w/ off-line training



CurieNeurons free library

- RBF classifier
- Single context
- No access to the neurons' registers

```
class CurieNeurons
{
    public:

        # define NEURONSIZE     128 //memory capacity of each neuron in byte
        # define MAXNEURONS     128 // number of silicon neurons

        CurieNeurons();
        void Init();
        void getNeuronsInfo(int* neuronSize, int* neuronsAvailable, int* neuronsCommitted);
        void Forget();
        void Forget(int Maxif);

        int Learn(unsigned char vector[], int length, int category);
        int Classify(unsigned char vector[], int length);
        int Classify(unsigned char vector[], int length, int* distance, int* category, int* nid);
        int Classify(unsigned char vector[], int length, int K, int distance[], int category[], int nid[]);

        void ReadNeuron(int nid, int* context, unsigned char model[], int* aif, int* category);
        void ReadNeuron(int nid, unsigned char neuron[]);
        int ReadNeurons(unsigned char neurons[]);
        int WriteNeurons(unsigned char neurons[]);
```

CurieNeuronsPro library

- Full access to the neurons' register
- Access to both RBF and KNN classifiers
- Access to multiple contexts
  - Sensor fusion
  - Cascade classifiers

```
//Functions available in the Geek Library
//----------------------------------------

void SetContext(int context, int minif, int maxif);
void GetContext(int* context, int* minif, int* maxif);
void SetRBF();
void SetKNN();

int NCOUNT();
void NSR(int value);
int NSR();
void MINIF(int value);
int MINIF();
void MAXIF(int value);
int MAXIF();
void GCR(int value);
int GCR();
int DIST();
void CAT(int value);
int CAT();
void NID(int value);
int NID();
void RSTCHAIN();
void AIF(int value);
int AIF();
void IDX(int value);
```

Simple examples to get started

Text/Data recognition

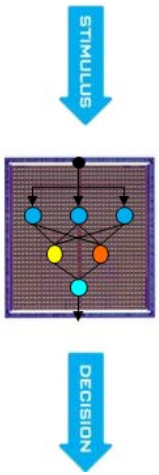
Gesture recognition

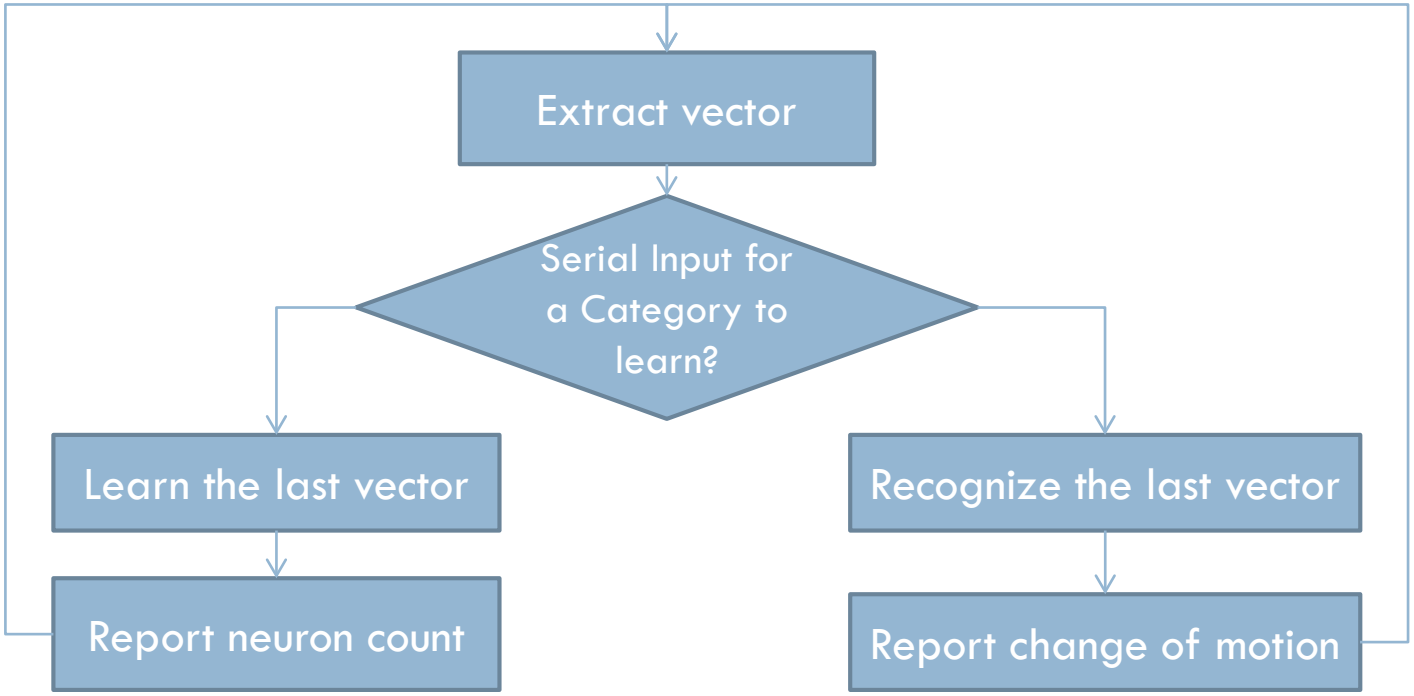
Image recognition

- Simple script
  - Understand the mechanism to learn, recognize user-generated vectors
- Gesture recognition
  - Using Curie's 6-axis accelerometer/gyro
- Video recognition
  - Requires the ArduCam Shield board

CurieNeurons_IMU Example

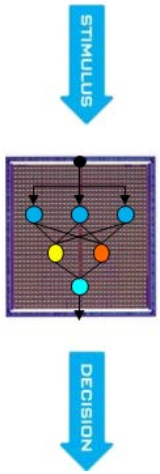
Stimuli = A simple feature vector is assembled and normalized over n samples
[ax1, ay1, az1, gx1,gy1, gz1, ax2, ay2, az2, gx2, gy2, gz2, … axn, ayn, azn, gxn, gyn, gzn]
Category= 1 for vertical, 2 for horizontal, 0 for anything else

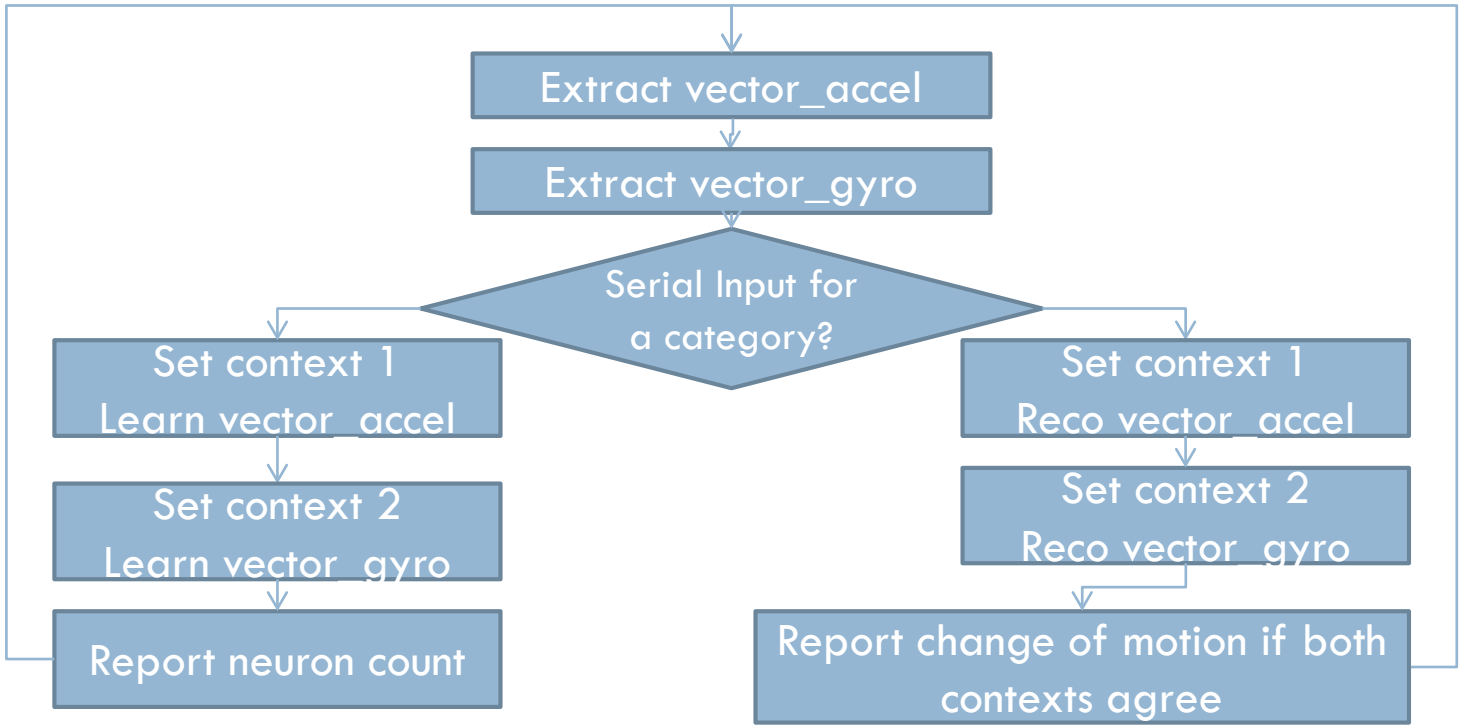




CurieNeurons_IMU2 (Pro only)

Stimuli = 2 simple feature vectors assembled and normalized over n samples
context 1, vector_accel= [ax1, ay1, az1, ax2, ay2, az2,... axn, ayn, azn]
context 2, vector_gyro= [gx1,gy1, gz1, gx2, gy2, gz2, ... gxn, gyn, gzn]
Category= 1 for vertical, 2 for horizontal, 0 for anything else
Observation= commits more neurons, but less false hits



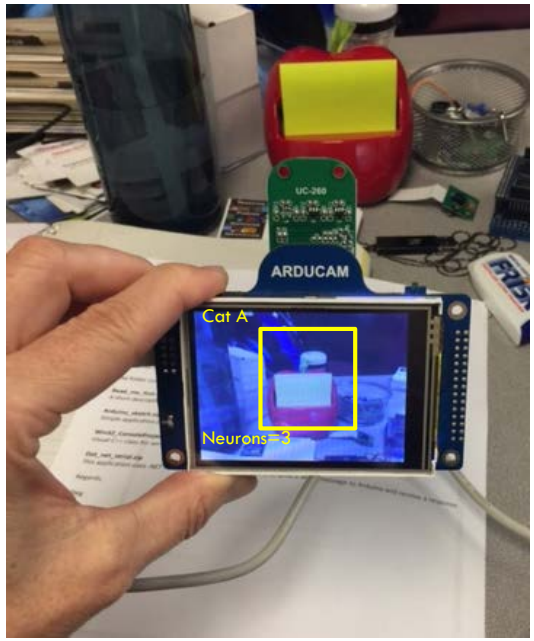


CurieNeurons w/ IMU (the movie)

View this introduction on our youtube account

CurieNeurons w ArduCam (Pro only)

- Operation modes
  - Interlaced video display and recognition
  - User-Interrupt for learning
  - Optional Save of the knowledge
- Input
  - Shutter button
    - < 2 sec : learn a new category
    - > 2 sec : learn a background/ null category
  - ROI is fixed and centered in video frame
- Output
  - LCD overlay after each frame capture
    - ROI rectangle
    - Text result



This demo shows the real-time image learning capabilities of the neurons, but can be significantly accelerated (read the comments in the script)

Under development

Text

Data

Signal

Audio

Biosensors

Image

Video

…

- Knowledge Builder apps
  - Off-line training and validation
  - NeuroMem KB, generic and agnostic to data type
  - Curie KB for acceleration and gyro
  - Image KB for image and video
  - More to come…

NeuroMem KB– Curie edition