AI in Embedded Systems

Class 5: Application Examples

February 28, 2020
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This Week's Agenda

Monday	Overview and Requirements
Tuesday	Toolkit - Algorithms
Wednesday	Toolkit - Hardware
Thursday	Systems
Friday	Application Examples

Course Description

This topic will cover a new approach to developing embedded systems which includes AI/Machine Learning(ML) as an element of the suite of tools available. As microcontroller devices become more powerful, these techniques are now within reach. We will look at the types of AI/ML algorithms available and appropriate in embedded systems. We will also look at how interaction with higher level systems, such as cloud analytics, can be integrated to create systems that evolve and improve over time and space.

Today's Agenda

- Overview
- Medical Device
- Object Detection
- Automotive
- Industrial
- Conclusion/Contact Info

Overview

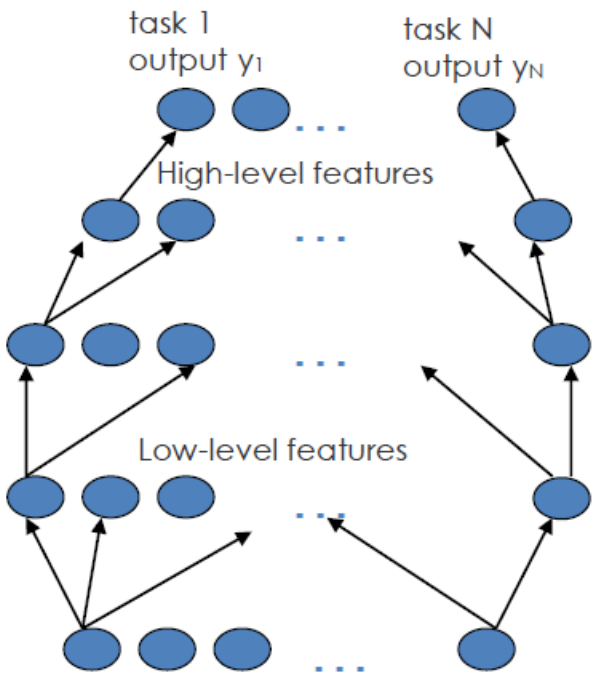
- Examples of embedded AI/ML will be given to give a feel for what can be done. These examples will range from simple to complex.
- These examples will not be given in great detail, since that would require a class for each
- They can often be used as a template for applications you may find yourself being involved in

Overview

- AI appears in a number of applications in many guises. Theses can range from simple statistical comparisons image recognition.
- In some cases it will be obvious that AI is critical and in others it will be buried in the application
  - As we mentioned in the first class, one reason to use AI is the marketing buzz, so it is generally a good thing to highlight it

Overview

- A note on DL: Recall that hidden layers successively refine and combine features



We can add or subtract layers to enhance operation as required. Takes experimentation.

Medical Device

- Cardiac Monitor
  - Vendor is Medtronic
  - This device uses ML in detection of arrythmias
  - Is a networked device, allowing a very small device to communicate with medical providers
  - Uses cellular infrastructure and Bluetooth
  - Parameters are initially set by the medical provider and then adaptively changed by the algorithms in the device itself to adapt to the particular patient and situation

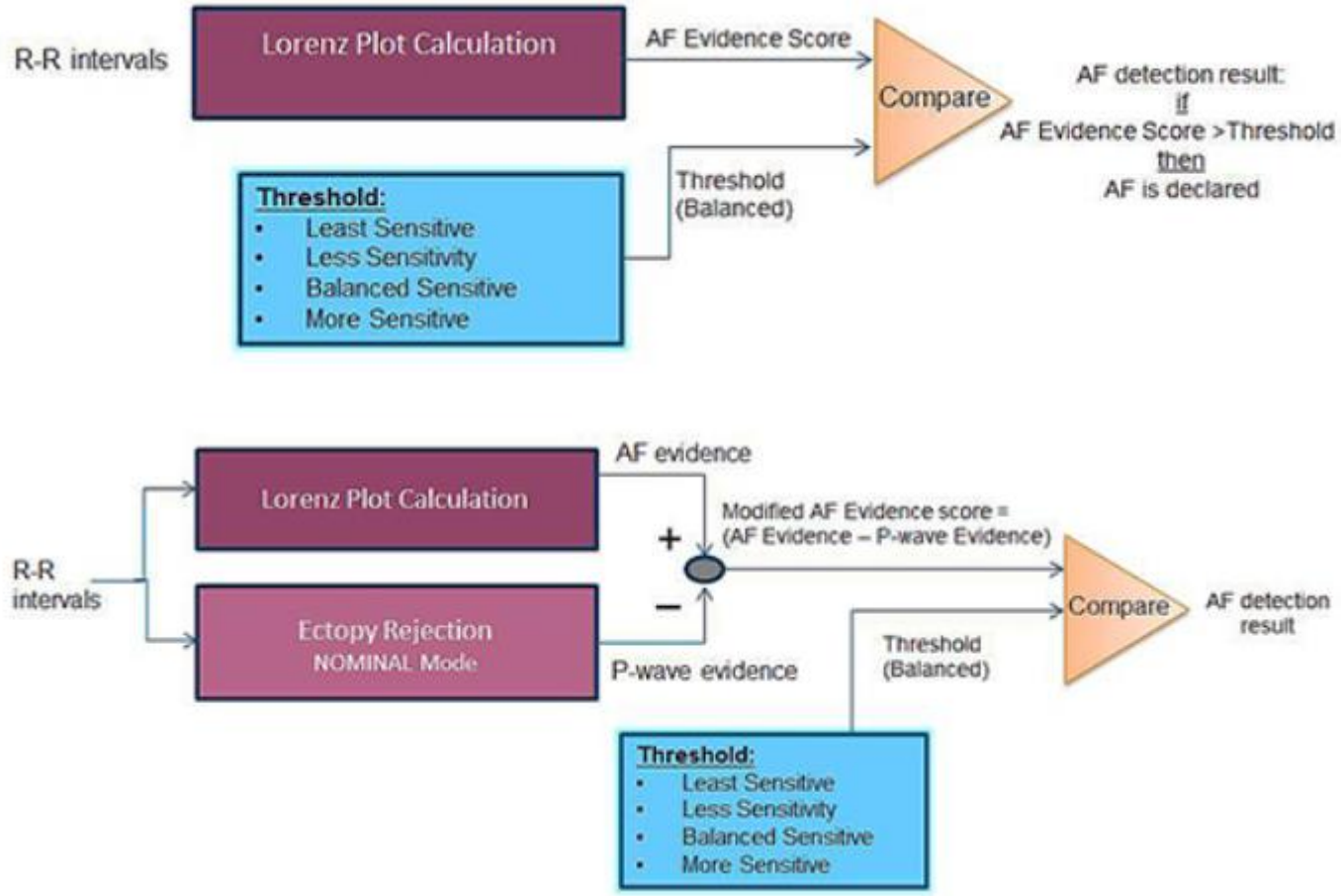
Medical Device

- Device is small, about the third of the size of a AAA battery
- Data from the device can be transmitted immediately after and event or at scheduled intervals

Medical Device

- Algorithm is called TruRhythm
  - Adaptive threshold setting
    - Reduces false positives to 4.7%
  - Several alert levels
  - Set and controlled by service provider as needed

Medical Device



Object Detection

- For this example we look at develop systems highlighted on the DigiKey website in an article by Jacob Beningo
- Uses an OpenMV H7 camera module with all the requisite electronics
  - Microprocessor is a STMicro STM32F765VIT6
    - 216 MHz, 2MB flash, 512KB RAM
  - Is Python programmable

Object Detection

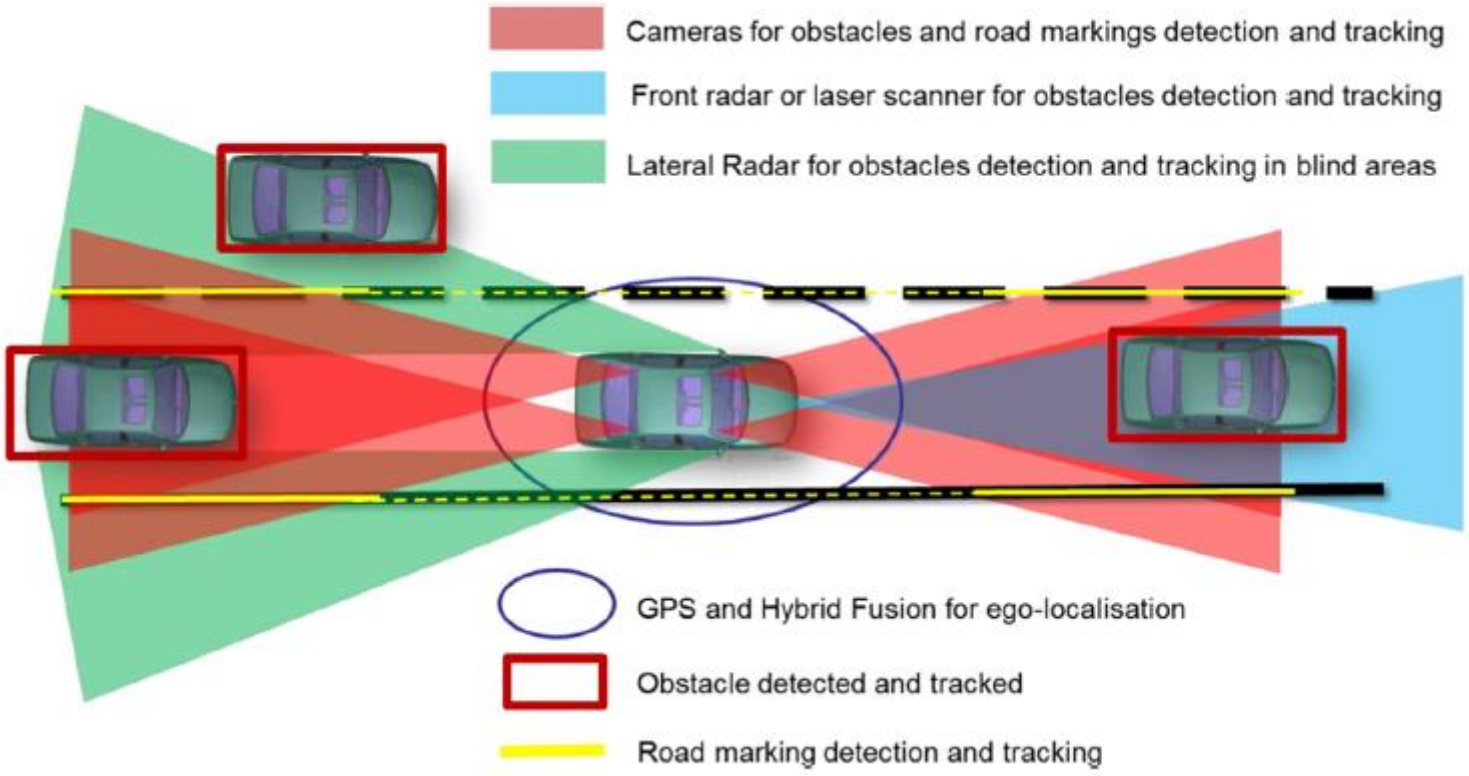
Object Detection

- A Convolutional Neural Network (CNN) for image classification
- Tagged data set is used to train the network
- When a new image is presented to the CNN it compute a confidence level for each of the objects it “knows”
  - This can then be used to decide which object is present

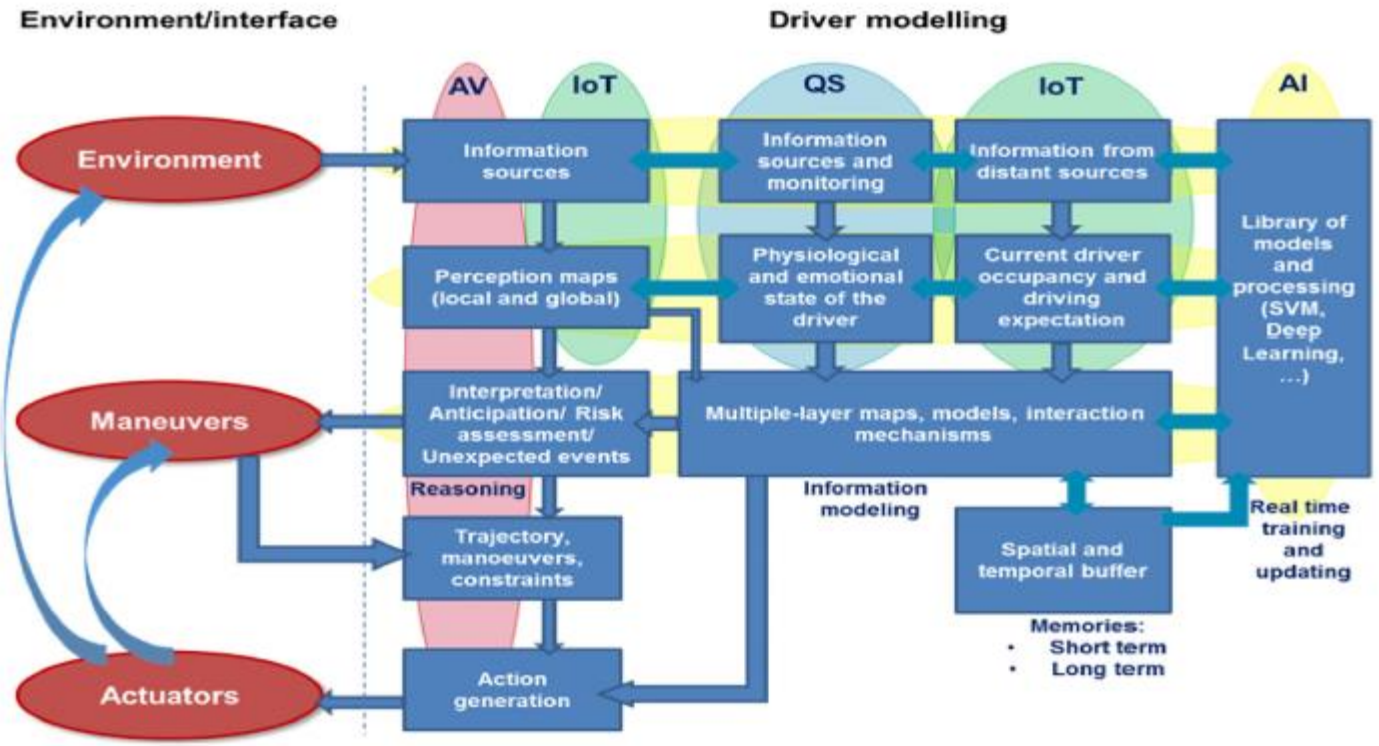
Automotive

- Self driving vehicles, and driver assist systems in manually driven vehicles, use machine learning algorithms in many ways
- Most are sensor processing algorithms
- Some are adaptive control algorithms
- This application shows the use of external data to train and adjust the model as well as local data to perform the task

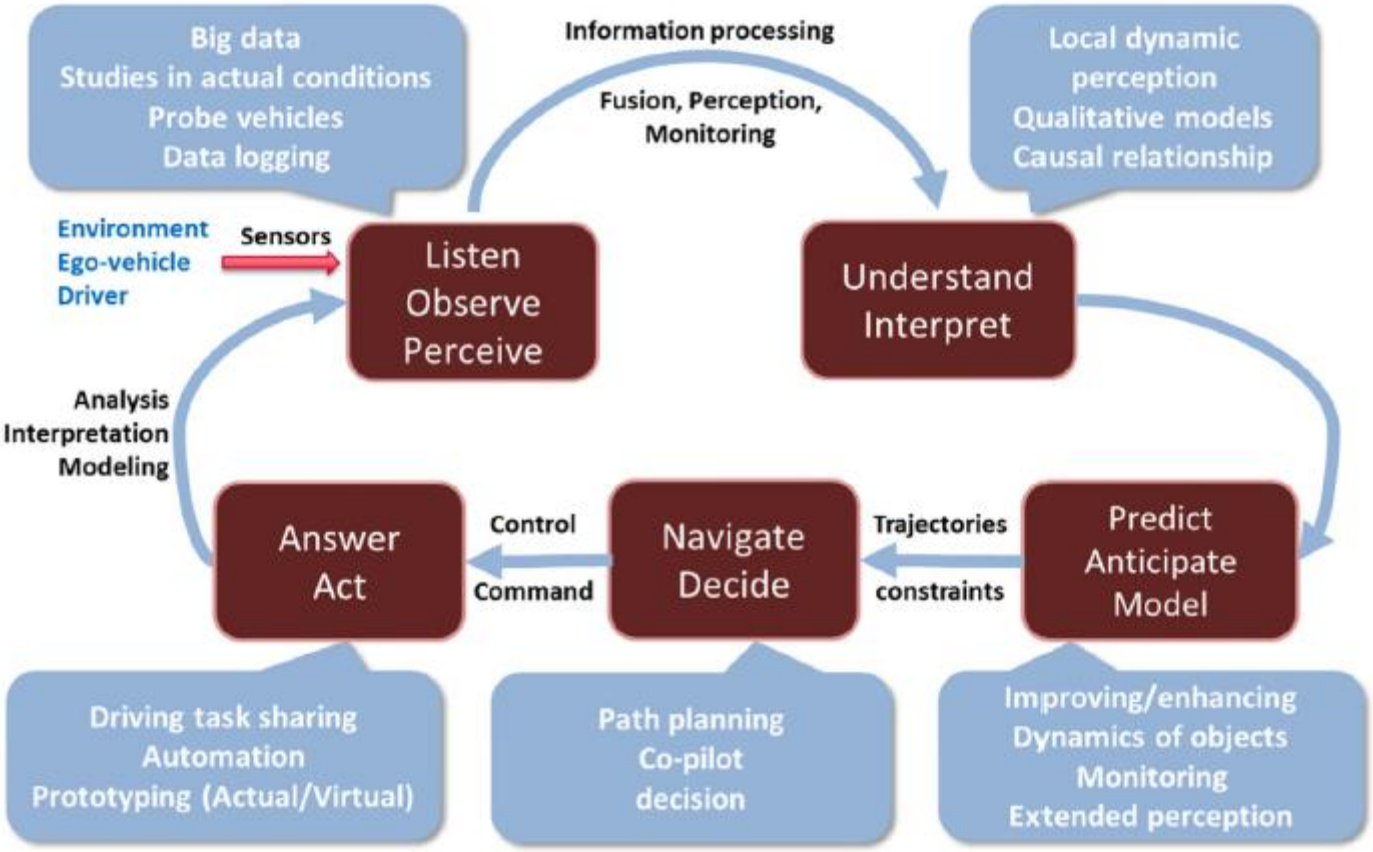
Automotive


Cameras for obstacles and road markings detection and tracking
Front radar or laser scanner for obstacles detection and tracking
Lateral Radar for obstacles detection and tracking in blind areas
GPS and Hybrid Fusion for ego-localisation
Obstacle detected and tracked
Road marking detection and tracking

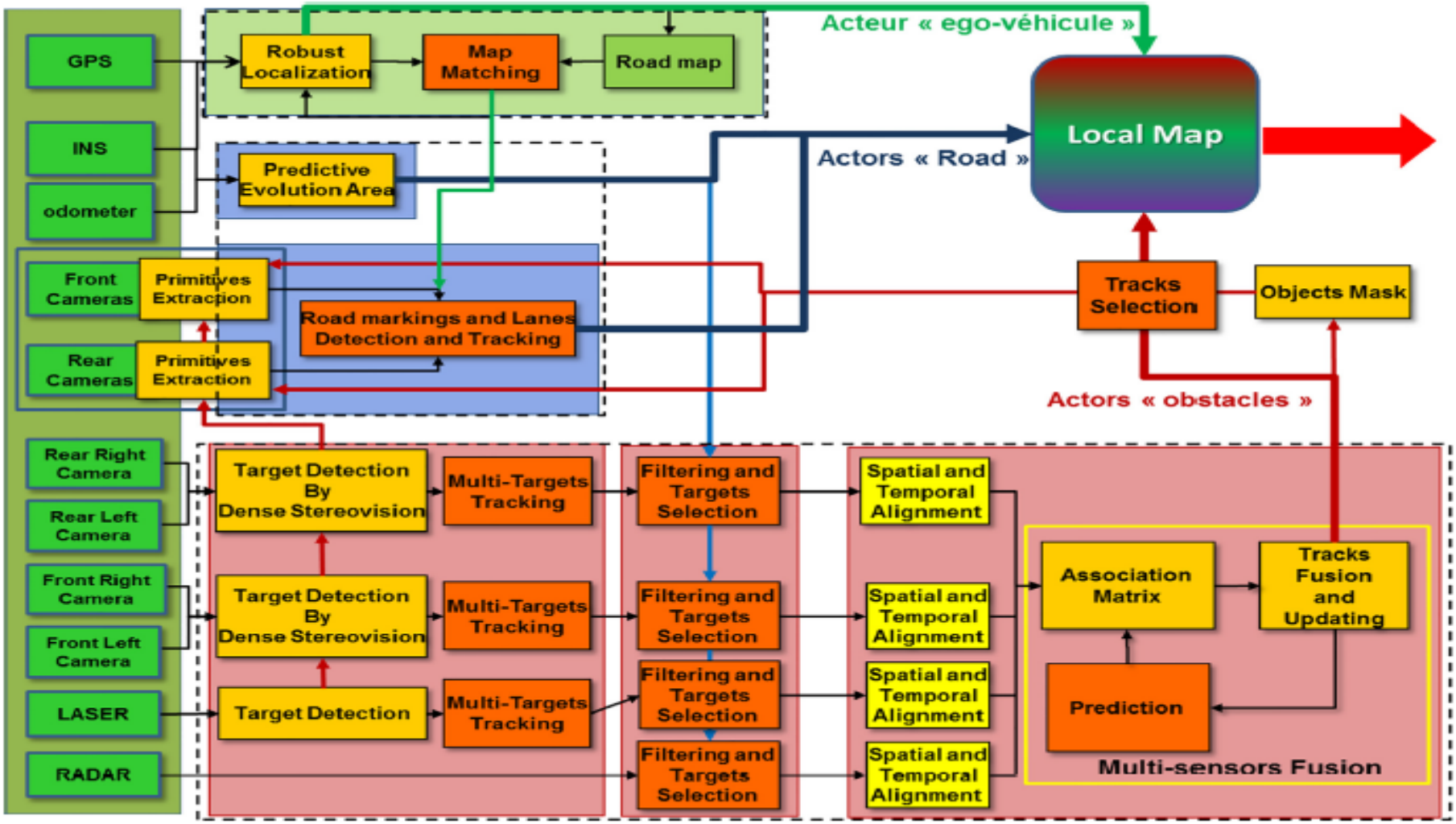
Automotive



Automotive


Big data
Studies in actual conditions
Probe vehicles
Data logging
Information processing
Fusion, Perception,
Monitoring
Local dynamic
perception
Qualitative models
Causal relationship
Environment
Ego-vehicle
Driver
Sensors
Listen
Observe
Perceive
Understand
Interpret
Analysis
Interpretation
Modeling
Answer
Act
Control
Command
Navigate
Decide
Trajectories
constraints
Predict
Anticipate
Model
Driving task sharing
Automation
Prototyping (Actual/Virtual)
Path planning
Co-pilot
decision
Improving/enhancing
Dynamics of objects
Monitoring
Extended perception

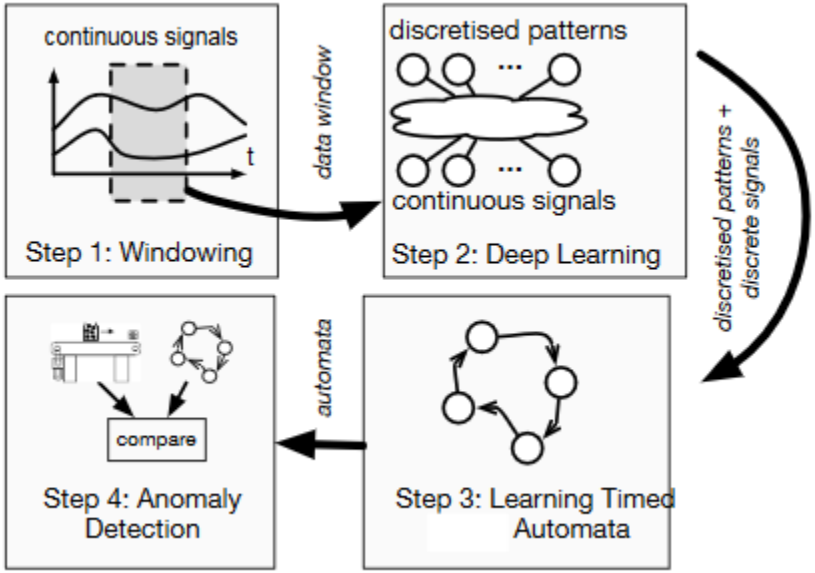
Automotive


GPS
INS
odometer
Front Cameras
Rear Cameras
Rear Right Camera
Rear Left Camera
Front Right Camera
Front Left Camera
LASER
RADAR
Robust Localization
Map Matching
Road map
Predictive Evolution Area
Primitives Extraction
Primitives Extraction
Road markings and Lanes Detection and Tracking
Acteur « ego-véhicule »
Local Map
Actors « Road »
Tracks Selection
Objects Mask
Actors « obstacles »
Target Detection By Dense Stereovision
Target Detection By Dense Stereovision
Target Detection
Multi-Targets Tracking
Multi-Targets Tracking
Multi-Targets Tracking
Filtering and Targets Selection
Filtering and Targets Selection
Filtering and Targets Selection
Filtering and Targets Selection
Spatial and Temporal Alignment
Spatial and Temporal Alignment
Spatial and Temporal Alignment
Spatial and Temporal Alignment
Association Matrix
Tracks Fusion and Updating
Prediction
Multi-sensors Fusion

Industrial

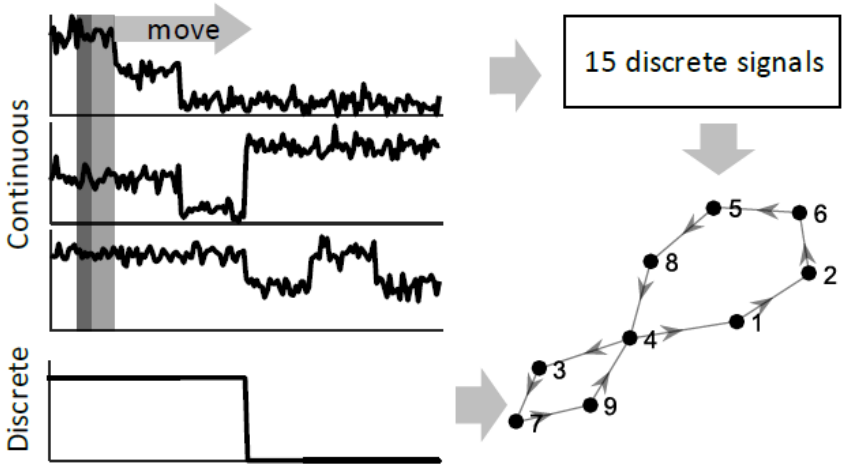
- There are many applications of AI in industrial systems, from anomaly detection to inspection
- In these situations we often are not presented with extreme size and power constraints, but are presented with high reliability requirements
- We will see examples applicable to various industries

Industrial Anomaly Detection



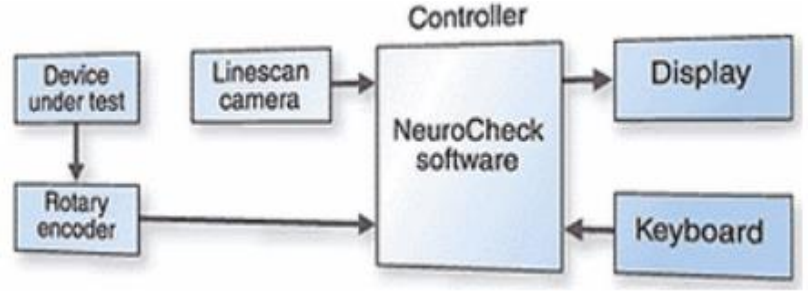
Structure of a deep learning anomaly detection system

Typical signal types

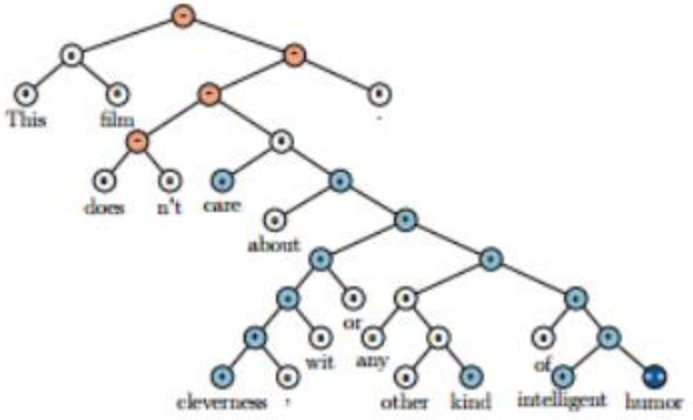


Industrial Anomaly Detection

- Typical System Architecture
  - Used for visual inspection



- Recursive Neural Network (subset of Recurrent Neural Networks)

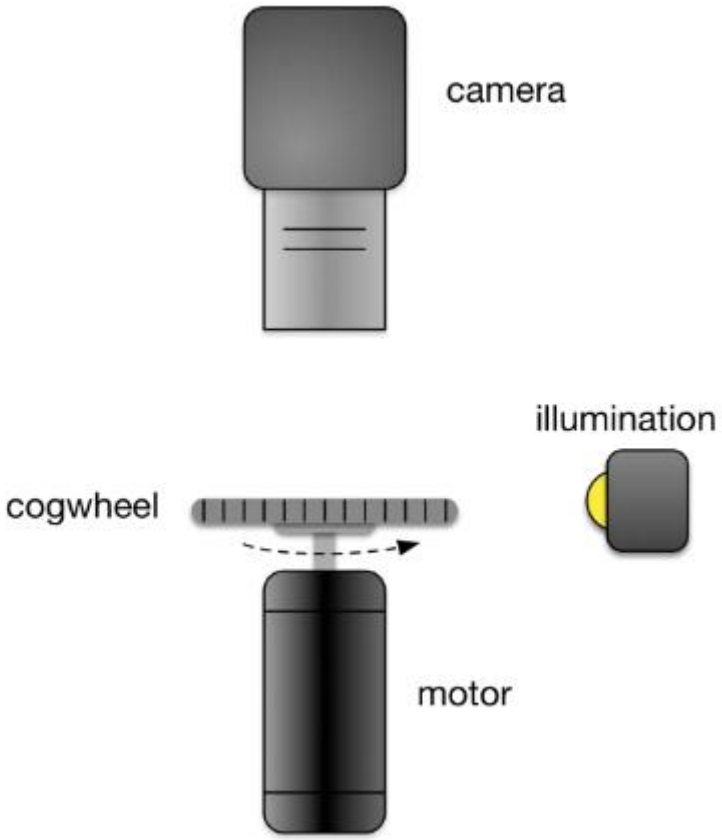


Industrial Inspection

- Images inputs must be clean and calibrated
  - For example, the images were submitted and the whole image used.
  - The edges of the image were not “clean”. This was just an image artifact
    - This affects the operation of the NN negatively
  - Images were cropped to eliminate the edges and performance increased significantly

Industrial Inspection

Inspection system layout (NOTE: does not include computational resources)



Typically the algorithms run on a PC based system or single board computer separate from the camera.
Smart cameras have computational resources built-in

Industrial Inspection

- The NN classifier is the core of these systems, but not the only part
  - It is still important to have all the SYSTEM components around the classifier
    - Image capture and input
    - Classification output in a form that can be used by downstream systems
    - Operational control
  - These classification approaches do not exist in a vacuum

Conclusion/Contact Info

- Today we looked at various applications of AI in Embedded Systems
- These cover a range of applications, but are in no way exhaustive
  - Look at these as templates for your application
- Contact Information
  - Twitter: @naperlou, use hashtag #DNCEC
  - Email: lgiokas@ieee.org