

# Intelligent Signal Processing

## Deep Learning for Signal Processing

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# Machine Learning

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- **Fuzzy Logic** is used to describe and operate with **vague** definitions
  - Example (control of a cement plant)
    - if the temperature is high add a little cement and increase the water a lot
- **Fuzzy logic** is a form of **many-valued logic**
  - the truth values of variables may be any real number between 0 and 1 inclusive



# Computational Intelligence

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## ■ Machine Learning

- study of computer algorithms that improve automatically through experience
- build a **mathematical model** based on sample data
  - training data
  - make predictions or decisions without being explicitly programmed to do so

## ■ Computational Intelligence

- set of **nature-inspired computational methodologies** and approaches to address complex real-world problems
  - Fuzzy Logic
  - Artificial Neural Networks
  - Evolutionary Computing



# Deep Learning

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- Deep Architectures
  - Deep Neural Networks
  - Deep Belief Networks
  - Deep Boltzmann Machine
  - Recurrent Neural Networks
    - Long Short-Term Memory (LSTM)
  - Convolutional Neural Networks (CNNs)
  - Autoencoders
  - Generative Adversarial Neural Networks



# Deep Learning

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- Deep Applications
  - Signal Processing
  - Computer Vision
  - Speech Recognition
  - Natural Language Processing
  - Audio Recognition
  - Social Network Filtering
  - Bioinformatics
  - Drug Design
  - Medical Image Analysis
  - Reinforcement learning
    - Game
    - Context awareness



# Signal Processing

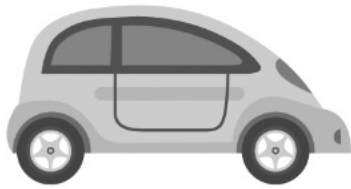
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- Classical Machine Learning approaches
  - Pre-processing
  - Feature extraction and/or selection
  - Machine Learning approach
    - Classification
    - Regression
- Deep Learning approaches
  - Pre-processing
  - Feature extraction and/or selection + Classification/Regression



# Signal Processing

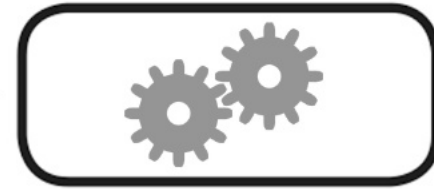
**Input**



**Feature extraction**  
(hand-crafted)



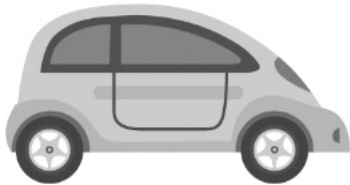
**Learning algorithm**  
SVM or Adaboost



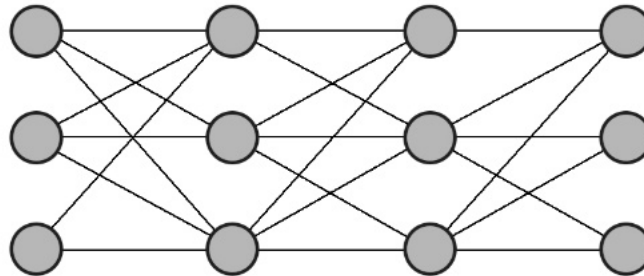
**Output**

Car  
Not a car

**Input**



**Feature extraction - Classification**



**Output**

Car  
Not a car



# Pre-processing

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- Normalization
  - e.g., 0 Mean and unit variance
- Whitening
- Filtering





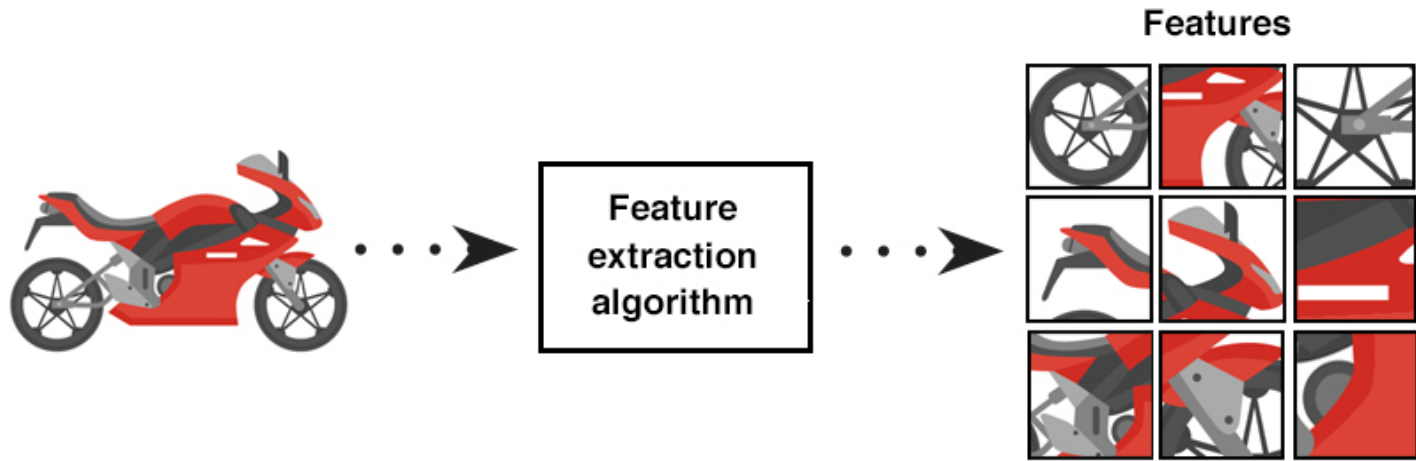
# Audio

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- Time domain
  - Principal and Independent Component Analysis
  - Linear Predictive Coding (LPC)
  - Sparse Coding
  - Clustering
  - ...
- Frequency domain
  - Fourier coefficients
  - DCT
  - Wavelet
  - Periodogram
  - Spectrogram
  - Mel Frequency Cepstral Coefficients (MFCC)
  - ...



# Images



# Images

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## ■ Pre-processing

- set of significant regions and objects
  - Filtering
  - Normalization
  - Segmentation
  - Object identification

## ■ Feature extraction

- are used to describe the content of the image
  - Shape
  - Texture
  - Color



# Images

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- **General features**

- **Pixel-level features**

- Features calculated at each pixel, e.g. color, location.

- **Local features**

- Features calculated over the results of subdivision of the image band on image segmentation or edge detection

- **Global features**

- Features calculated over the entire image or just regular sub-area of an image



# Images

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- **Domain-specific features**
  - These features are often a synthesis of low-level features for a specific domain
  - Application dependent features
    - human faces
    - fingerprints
    - conceptual features
    - ...



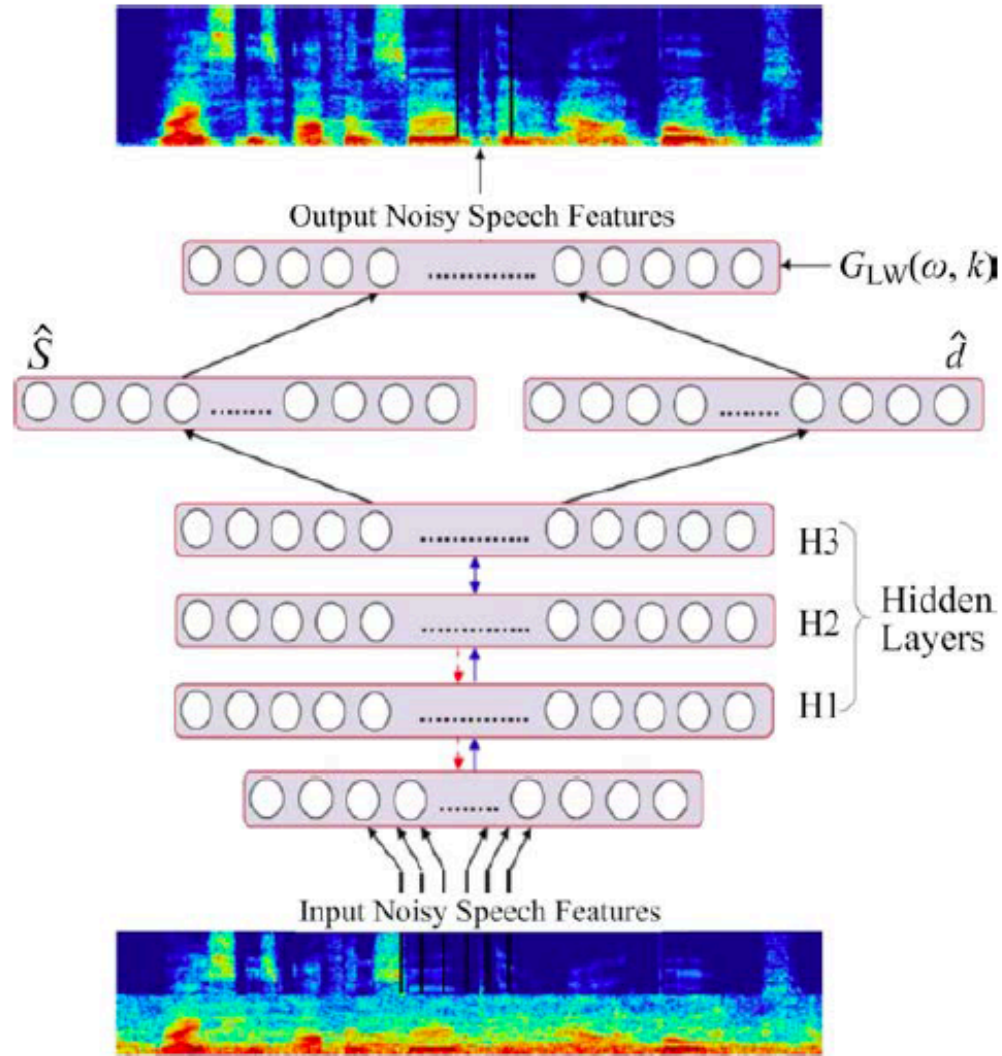
# Images and video

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- Example of handcrafted feature sets
  - Histogram of Oriented Gradients (HOG)
  - Haar Cascades
  - Scale-Invariant Feature Transform (SIFT)
  - Speeded Up Robust Feature (SURF)



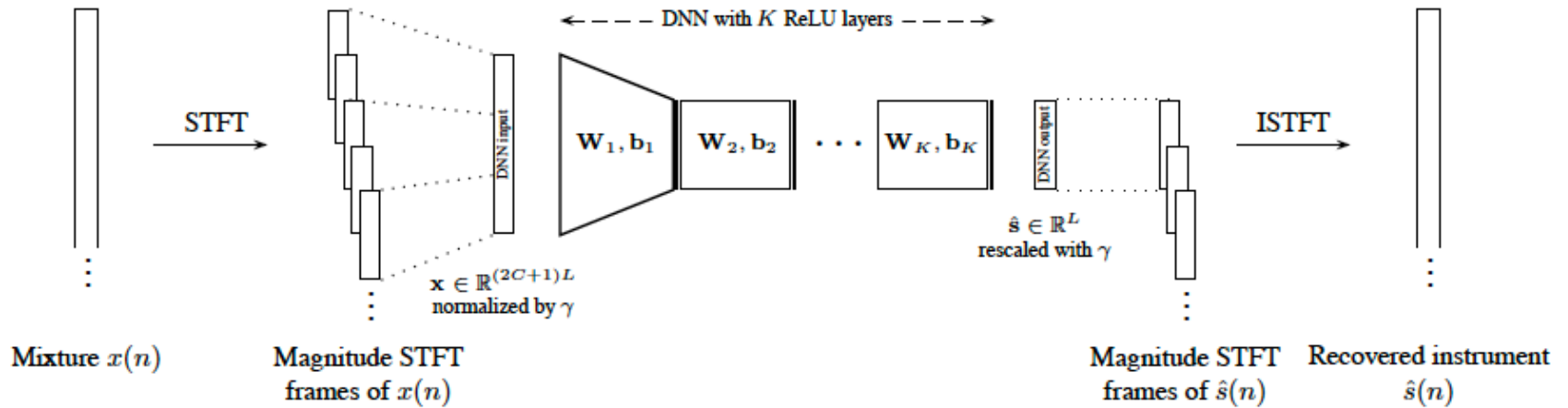
# Audio processing



Deep Neural Network for Supervised Single-Channel Speech Enhancement



# Audio processing

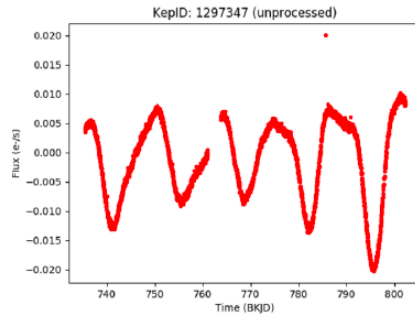


Deep Neural Network Based Instrument Extraction from Music

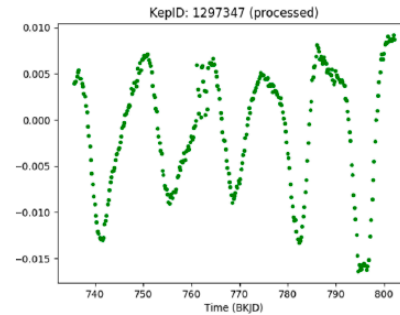




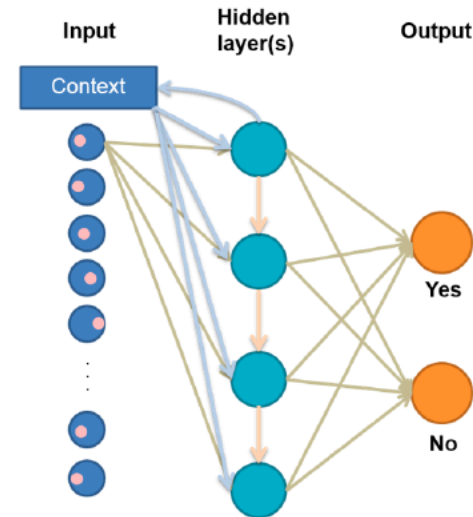
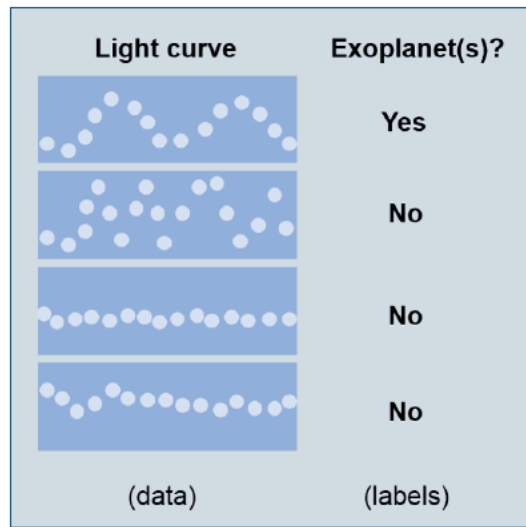
# Astrophysics



(a)



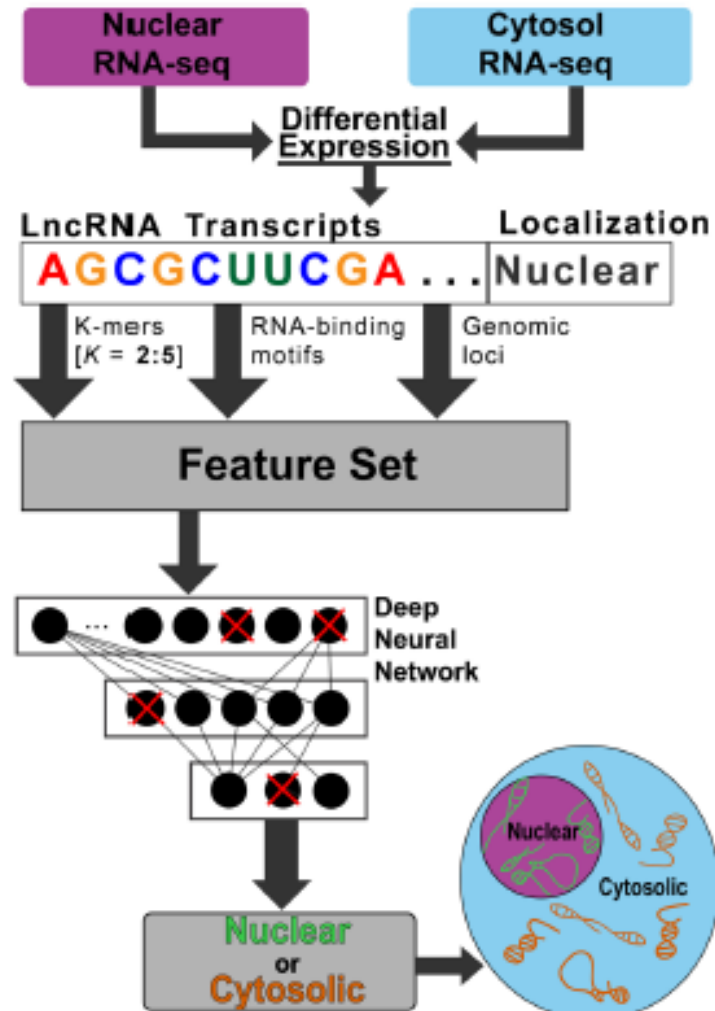
(b)



Machine Learning Techniques for Stellar Light Curve Classification



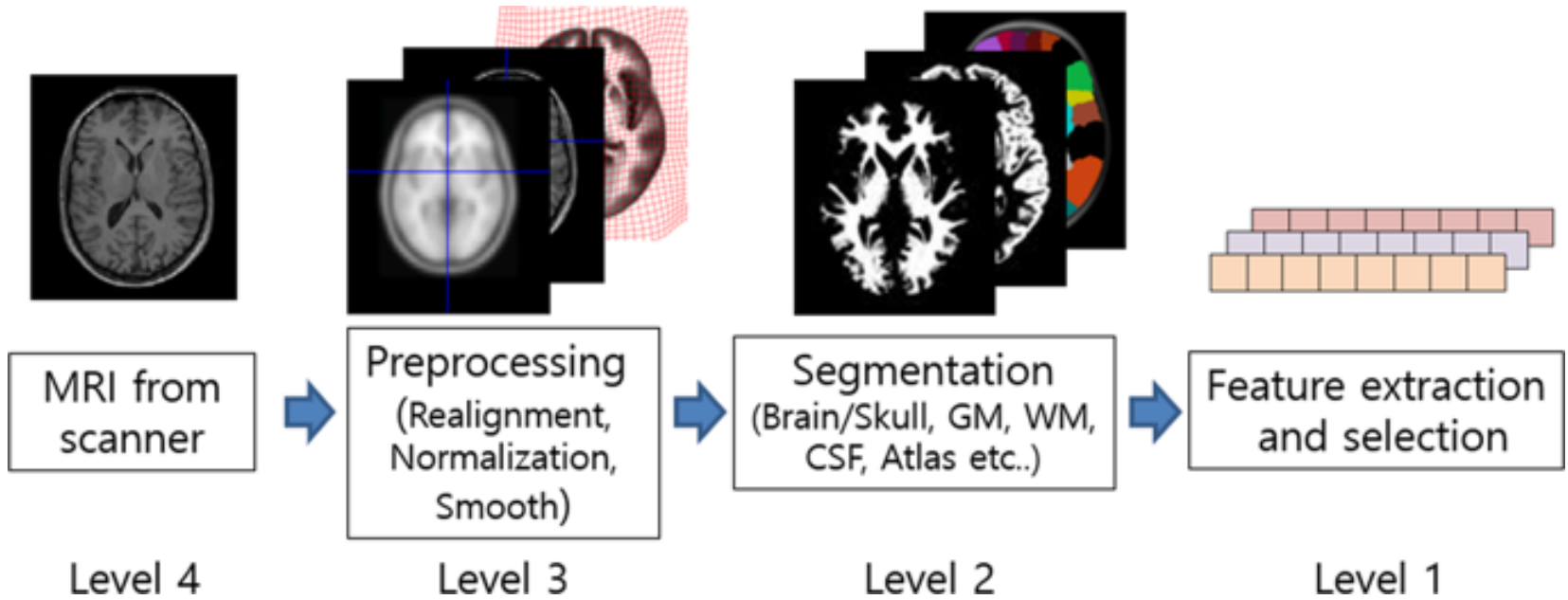
# Bioinformatics



LncRNA Subcellular Localization with Deep Learning



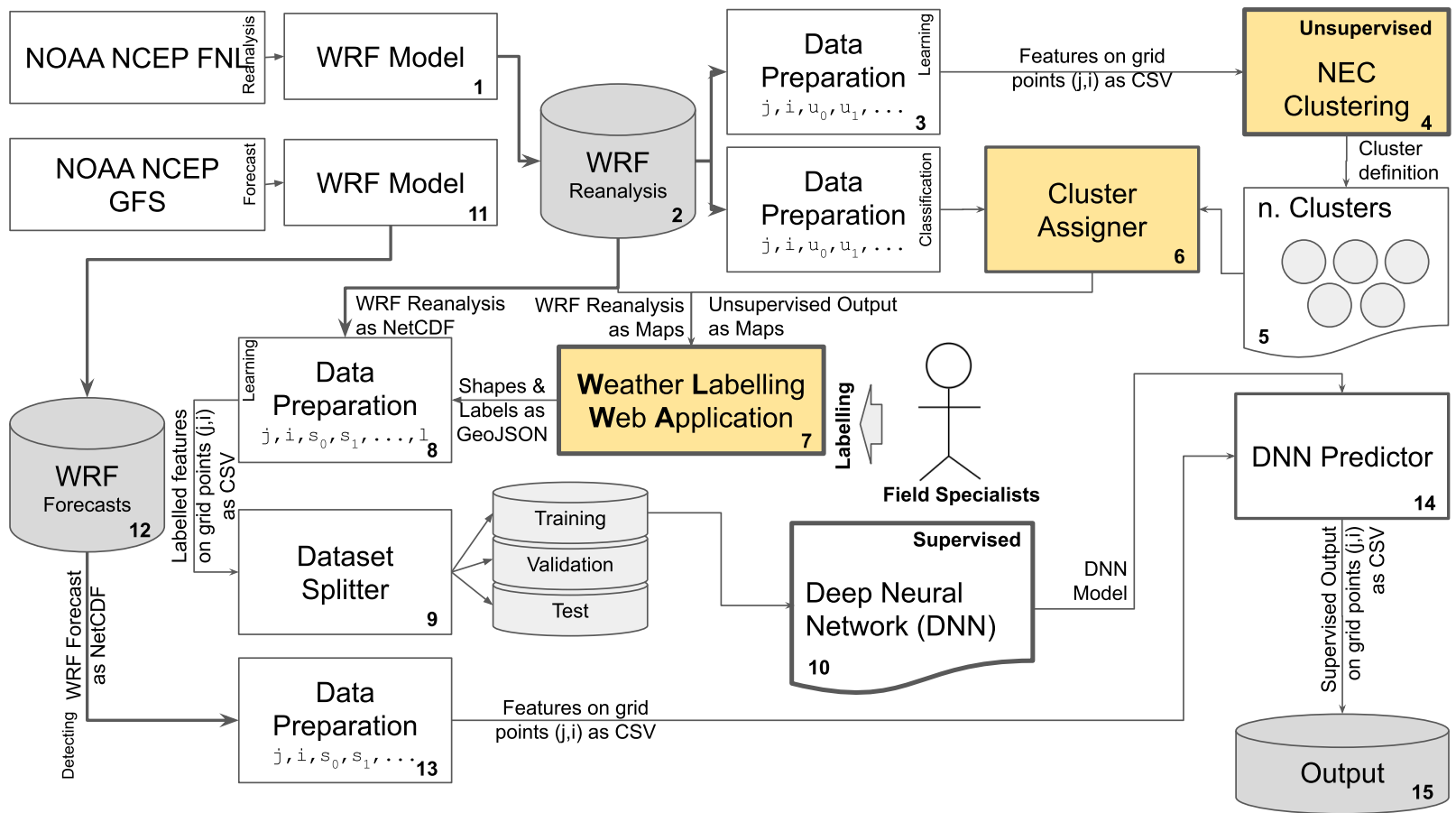
# Neuroimaging



Classification and Visualization of Alzheimer's Disease using Volumetric Convolutional Neural Network and Transfer Learning



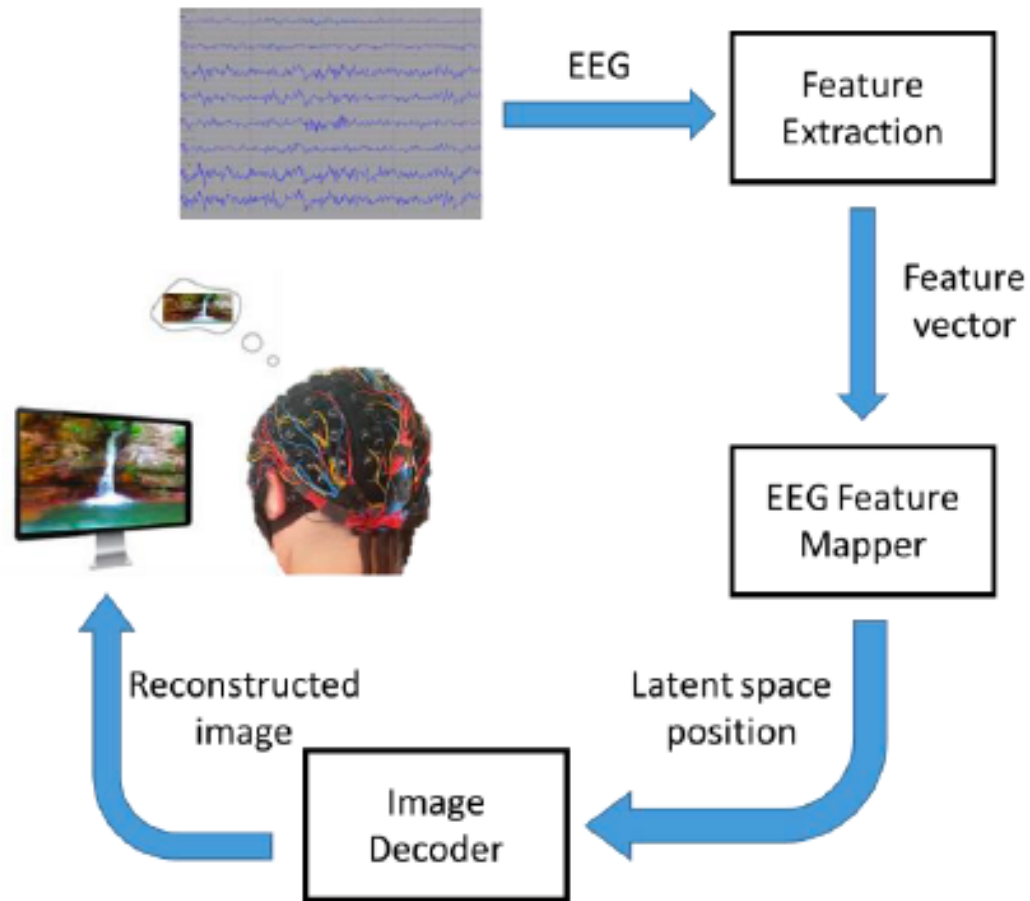
# StormSeeker



StormSeeker: a deep learning-powered weather pattern recognition system



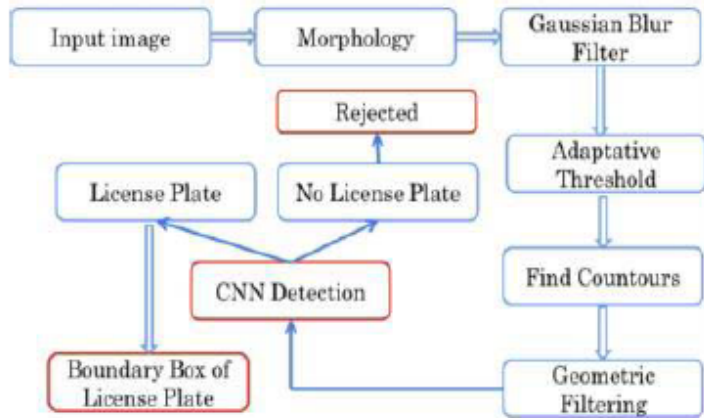
# Brain Computer Interface



Natural image reconstruction from brain waves: a novel visual BCI system with native feedback



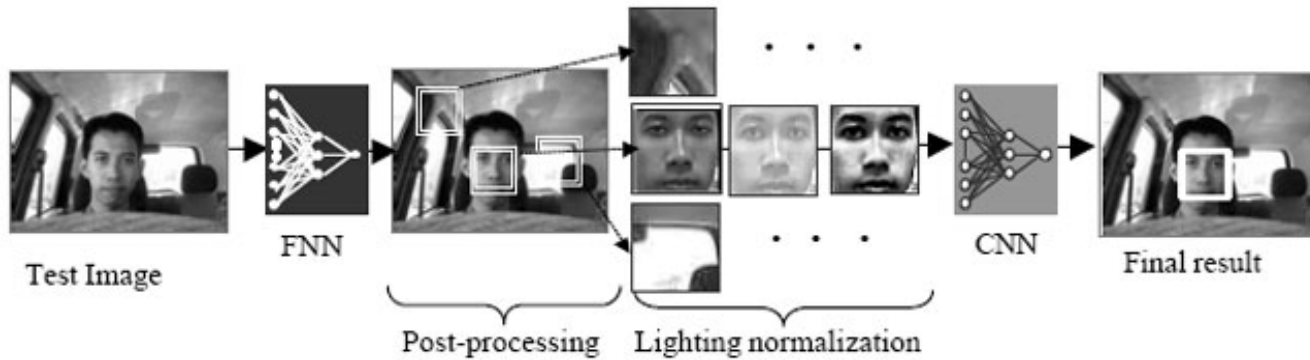
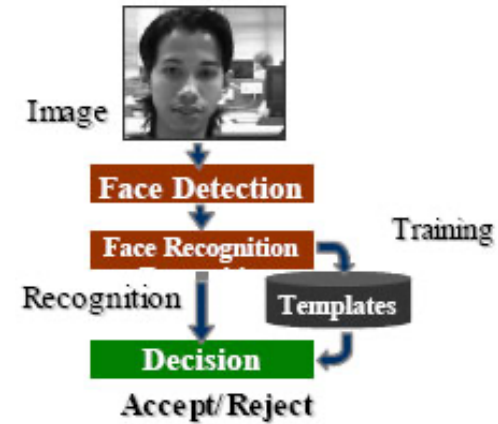
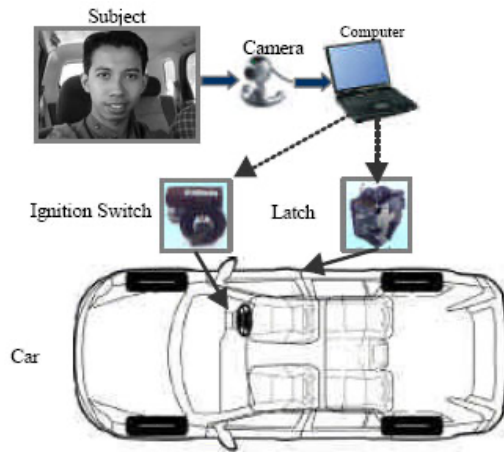
# Object recognition



Deep Learning System for Automatic License Plate Detection and Recognition



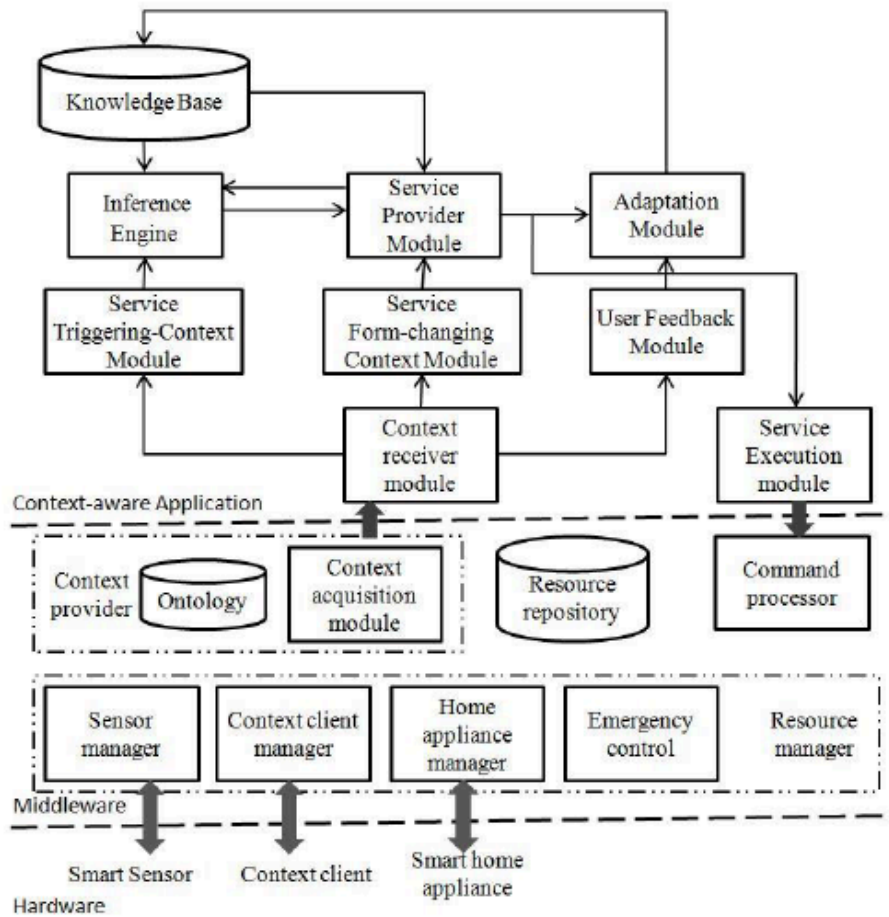
# Face Detection and recognition



A Face Detection and Recognition System for Intelligent Vehicles



# Context-Aware



Smart Home Context-aware Application: A Machine Learning based Approach





# Audio and video fake

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# Anomaly detection (INGV)

