Artificial Intelligence in Sleep Medicine

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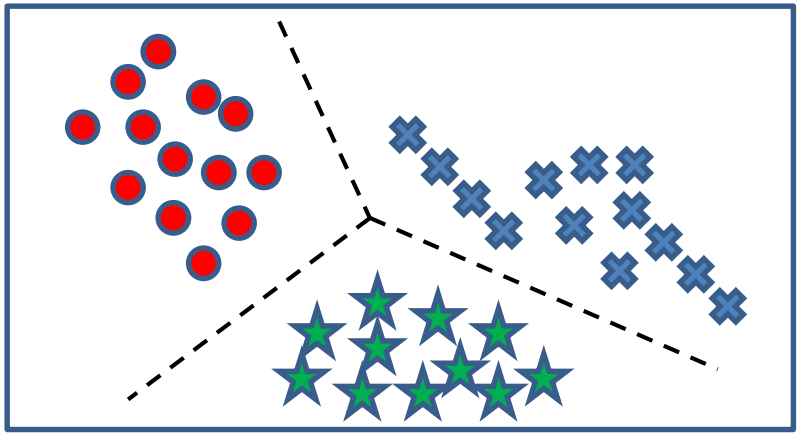
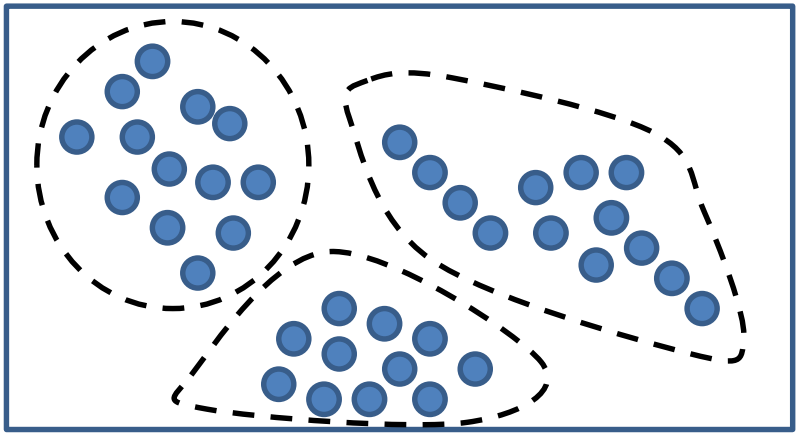
What is Machine Learning?

Machine Learning is concerned with the development of **algorithms** and techniques that allow computers to learn.



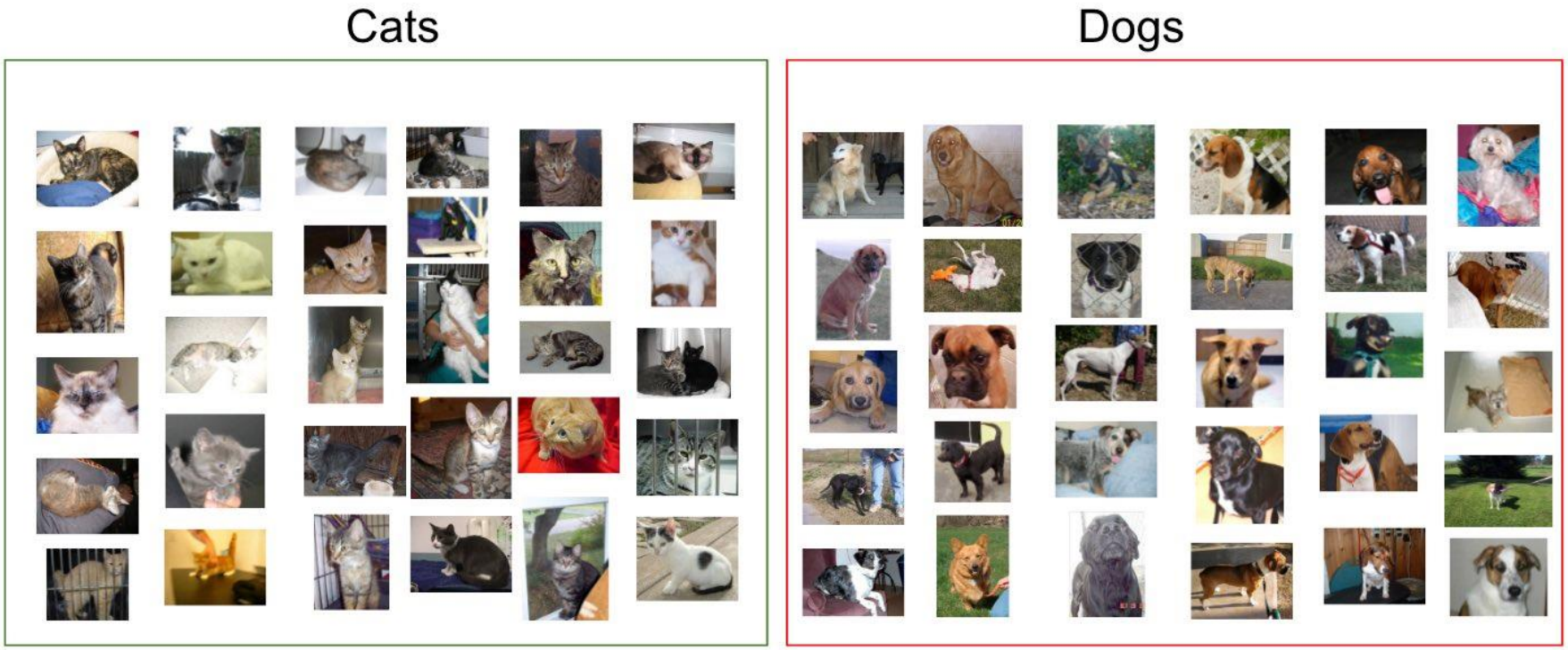
Supervised Learning



Unsupervised Learning

Related Fields: **Artificial Intelligence, Statistics, Data Mining, Computer Science.**

Supervised Learning



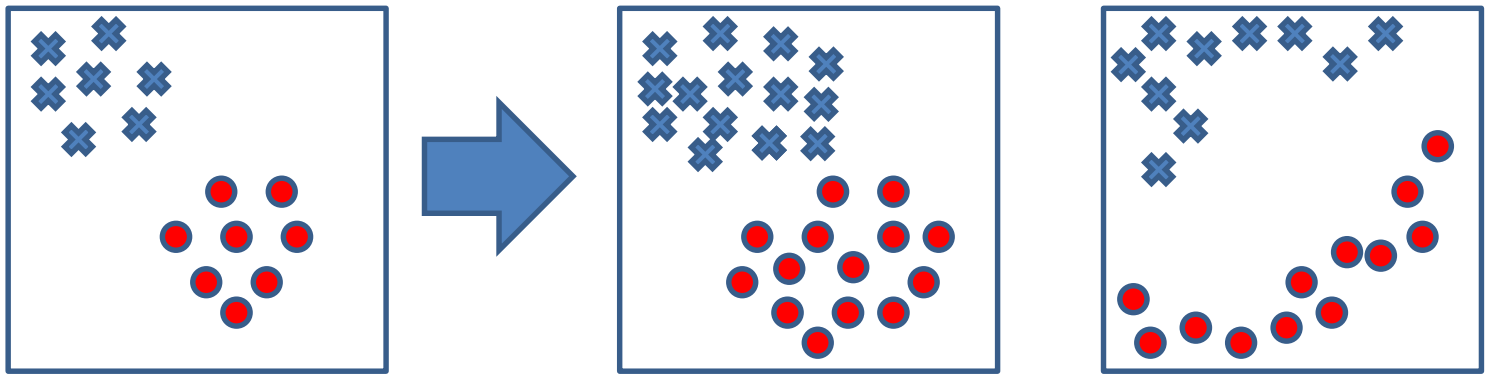
Sample of cats & dogs images from Kaggle Dataset

Unsupervised Learning

Training and testing

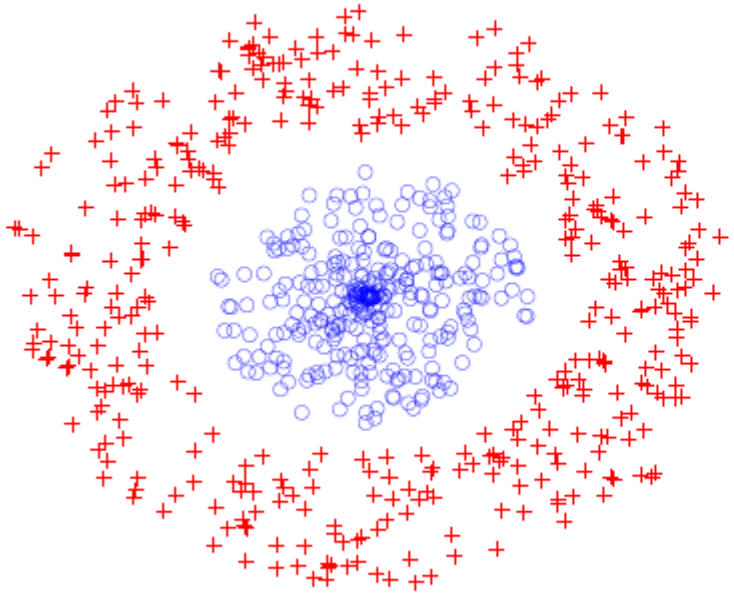
- Training is the process of making the system able to learn.

- No free lunch rule:
  - Training set and testing set come from the same distribution
  - Need to make some assumptions or bias

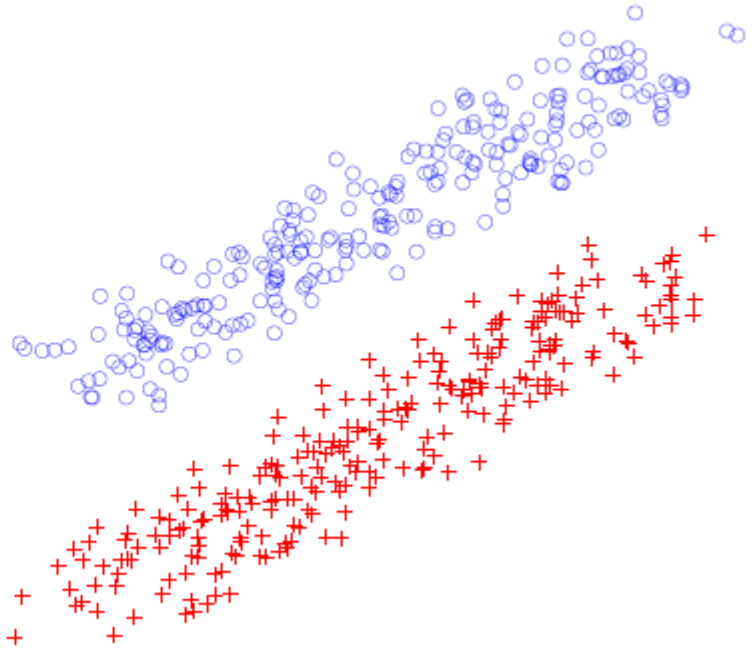


Supervised Learning Techniques

Non-linear vs. Linear Classifiers



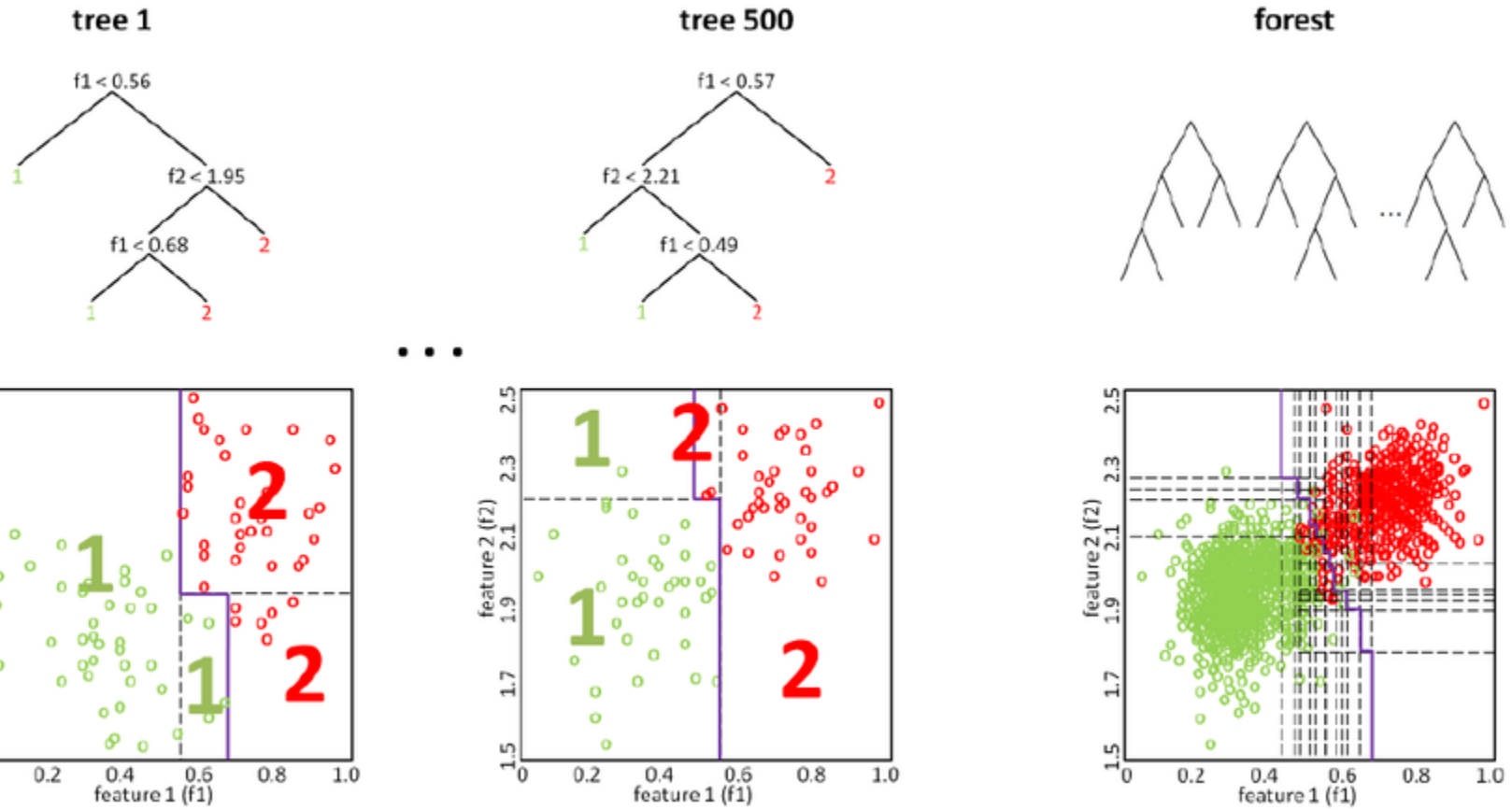
Support Vector Machine



Linear or Logistic Regression

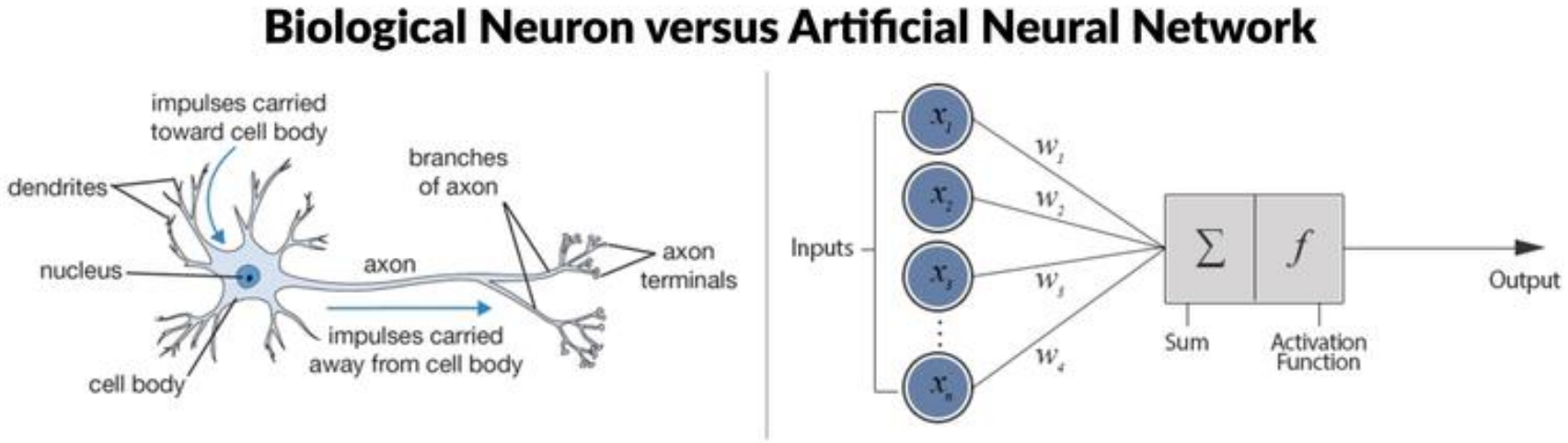
Supervised Learning Techniques

(Random Forest) Decision Tree



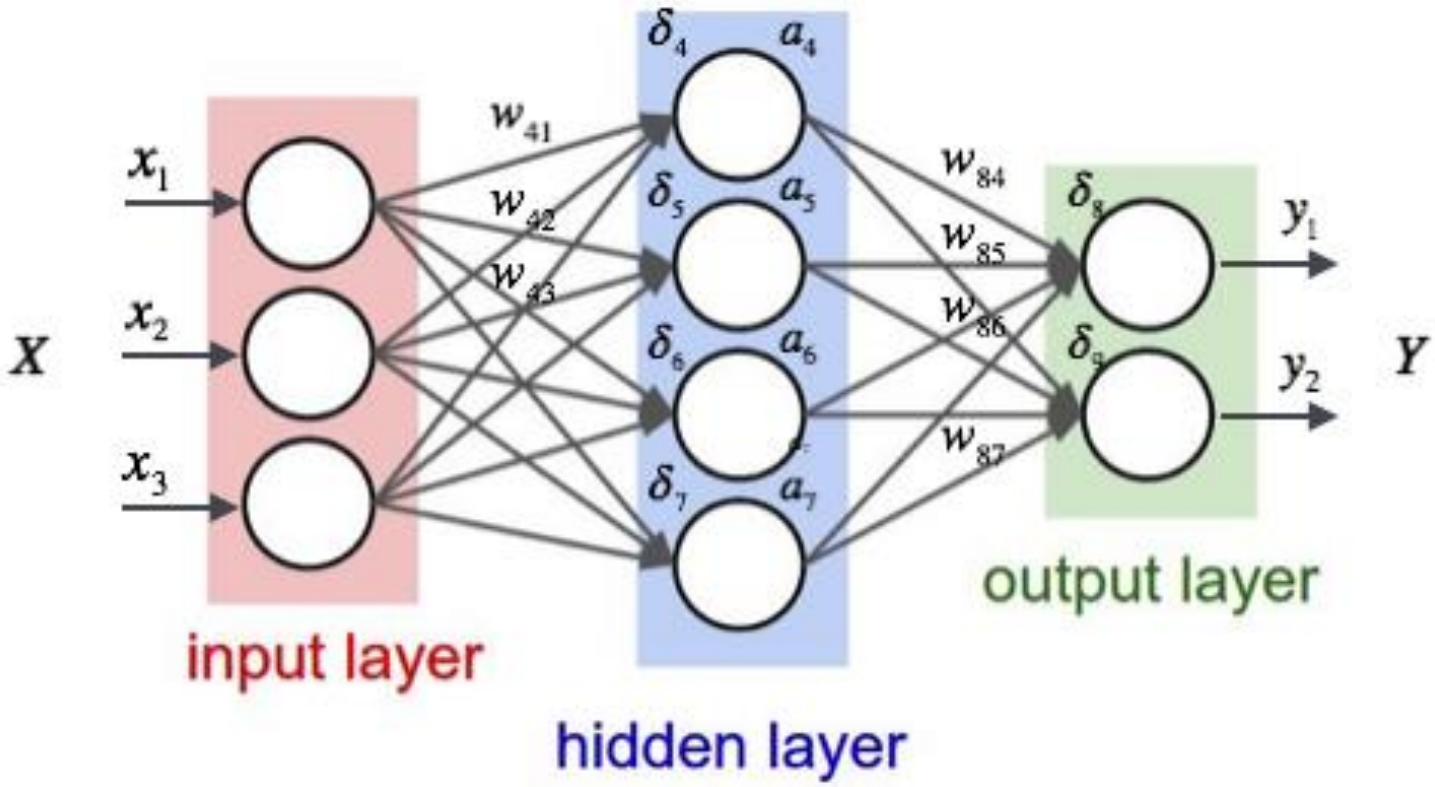
Supervised Learning Techniques

Neural Network



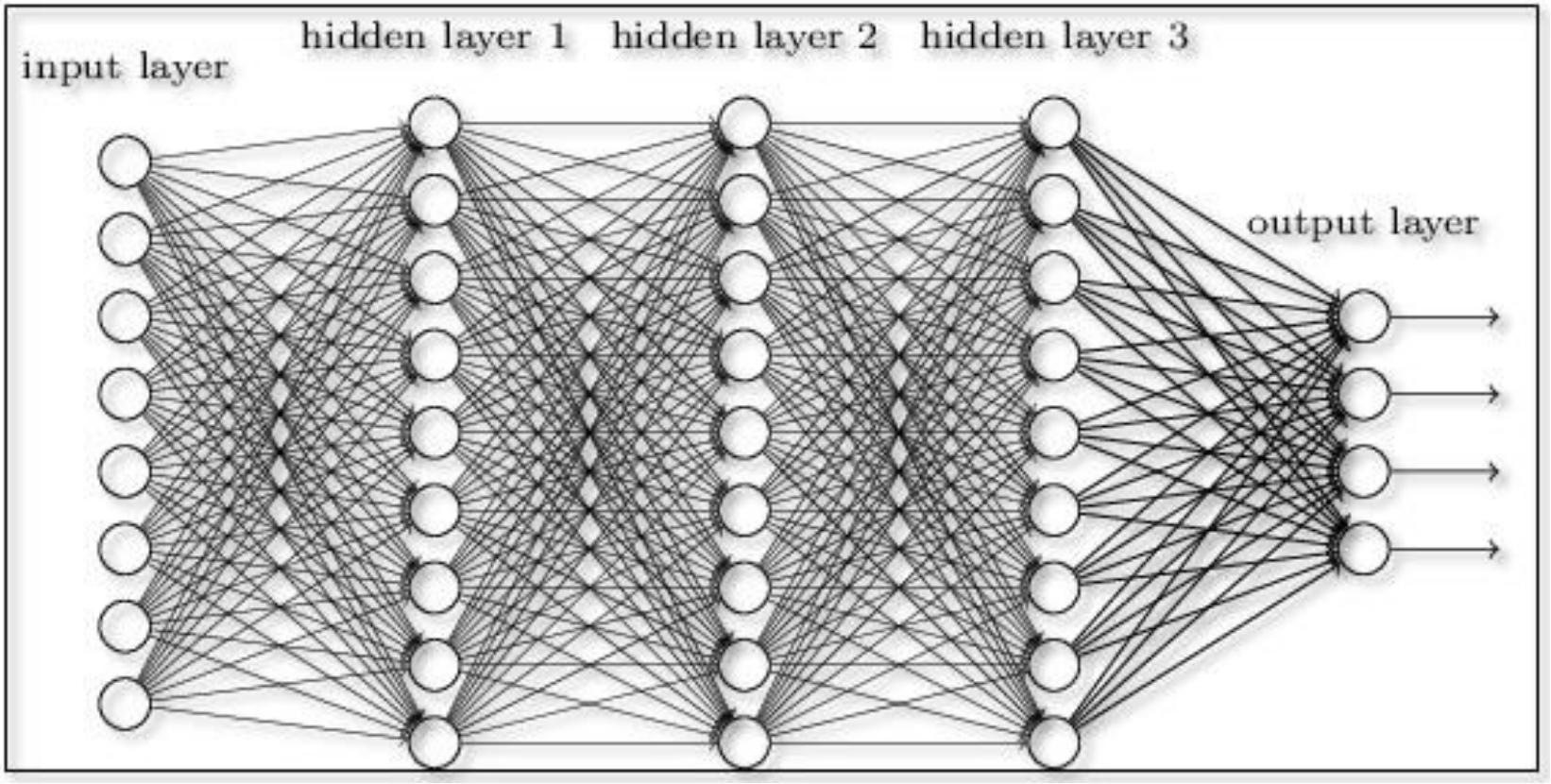
Supervised Learning Techniques

Simple Neural Network



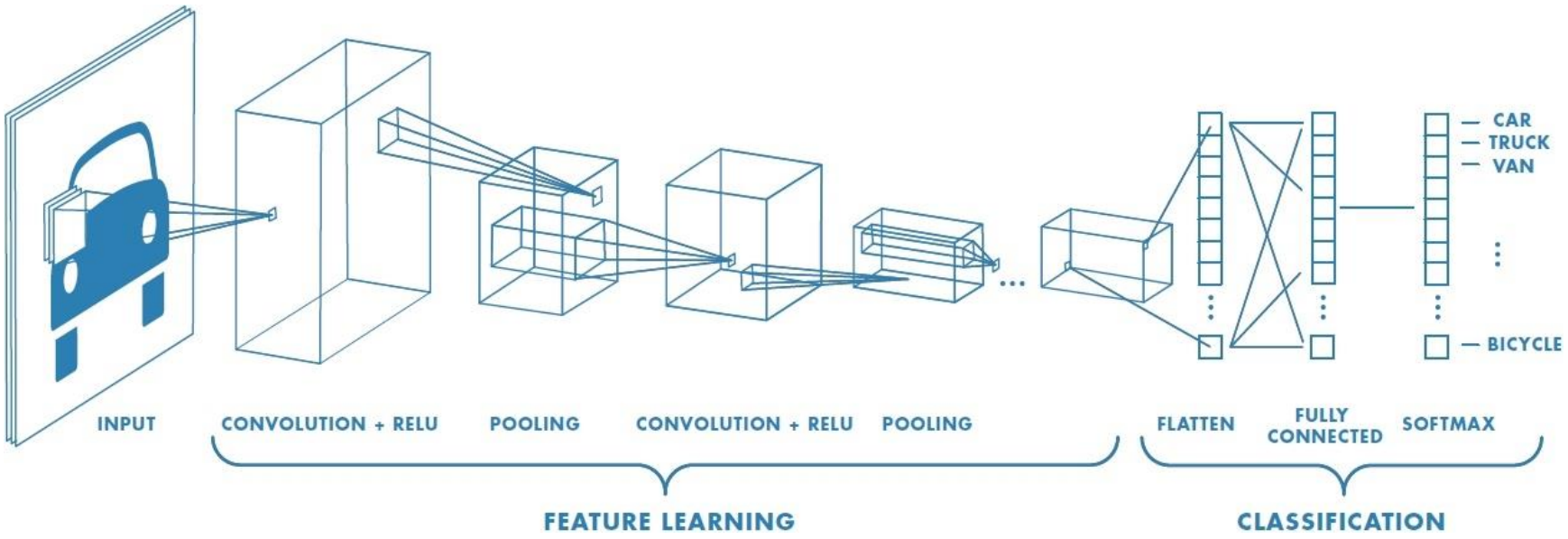
Supervised Learning Techniques

Deep Neural Network



Supervised Learning Techniques

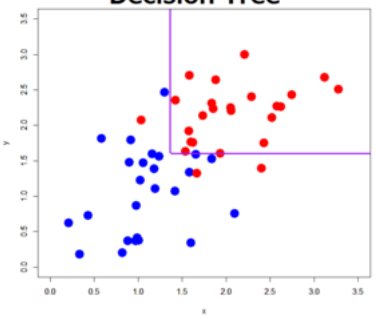
Convolutional Neural Network



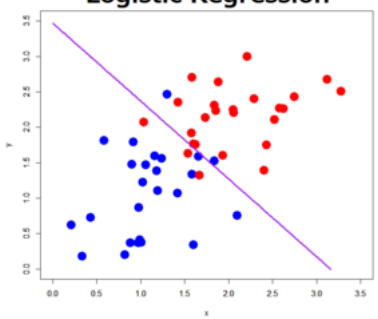
Supervised Learning Techniques

Comparisons

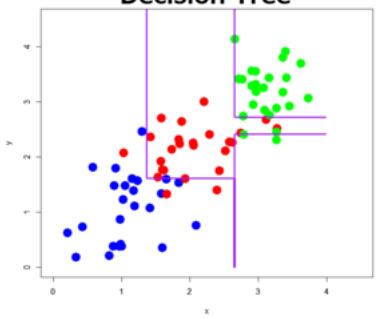
Decision Tree



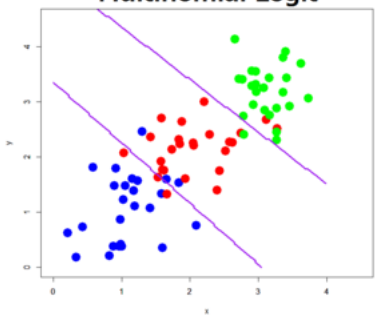
Logistic Regression



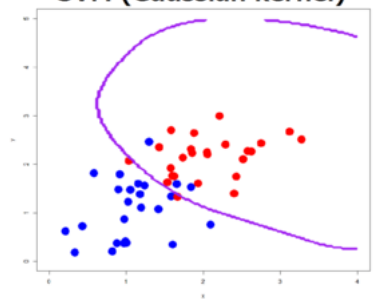
Decision Tree



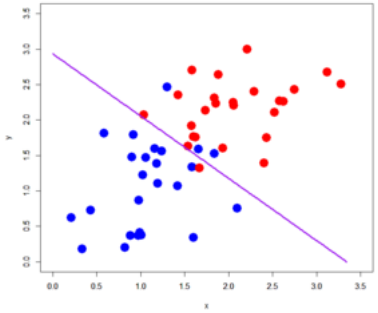
Multinomial Logit



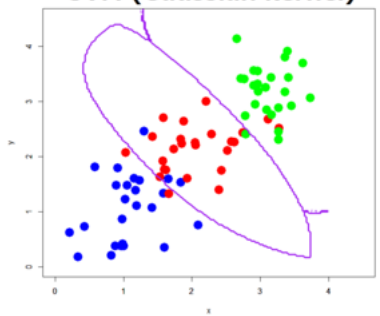
SVM (Gaussian kernel)



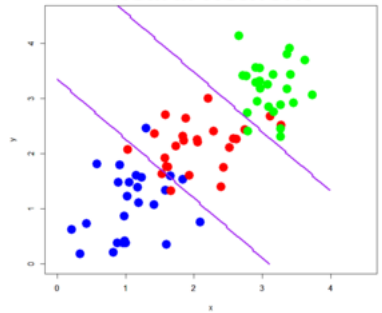
Neural Network



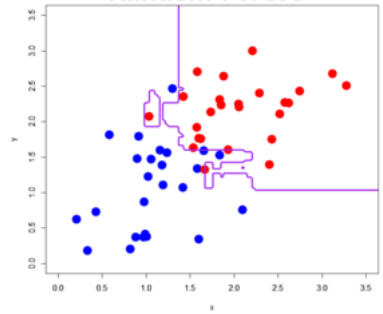
SVM (Gaussian kernel)



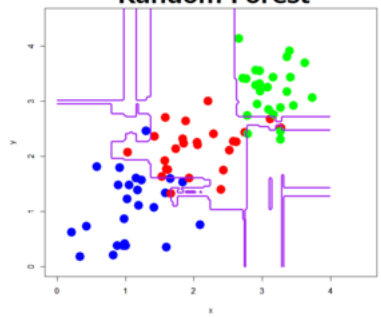
Neural Network



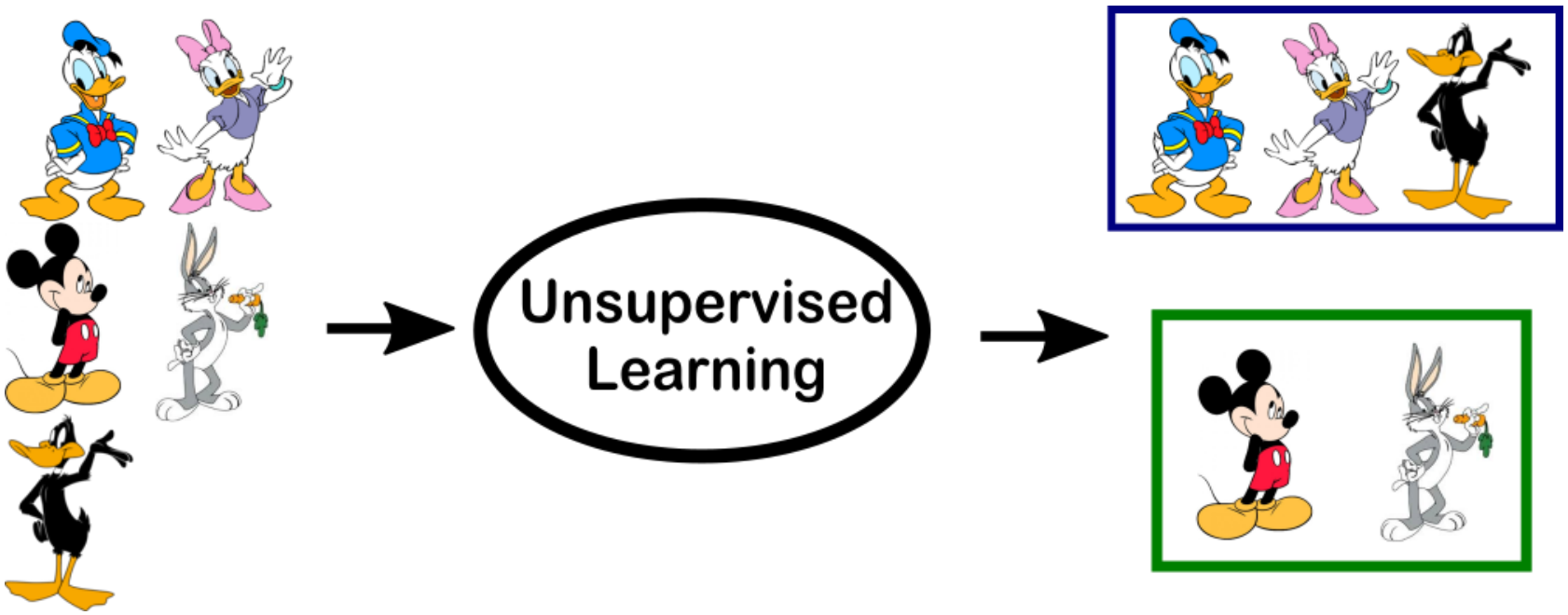
Random Forest



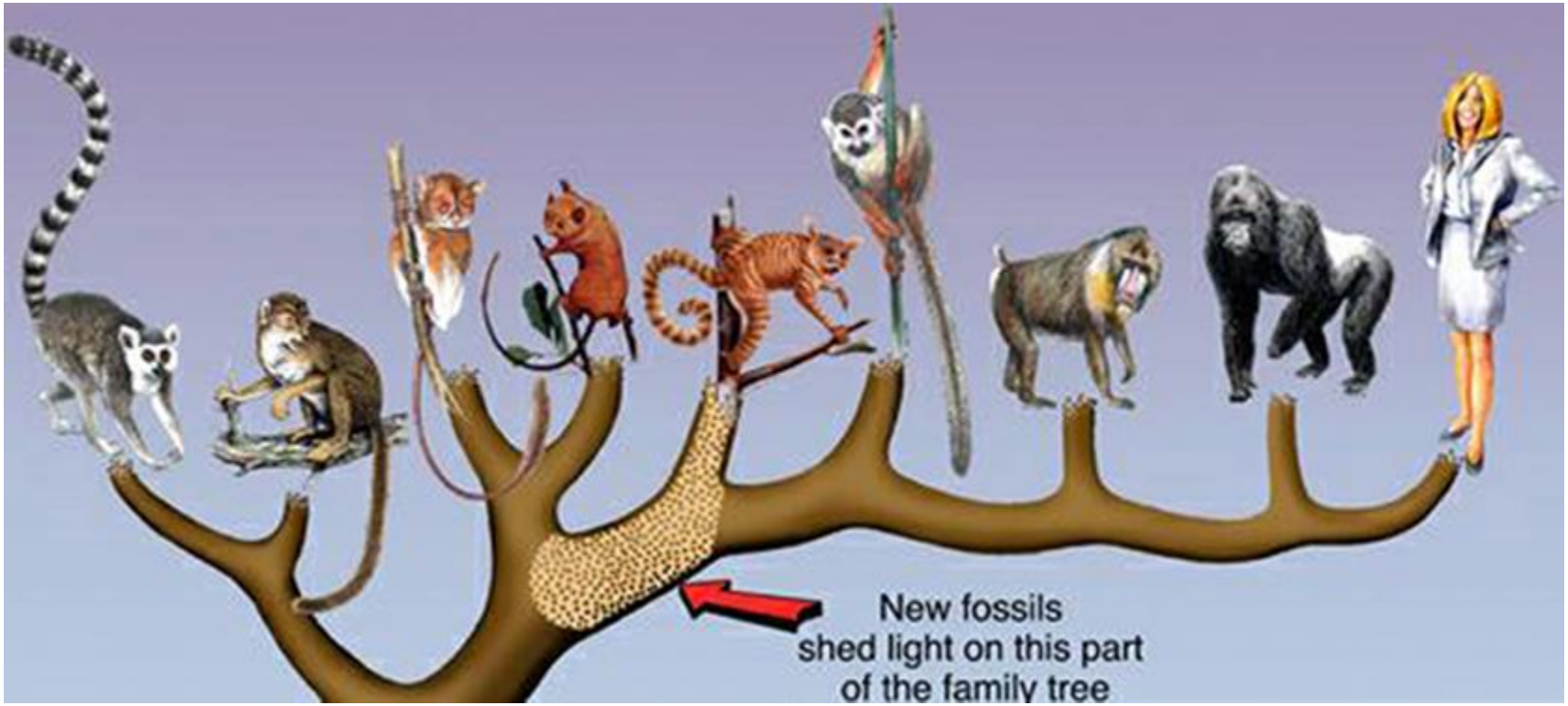
Random Forest



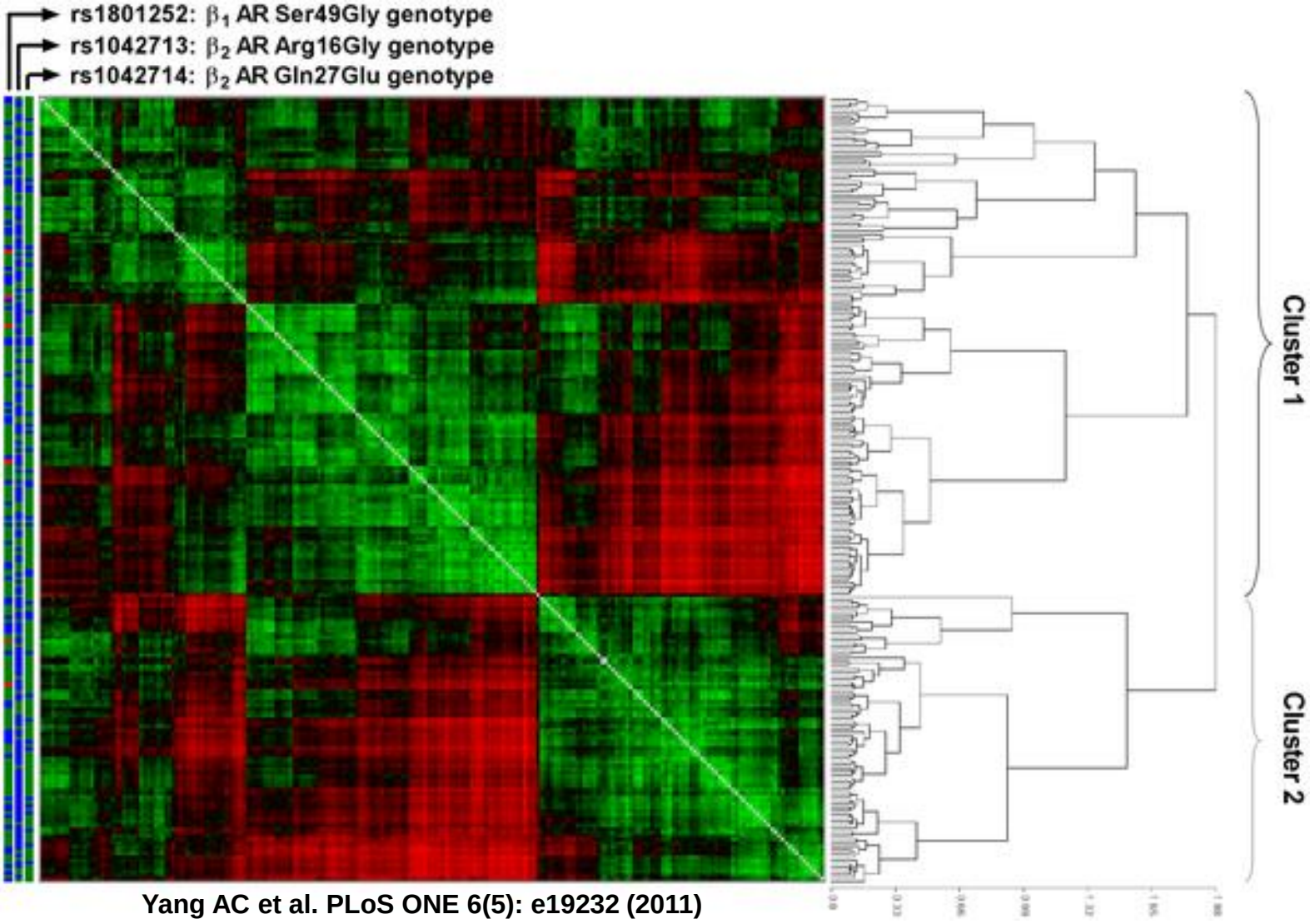
Unsupervised Learning Techniques



Phylogenetic (Cluster) Tree Construction



Clustering of Human Heartbeat Is Associated with β2-AR Gene Polymorphisms



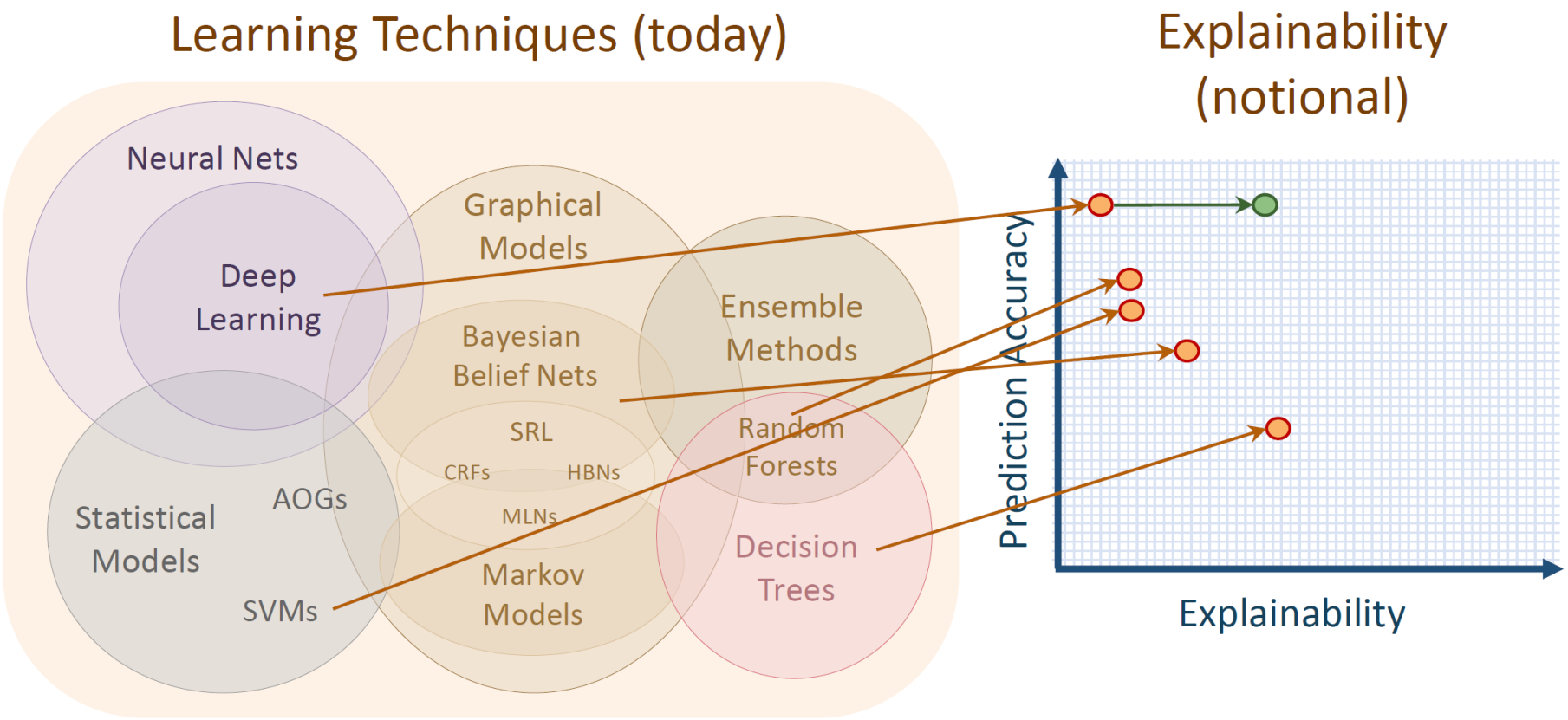
Yang AC et al. PLoS ONE 6(5): e19232 (2011)

The Need of Explainable AI

- The current generation of AI systems offer tremendous benefits, but their effectiveness will be limited by the machine's inability to explain its decisions and actions to users.
- Explainable AI will be essential if users are to understand, appropriately trust, and effectively manage this incoming generation of artificially intelligent partners.

DARPA, 2017

Explainability of Different AI Methods

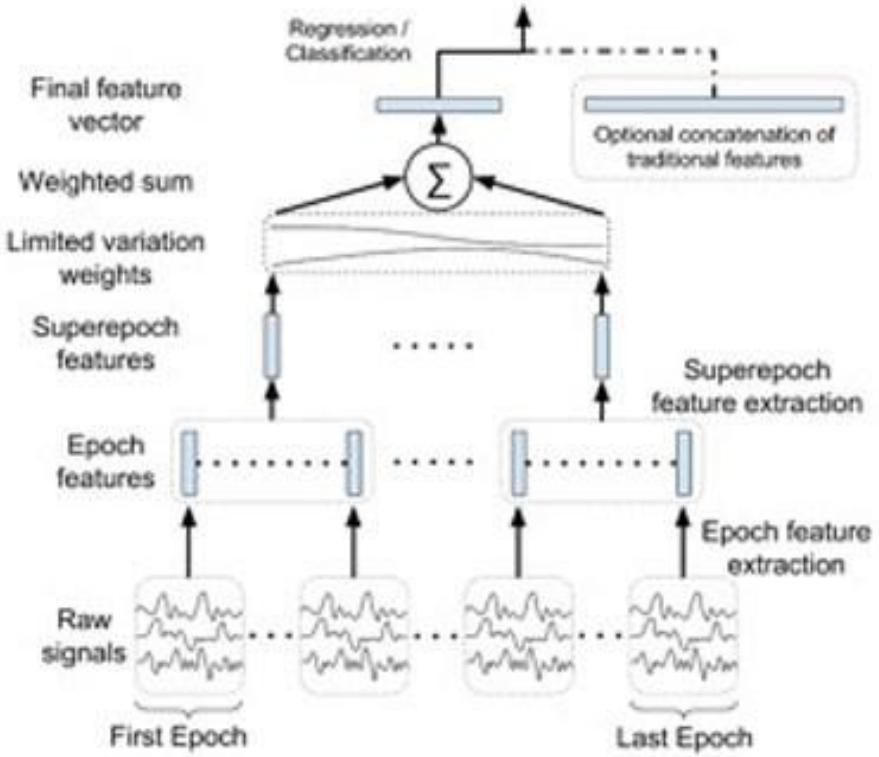


DARPA, 2017

Computational Sleep Science

Machine Learning for the Detection, Diagnosis and Treatment of Sleep Problems

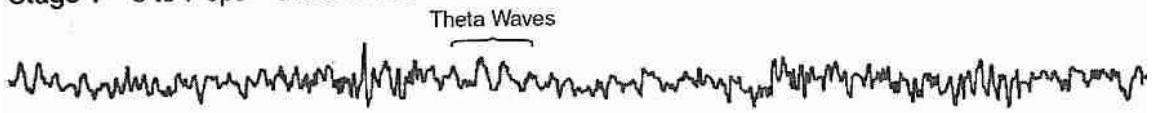
Sleep Quality



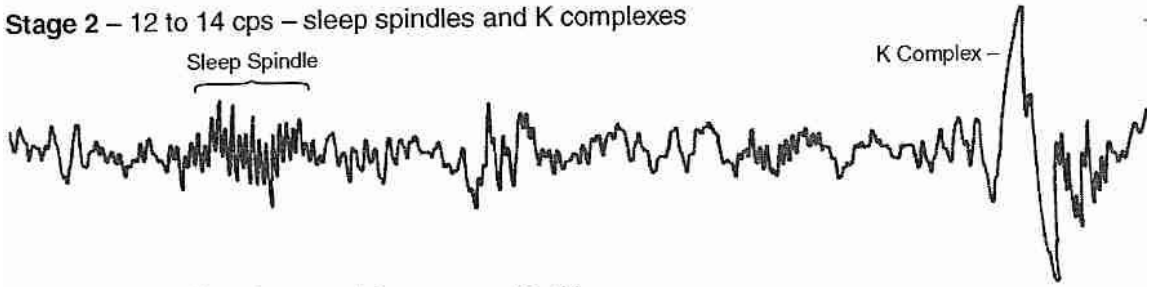
Awake – low voltage – random, fast

Drowsy – 8 to 12 cps – alpha waves

Stage 1 – 3 to 7 cps – theta waves

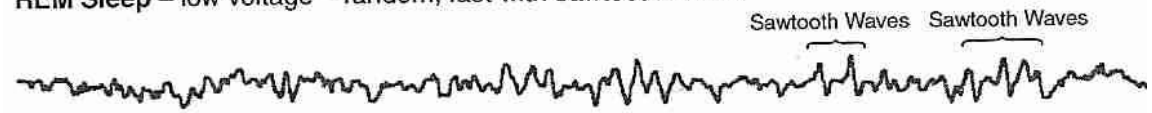


Stage 2 – 12 to 14 cps – sleep spindles and K complexes



Delta Sleep – 1/2 to 2 cps – delta waves >75 μV

REM Sleep – low voltage – random, fast with sawtooth waves

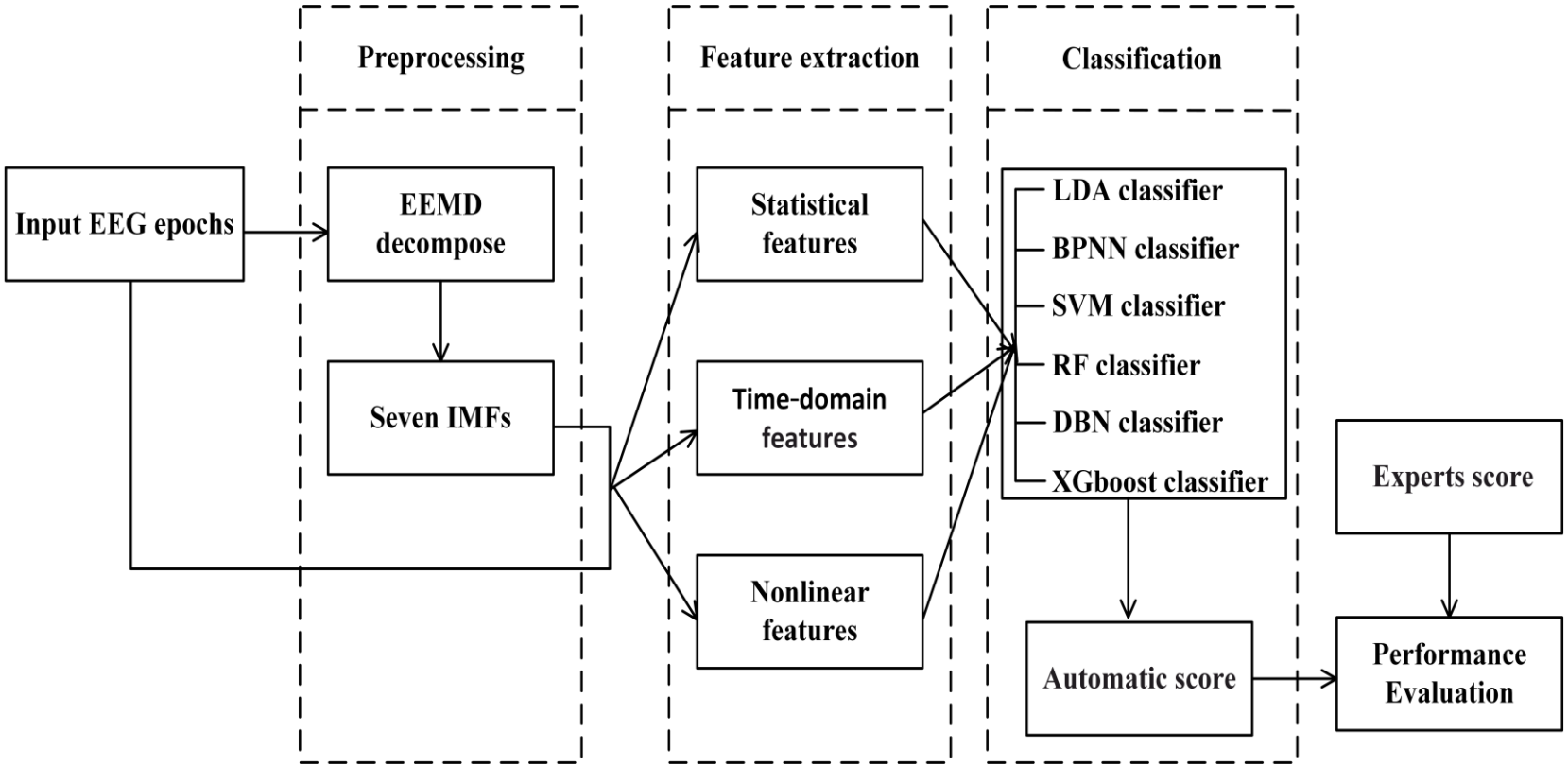


Literature Review of
Automatic Sleep Staging

Table 1 A review of the existing method on automatic sleep scoring based on single channel EEG.

Name	Subject/Number of epochs	Derivation	Features	Classifier	ACC	
					4-class	5-class
Han [3]	4/7694	C3-A2	Relative power based on the fast Fourier transform	Fuzzy classifier	84.6%	---
Wang [5]	99/85206	A1-A2	Time-domain and Frequency-domain features	Z-PLUS	82.2%	---
Fraiwan [24]	16/20269	C3-A1	Time–frequency and entropy features based on continuous wavelet transform	Random forest	---	82.6%
Radha [37]	10/---	F4-A1	Frequency-domain, time-domain, linear, and nonlinear features	Random forest and Support vector machine	---	80.0% / 77.0%
da Silveira [26]	20/106376	Pz-Oz	Statistical features based on discrete wavelet transform	Random forest	92.3%	**91.5%**
Liang [27]	20/16976	C3-A2	Multiscale entropy and autoregressive model features	Linear discriminant analysis	---	76.9%
Zhu [28]	8/14963	Pz-Oz	Degree distributions based on difference visibility graphs	Support vector machine	89.3%	88.9%
Hassan [29]	8/15188	Pz-Oz	Statistical features based on empirical mode decomposition	Adaptive Boosting and decision trees	91.2%	**90.1%**
Günes [30]	5/4196	C4-A1	Frequency-domain features	Decision tree	---	82.2%
Ronzhina [31]	8/7730	Pz-Oz	Frequency-domain, time-domain, nonlinear and hybrid features	Artificial neural network	81.6%	76.4%
Saastamoinen [32]	15/---	C3-M2	Frequency-domain features	---	66.5%	---
Berthomier [33]	15/14607	Cz-Pz	Frequency-domain features	Fuzzy classifier	74.5%	70.7%
Mohammadi [35]	36/5000	C3-A2	Time–frequency domain features based on singular spectrum analysis	Support vector machine	83.6%	---
Şen [36]	25/5160	C3-A2	Time-domain, frequency domain, and nonlinear analysis	Random forest	---	**98.02%**

Heuristic Approach



Frequency Ranges of IMFs

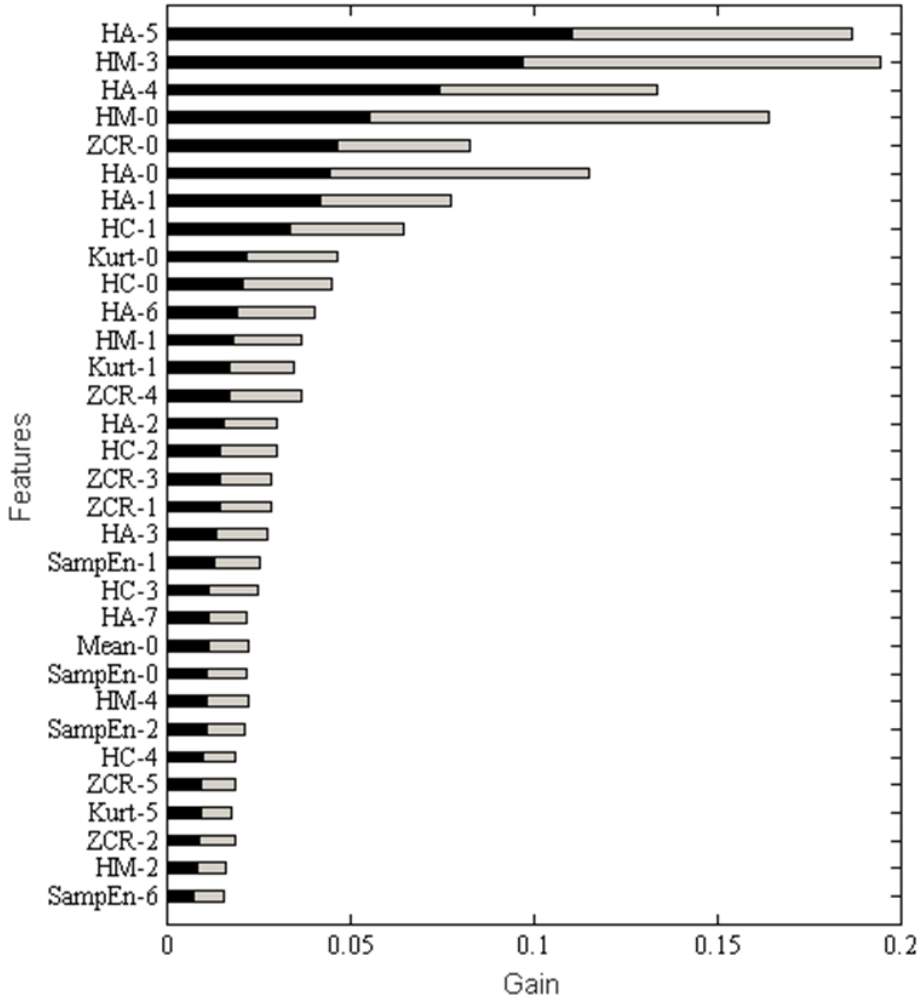
Table 4 Frequency range in seven IMFs of EEMD.

Signal	Frequency range (Hz)	Corresponded brain rhythm
IMF1	25.2 [20.2-38.1]	beta
IMF2	12.1 [10.3-16.9]	alpha
IMF3	6.3 [5.5-8.8]	theta
IMF4	3.5 [2.8-4.9]	delta
IMF5	2.1 [1.3-3.5]	delta
IMF6	1.5 [0.6-3.5]	delta
IMF7	1.1 [0.3-3.9]	delta

Classification Accuracy

Classifier	5-Class		4-Class	
	ACC	Kappa	ACC	Kappa
LDA	69.9%	0.593	74.9%	0.643
SVM	84.1%	0.770	85.4%	0.781
BPNN	82.1%	0.741	83.6%	0.754
RF	83.4%	0.759	84.9%	0.772
DBN	80.2%	0.713	81.6%	0.724
XGboost	**85.2%**	**0.786**	**86.8%**	**0.801**

Significant Features



Amazon Echo

Endurance: A Companion for Dementia Patients

Image via Endurance

Casper: Helping Insomniacs Get Through the Night

Image via Casper

MedWhat: Making Medical Diagnoses Faster

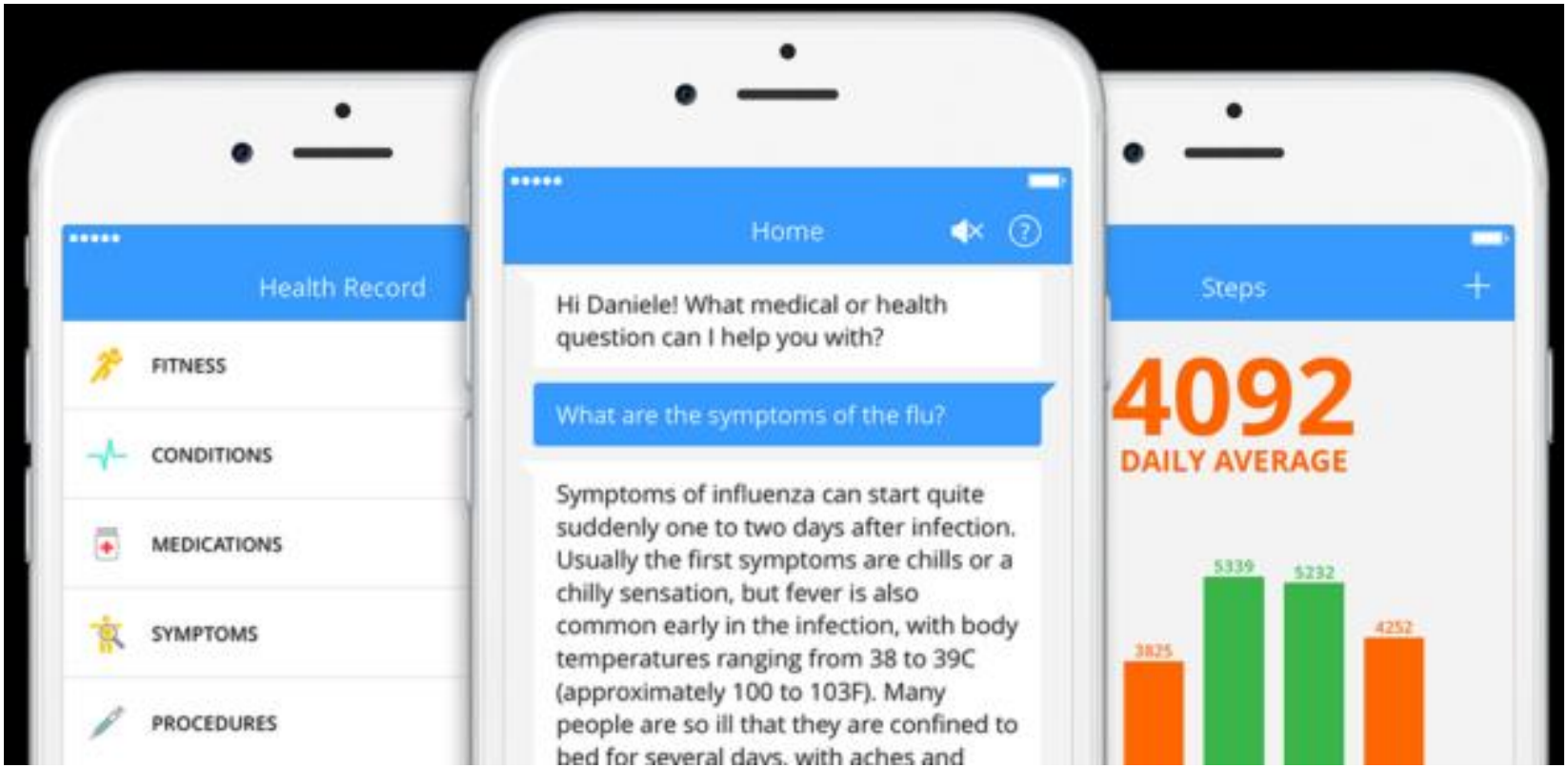
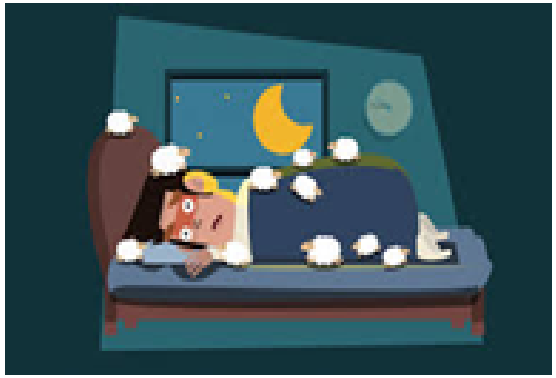


Image via MedWhat

Medical Visit Reform

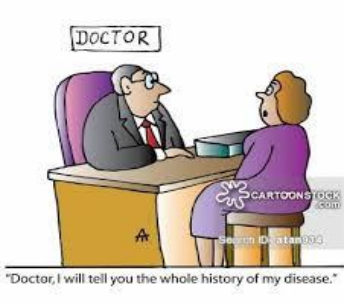


Patient

Doctor Visits

Differentiate 60+ Sleep Diagnoses

Diagnosis



Conventional

Current

Future

Summary

- Machine learning is important to advance the practice of sleep medicine

- Challenges include
  - Clean label of sleep data
  - Identify sleep disorders from complex physiologic signals