Department of
Electronics & Communication Engineering
Since 1987

Intelligent Decision Support Systems in Biomedical Engineering

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Decision Support System

A decision support system (DSS) is an intelligent system, which offers excellent assistance in diverse levels of various applications

Decision Support System

Evaluation of the overall effectiveness of decision support systems (DSS) has been a research topic since the early 1980s.

As artificial intelligence methods have been incorporated into systems to create intelligent decision support systems (IDSS), researchers have attempted to quantify the value of the additional capabilities.

Intelligent Decision Support Systems

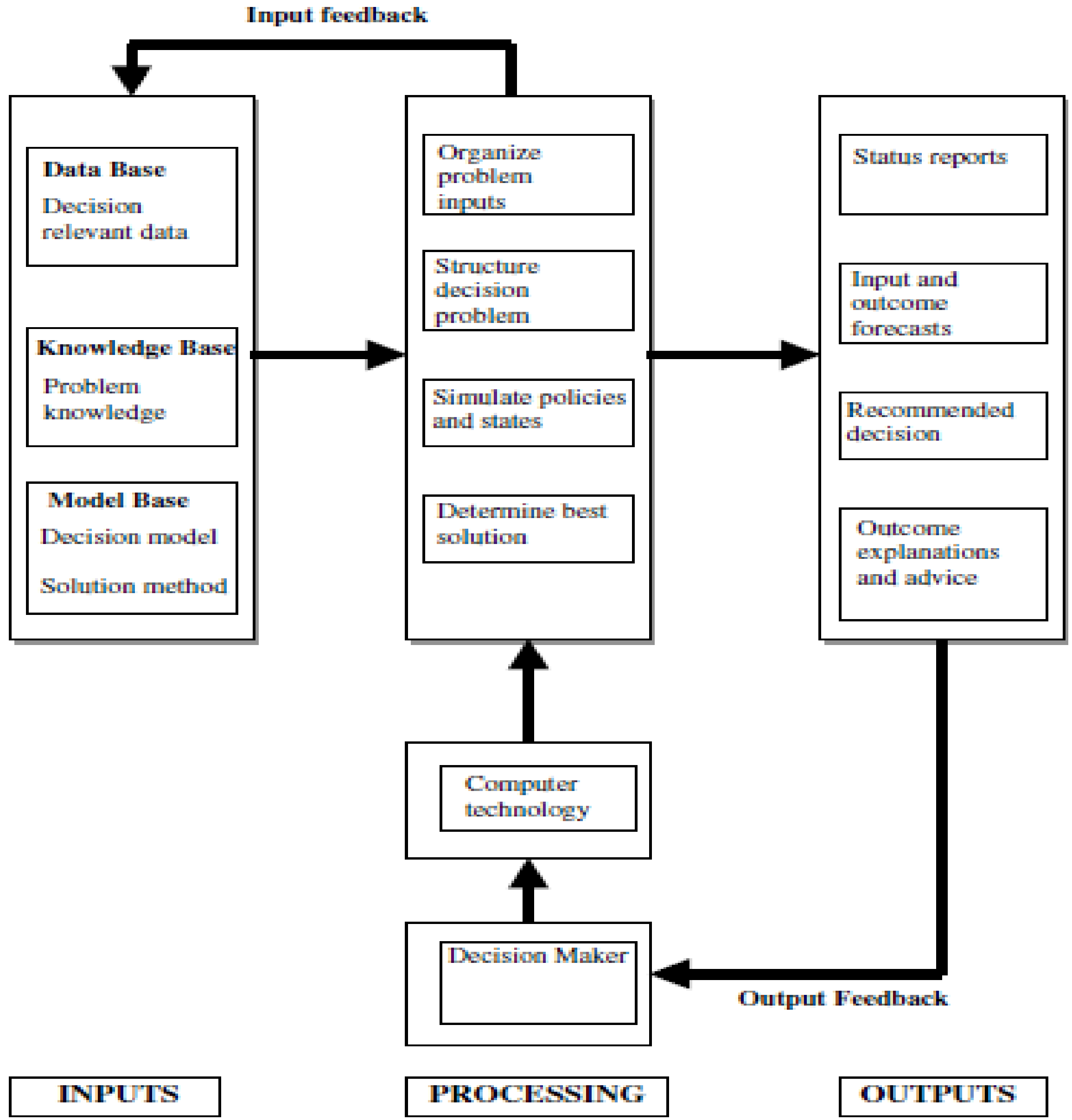
Intelligent Decision Support Systems (IDSSs) represent an interdisciplinary research domain bringing together Artificial Intelligence/Machine Learning (AI/ML), Decision Science (DS), and Information Systems (IS).

IDSS refers to the use of AI/ML techniques in decision support systems.

Intelligent Decision Support Systems

IDSS add artificial intelligence (AI) functions to traditional DSS with the aim of guiding users through some of the decision-making phases and tasks or supplying new capabilities.

IDSS Structure



IDSS Structure

IDSS usually uses model and builds it through interaction and recursion process.

An IDSS has a

- **Data base**
- **Knowledge base**
- **Model base**

Some or all of which will utilize AI methods

IDSS Structure

The data base contains the data directly relevant to the decision problem, including the values for the states of nature, courses of action, and measures of performance.

The knowledge base holds problem knowledge, such as guidance for selecting decision alternatives or advice in interpreting possible outcomes.

The model base is a repository for the formal models of the decision problem and the approaches (algorithms and methodologies) for developing outcomes from the formal models.

IDSS Structure

Decision-makers utilize computer and information technology to process the inputs into problem-relevant outputs.

Processing involve:

(a) organizing problem inputs;

(b) structuring the decision problem decision model;

(c) using the decision model to simulate policies and events;

(d) finding the best problem solution.

IDSS can use knowledge drawn from the knowledge base to assist users in performing these processing tasks.

Intelligent Decision Support System (IDSS) Structure

Processing will generate

- **Status Reports**
- **Forecasts**
- **Recommendations**
- **Explanations**

IDSS Structure

Status reports will identify relevant states, courses of action, and measures of performance and show the current values for these problem elements.

Forecasts will report the states and actions specified in the simulations and the resulting projected values for the measures of performance.

IDSS Structure

Recommendations will suggest the values for the actions that best meet the measures of performance.

Explanations will justify the recommendations and offer advice on further decision making.

Such advice include suggestions on interpreting the output and guidance for examining additional problem scenarios.

IDSS Structure

Input feedback from the processing provides additional data, knowledge, and models that may be useful for future decision making.

This feedback is provided dynamically to update the models and inputs in real time without external intervention.

Output feedback is used to extend or revise the original analyses and evaluations.

Classification of IDSS

IDSS can be divided into 3 types

- **IDSS based on Artificial Intelligence**
- **IDSS based on Data Warehouse**
- **IDSS based on Case Reasoning**

IDSS based on AI

IDSS based on AI includes

- **IDSS based on Expert System**
- **IDSS based on Machine Learning**
- **IDSS based on Agent**

IDSS based on AI

IDSS based on Expert System

- **Comprised of knowledge base, inference engine and database.**
- **Uses non-quantitative logical statements to express knowledge and uses automatic reasoning to solve questions.**
- **Mainly uses quantification method to model problems and offers decision support utilizing the calculation result of value model.**

IDSS based on AI

IDSS based on Machine Learning

- **ML is to get the knowledge of solving human’s problems through computer simulating human’s learning.**
- **ML can automatically acquire knowledge.**
- **Therefore, the bottleneck of acquiring knowledge in expert system can be solved in certain degree.**

IDSS based on AI

IDSS based on Agent

- **Agent is a research hotspot in AI field.**
- **It can be anything that perceive its environment and act upon.**
- **It runs in the cycle of perceiving, thinking, & acting.**

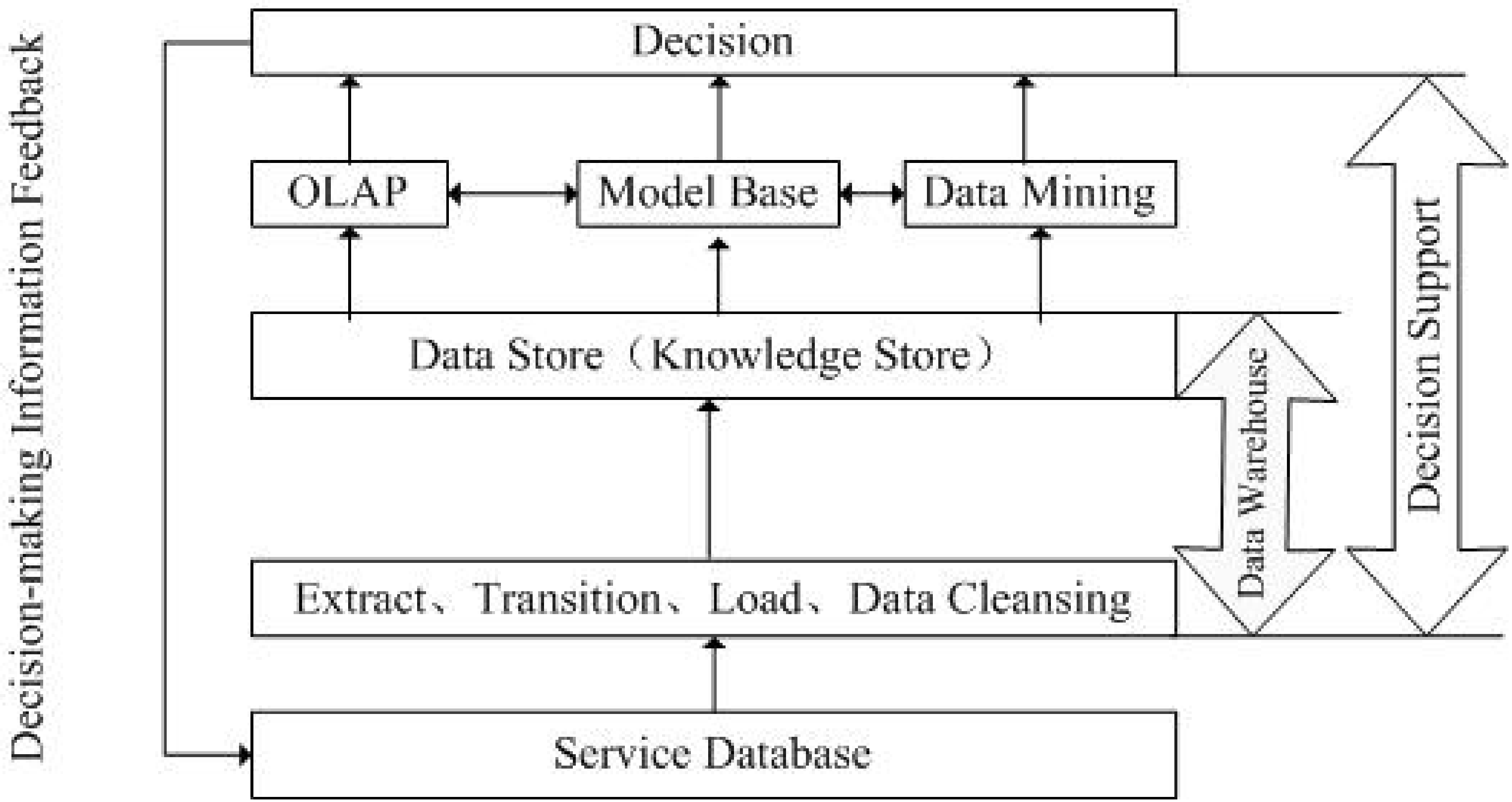
IDSS based on Agent includes research on

- **Intelligent Agent**
- **Multi-Agent system**
- **Agent-oriented program design**

The IDSS based on Data Warehouse

- **Data warehouse builds integrated, changeable and durable data set through summarizing, gathering and integrating data source information and offers useable information for making decisions.**
- **OLAP(On-line Analytical Processing) simultaneously develops with data warehouse.**
- **Multidimensional data analysis of OLAP can be in the forms of stripping and slicing, rotation and drilling.**

The IDSS based on Data Warehouse



The IDSS based on Case Reasoning

- **The reasoning based on case is to find the method of solving the current problems from the previous experience.**
- **The set of previous incidents can form a case base, namely the model of problems processing.**
- **The current problems are target cases; the problems or circumstances in memory are source cases.**

The IDSS based on Case Reasoning

- **The reasoning based on case simplifies the process of acquiring knowledge, reuses previous solving process and plays good functions to the problems which can be solved through calculation.**

Characteristics of IDSS

- **Certain self-directed learning ability**

  Decision makers are permitted to modify and broaden the knowledge in knowledge base. Therefore, the ability of solving problems can be further enhanced.

- **IDSS has reasoning mechanism**

  It simulates the thinking process of decision makers and applies relevant knowledge to guide decision makers to choose proper decision models through man-machine interview according to the demand of decision makers.

Characteristics of IDSS

- **Has intelligent model management function**

  It manages model as a kind of knowledge structure and simplifies the interface between different subsystems.

- **Builds universal structure of DSS**

  To expand the service field of the system and make the system better adapt to the

  - **change of environment**
  - **change of the form of decisions**

IDSS: Healthcare Perspective

IDSS: Healthcare Perspective

- **Decision-making is a crucial task for decision makers in healthcare, especially because decisions must be made quickly, accurately and under uncertainty.**
- **Considering the importance of providing quality decisions, offering assistance in this complex process has been one of the main challenges of Artificial Intelligence throughout history.**
- **Decision Support Systems (DSS) have gained popularity in the medical field for their efficacy to assist decision-making.**
- **Intelligent Decision Support Systems (IDSS) provides comprehensive support for a wide range of decisions with the purpose of improving medical treatment for patients.**

IDSS: Healthcare Perspective

- **AI based IDSS can adopt in new environment and to learn with time.**
- **Various methods are used to gather information used for the process of Decision making in Computer Aided Support Systems.**
- **These methods include Statistical Method, Neural Network, Knowledge Based Methods, Fuzzy Logic Rule Based, etc.**

IDSS: Healthcare Perspective

The selection of a particular methodology depends upon various parameters such as

- **What is the problem domain?**
- **What can be the solution?**
- **Amount of data available**
- **Researcher choice and purpose**

IDSS: Healthcare Perspective

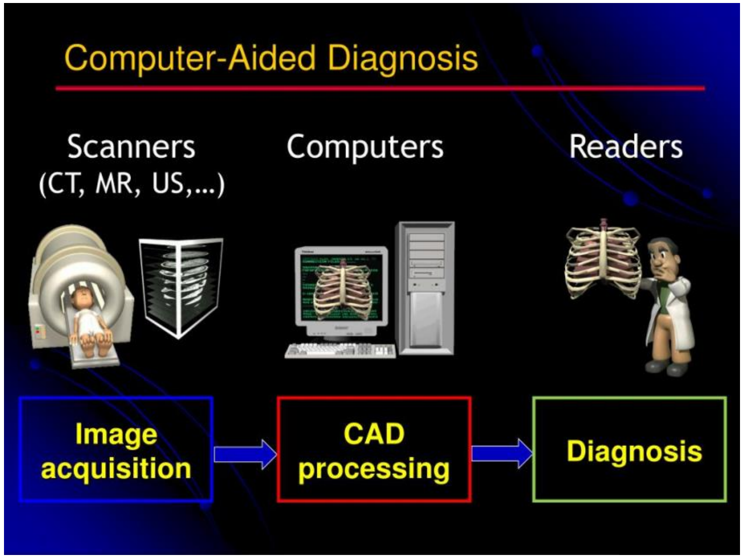
For the diagnosis / detection of a disease, medical science needs Computer Aided Software that can collect the health-related signals from patients and transform them in decision values

Computer Aided Diagnosis?

- Aid of computers in the process of diagnosis
- Generally, Radiologists uses the output of a computer analysis as a second opinion for making a disease diagnosis
- CAD systems were introduced to reduce the subjective variability among radiologists

Computer Aided Diagnosis

CAD systems provide consistent interpretations of inputs to **improve the precision of a diagnosis**



These systems compute **outputs based on information from diverse sources, medical signals / images** captured using various methods

Computer Aided Diagnosis

Computer Aided Diagnosis (CAD) is **computerized analysis of medical signals / images** and is widely used as a **tool in detection and differential diagnosis of abnormalities**

Computer Aided Diagnosis

- CAD is an **interdisciplinary field** combining elements of **Artificial Intelligence(AI)** and **Signal Processing / Computer Vision Techniques**
- CAD uses **AI techniques to analyze** imaging and/or non imaging **patient data** and makes assessment of the patient's condition
- The goal of CAD systems is to improve the accuracy of radiologists with a **reduction of time in the interpretation**

Computer Aided Diagnosis

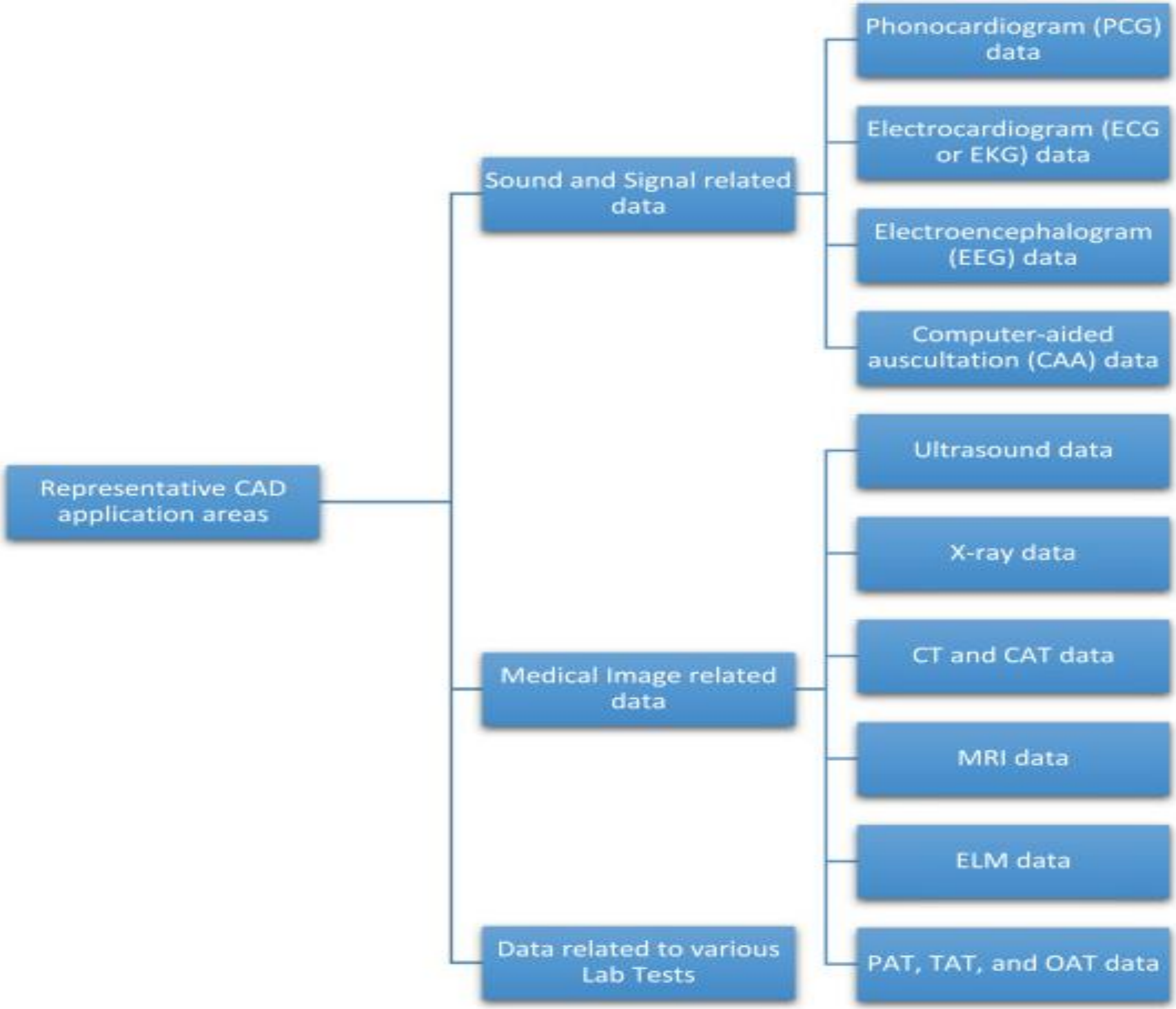
- With CAD, the **performance by computers does not** have to be comparable to or **better than that by physicians**
- but needs to be **complementary to that by physicians.**

Computer Aided Diagnosis

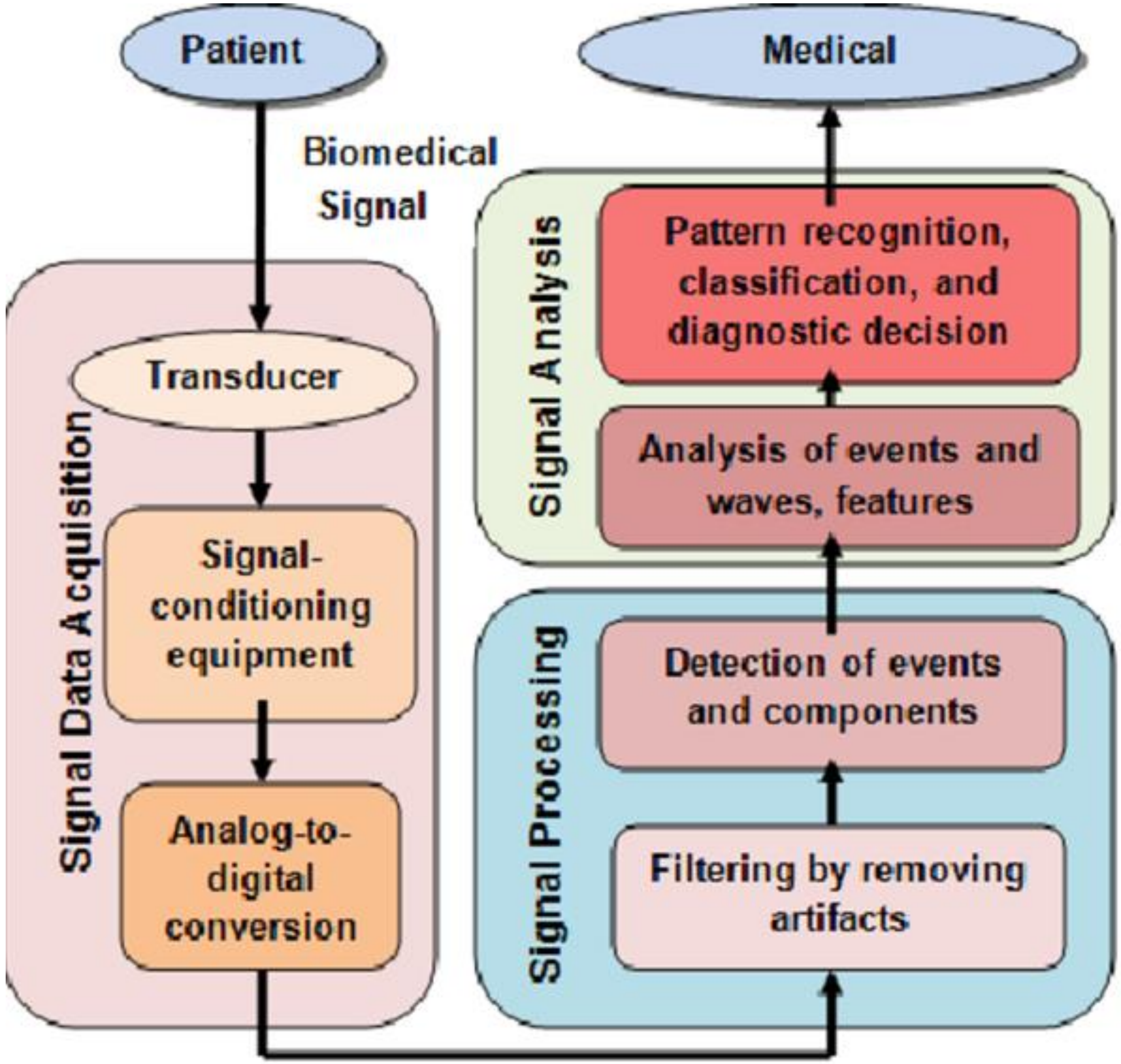
Objectives of CAD Systems

- Improving the accuracy of exams
- Increasing consistency in interpretation of data
- Helping the prognostic evaluation
- Supporting the therapeutic decision-making process

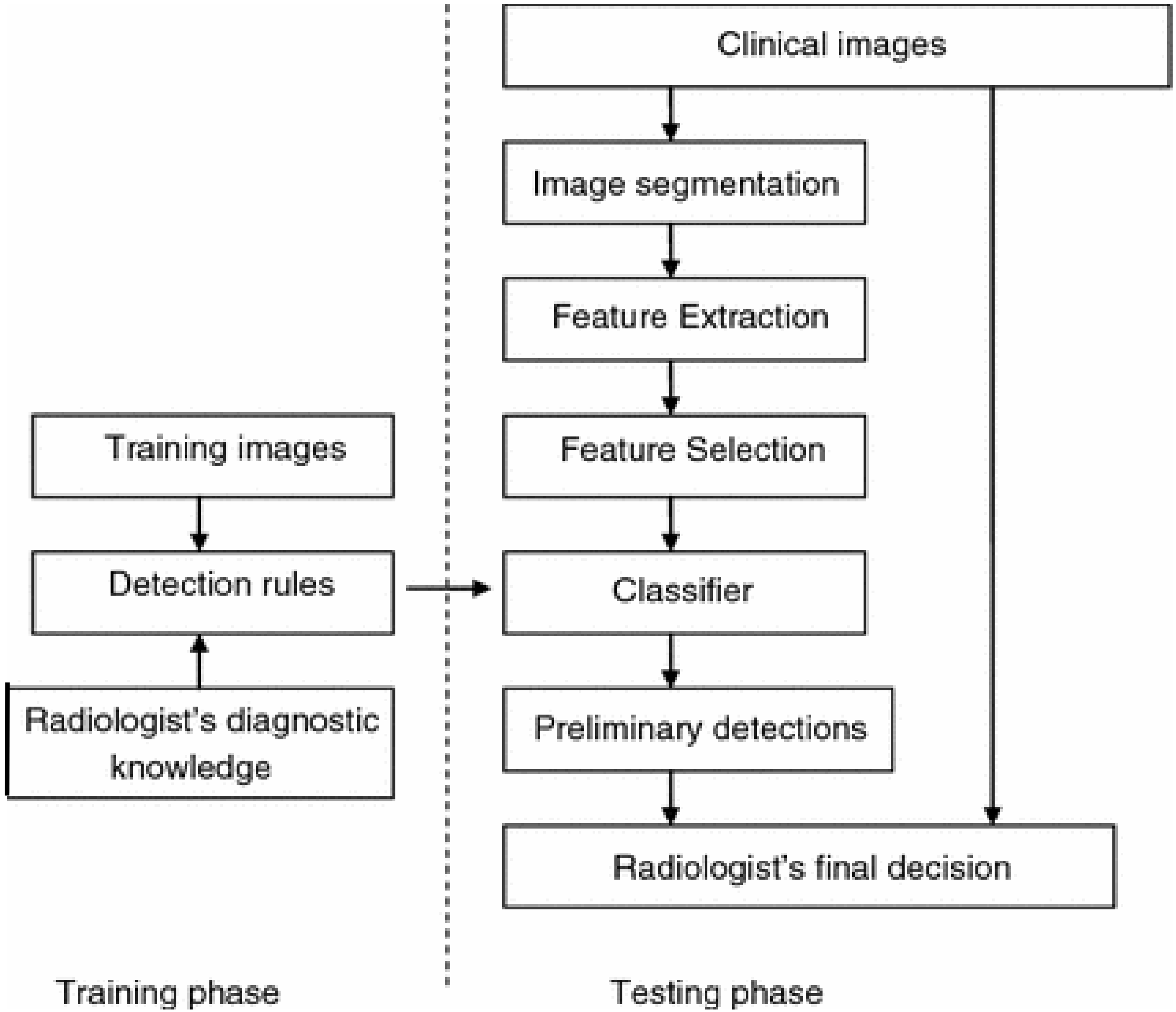
Computer Aided Diagnosis: Data types



CAD with Signals



CAD with Images



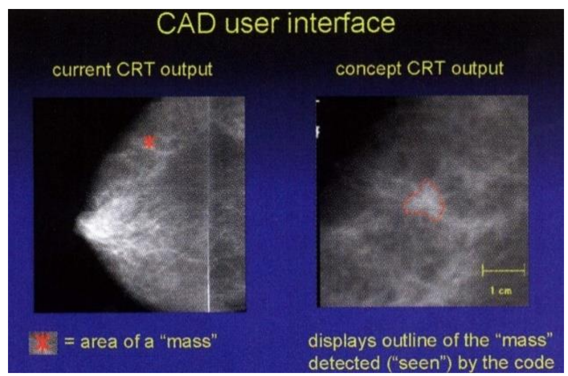
Computer Aided Diagnosis: Types

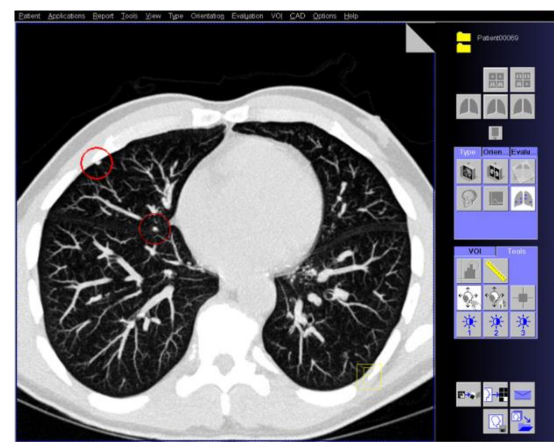
CAD systems are classified into two groups:

- Computer-Aided Detection (CADe) systems
- Computer-Aided Diagnosis (CADx) systems

Computer Aided Diagnosis: Types

- **Computer-Aided Detection (CADe)**
  - **Usually confined to marking suspicious structures and sections**
  - **Detect the specific location of abnormalities**
  - **Reduce the risk of missing pathologies of interest**
  - **Initially approved by FDA-USA in 1998 for mammography**

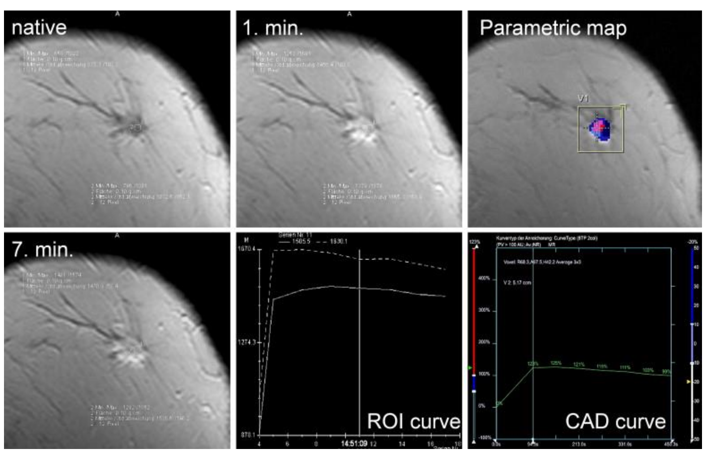


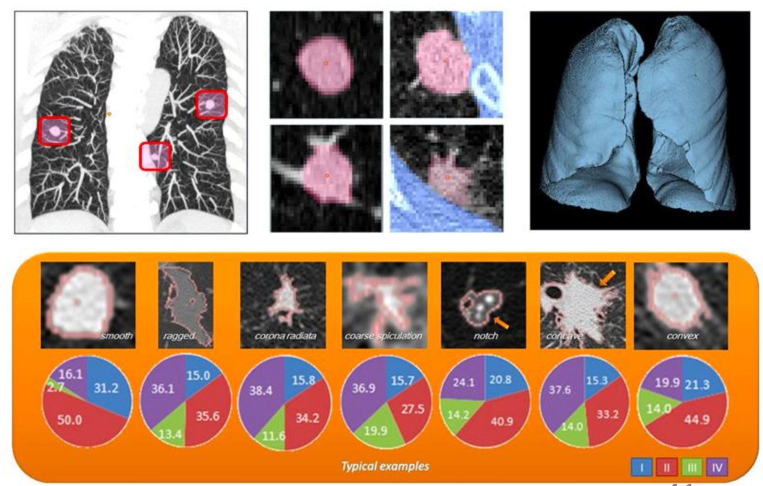


Computer Aided Diagnosis: Types

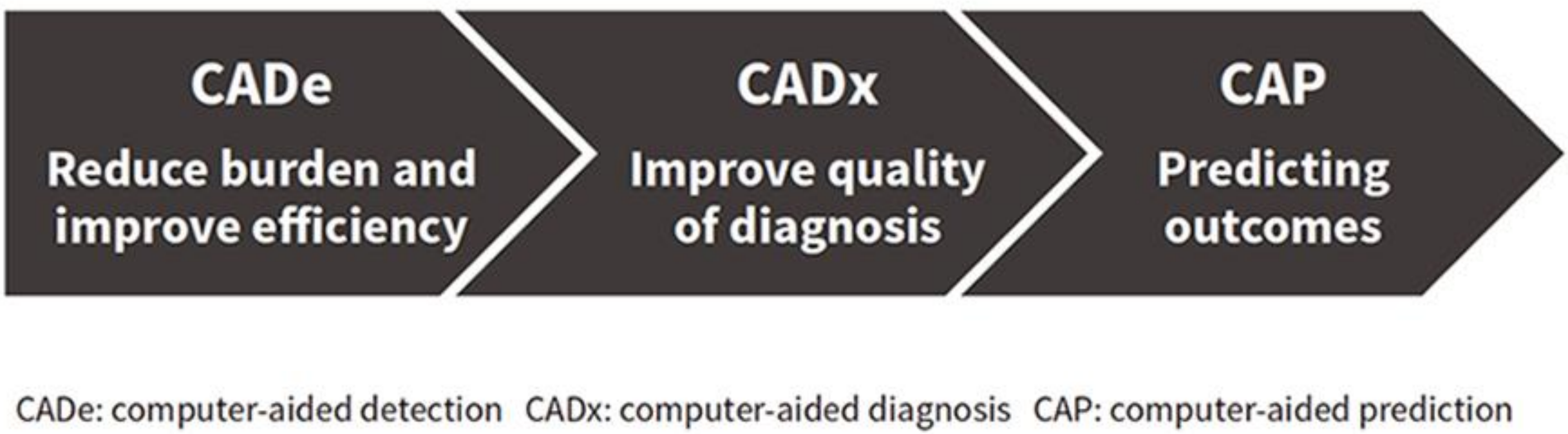
- **Computer-aided Diagnosis (CADx)**
  - **Usually focused on to classify detected regions**
  - **Perform the characterization of the lesions**
  - **Helps a practitioner assess and classify pathology**

Eg: Distinction b/w benign & Malignant tumors





CADe vs CADx Systems



Computer Aided Diagnosis: Applications

Used in the diagnosis of

- **Breast Cancer**
- **Lung Cancer**
- **Colon Cancer**
- **Prostate Cancer**
- **Bone Metastases**
- **Coronary Artery Disease**
- **Congenital Heart Defect**
- **Pathological Brain Detection**
- **Alzheimer's Disease**
- **Diabetic Retinopathy**

CAD - Knowledge Involved

- Computer Vision (quantitative features extraction)
  - Preprocessing (noise reduction and enhancement)
  - Segmentation (regions, edges, structures)
  - Structure/ROI Analyze (form, size and location, texture, topology)

- Artificial Intelligence (classification)
  - Features selection
  - Classification

Artificial Intelligence in CAD

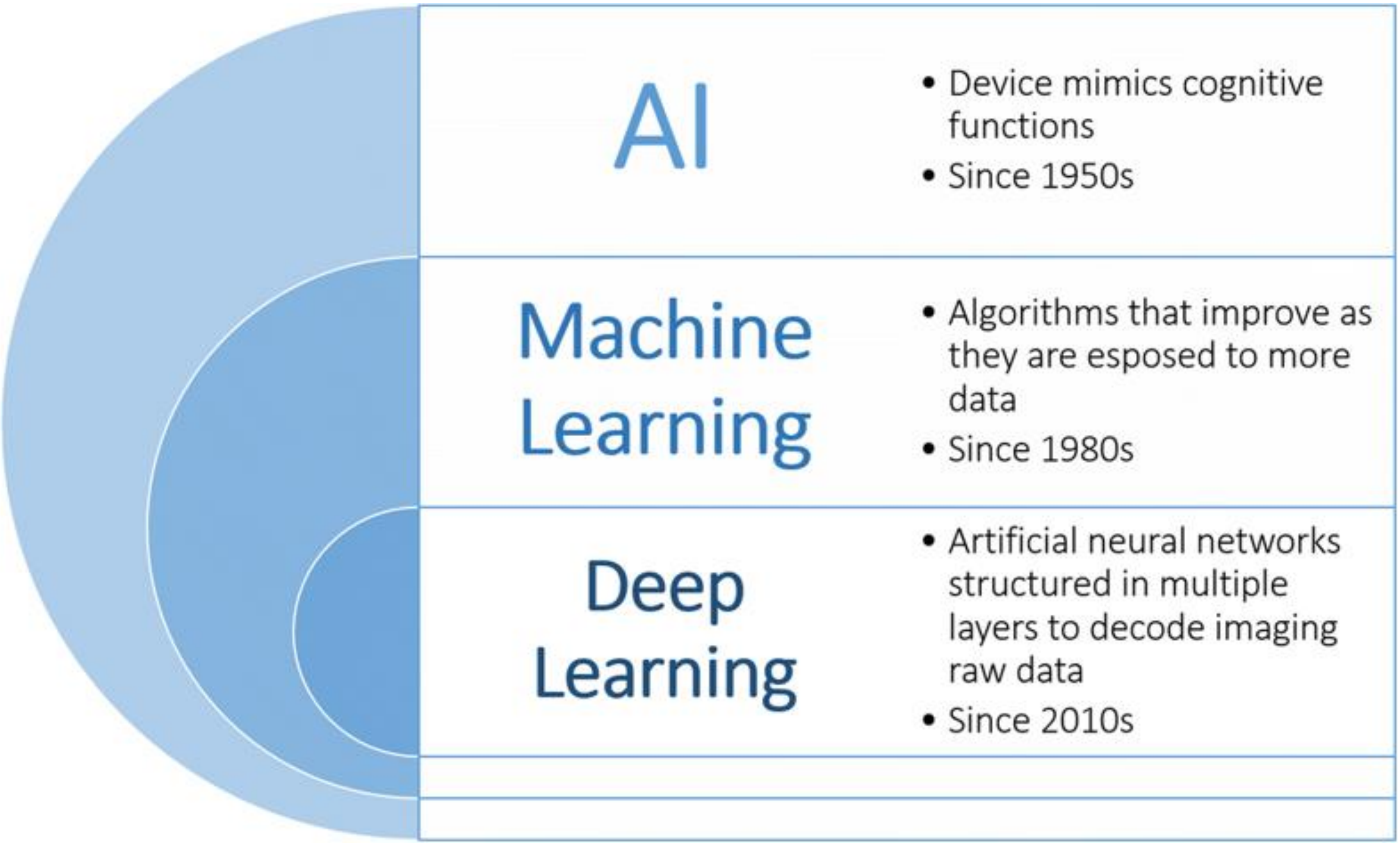
Artificial Intelligence in CAD

Artificial Intelligence (AI) is the branch of computer sciences that emphasizes the development of intelligence machines, thinking and working like humans

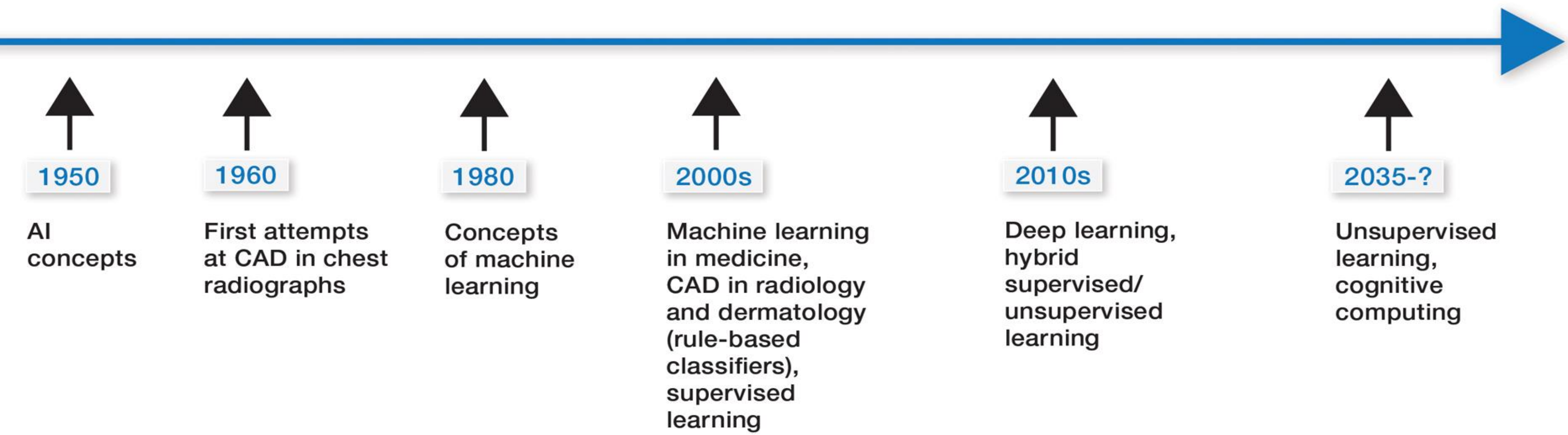
Eg

- **Speech recognition**
- **Image classification**
- **Problem-solving**
- **Learning and planning**

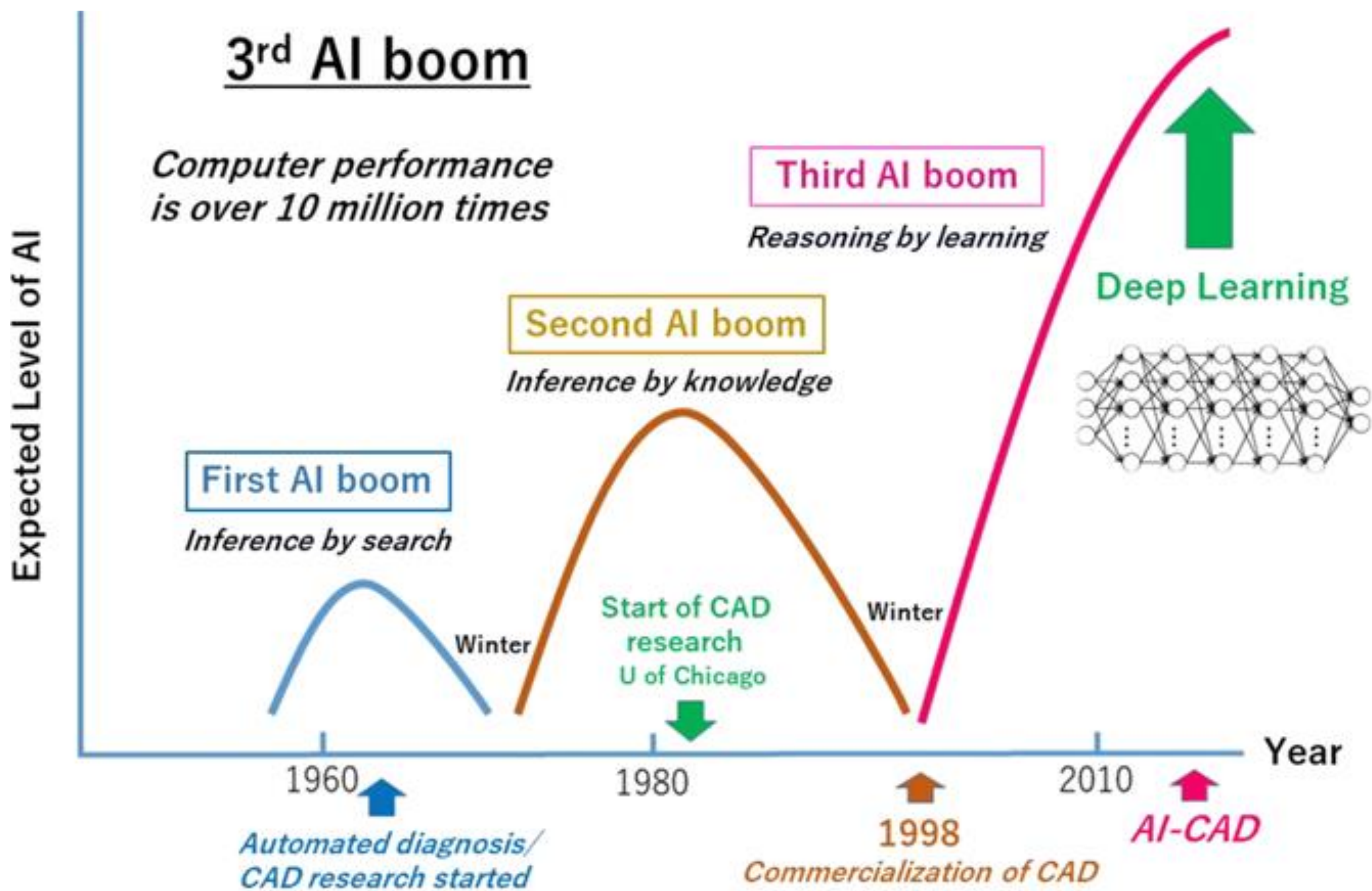
Artificial Intelligence



AI and CAD

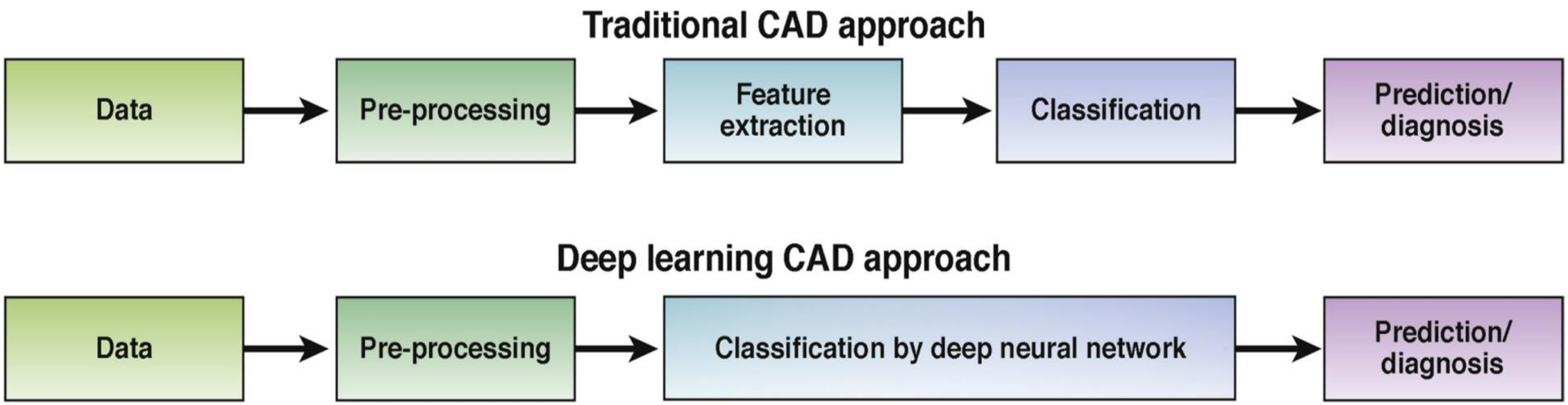

1950
AI concepts
1960
First attempts at CAD in chest radiographs
1980
Concepts of machine learning
2000s
Machine learning in medicine, CAD in radiology and dermatology (rule-based classifiers), supervised learning
2010s
Deep learning, hybrid supervised/ unsupervised learning
2035-?
Unsupervised learning, cognitive computing

AI and CAD



3rd AI boom
Computer performance is over 10 million times
Expected Level of AI
Third AI boom
Reasoning by learning
Deep Learning
Second AI boom
Inference by knowledge
First AI boom
Inference by search
Winter
Start of CAD research
U of Chicago
Winter
Year
1960
1980
2010
Automated diagnosis/ CAD research started
1998
Commercialization of CAD
AI-CAD

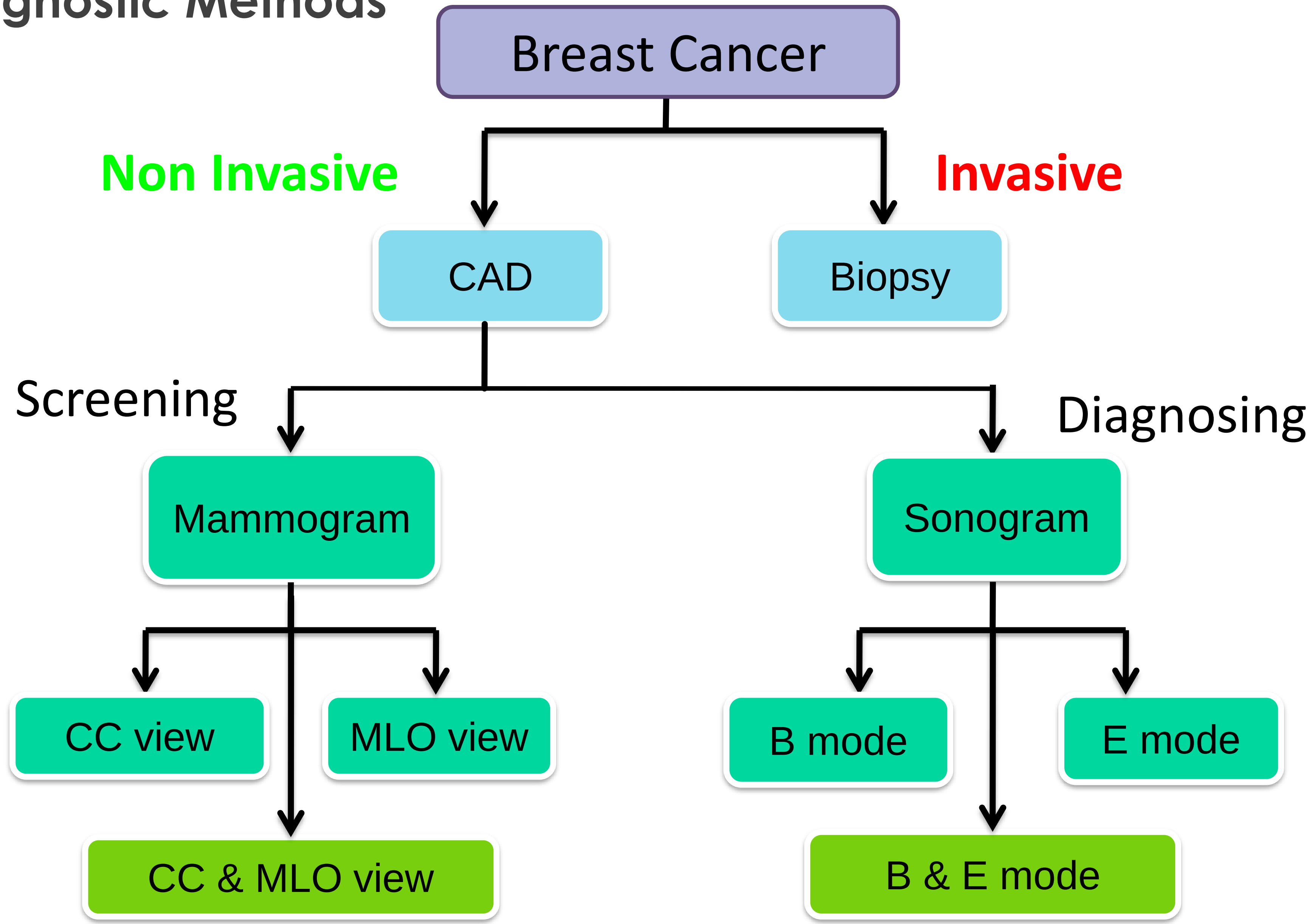
CAD Approaches



Machine Learning Based Systems

Breast Cancer Detection

Diagnostic Methods

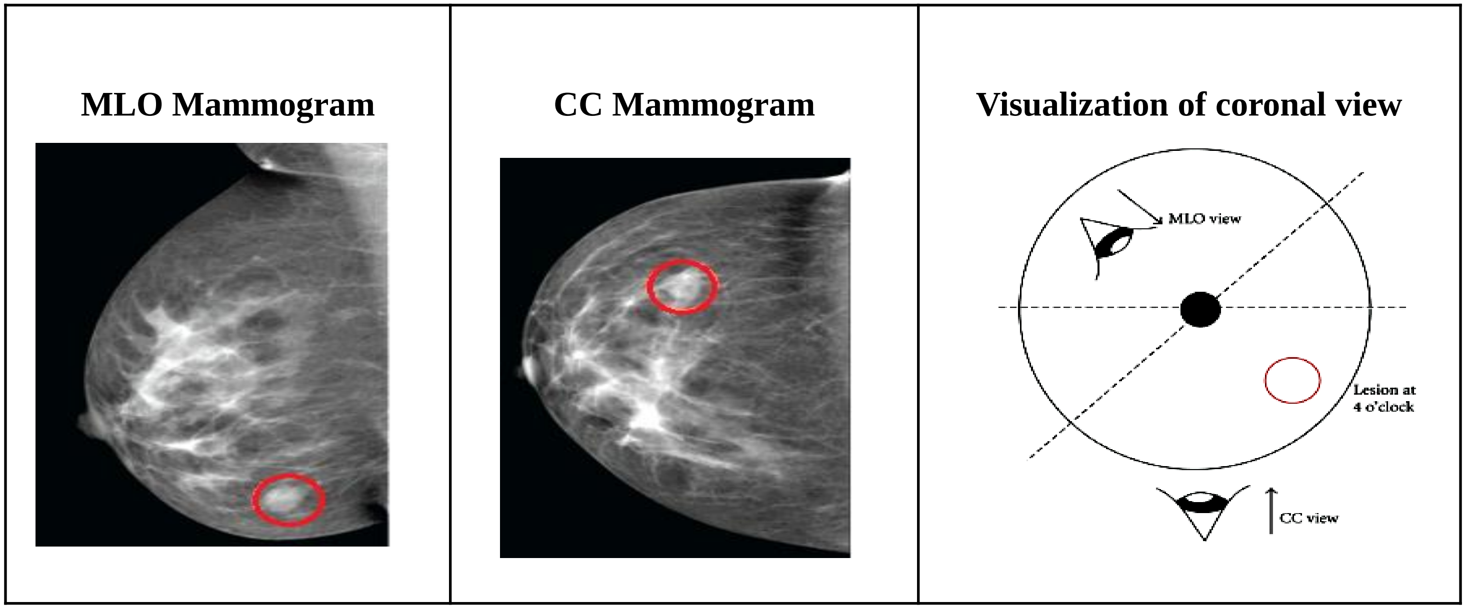


Diagnostic Methods

Mammography

- **Gold std over 40 yrs, Misses many cancers in dense breasted women**
- **Patient discomfort – Compression & repositioning of breast for different views**
- **Subject to a FP as well as FN - cause some unnecessary biopsies**
- **Increasing the no. of views improves the diagnostic performance**
- **Harmfulness of its ionizing radiation to both radiologists and patients**

4 O'clock Position of a Lesion on a Right Breast



Diagnostic Methods

Sonography

- **Capable of detecting and discriminating benign and malignant masses with high accuracy and diminish the number of unnecessary biopsies**

- **Adjuncts to mammography to assist physicians in diagnosing the breast abnormalities**

- **Combining B mode and E mode information will give better performance**

B mode and E mode

- **B mode US or echographic imaging provides composite properties of tissues by capturing the characteristics of backscattered ultrasonic waves.**

- **Tumours possessing insufficient echographic properties provide inadequate details in B mode US image.**

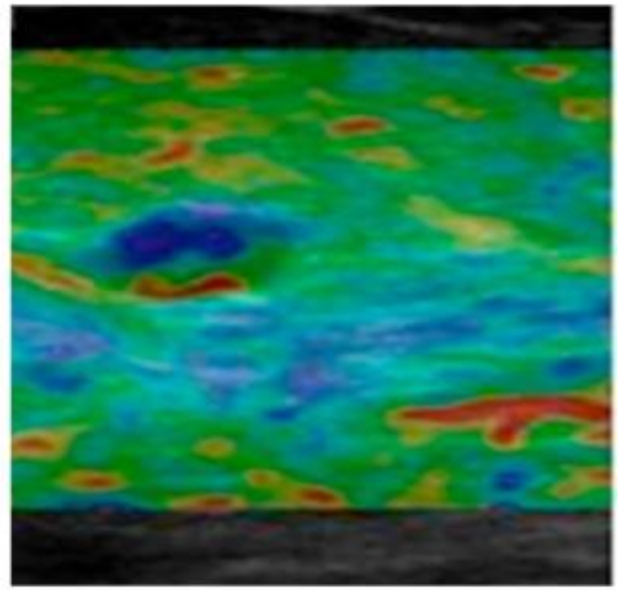
- **US Strain Elastography (SE) mode image describes tissue stiffness and hardness in terms of spatial variations of the elastic modulus.**

- **Pathologic tumours are more than 30 times stiffer than sorrounding tissues**

- **SE supplements useful and additional information about tumours for diagnosis**

24 Years Female with Palpable Right Breast Lump

(a)



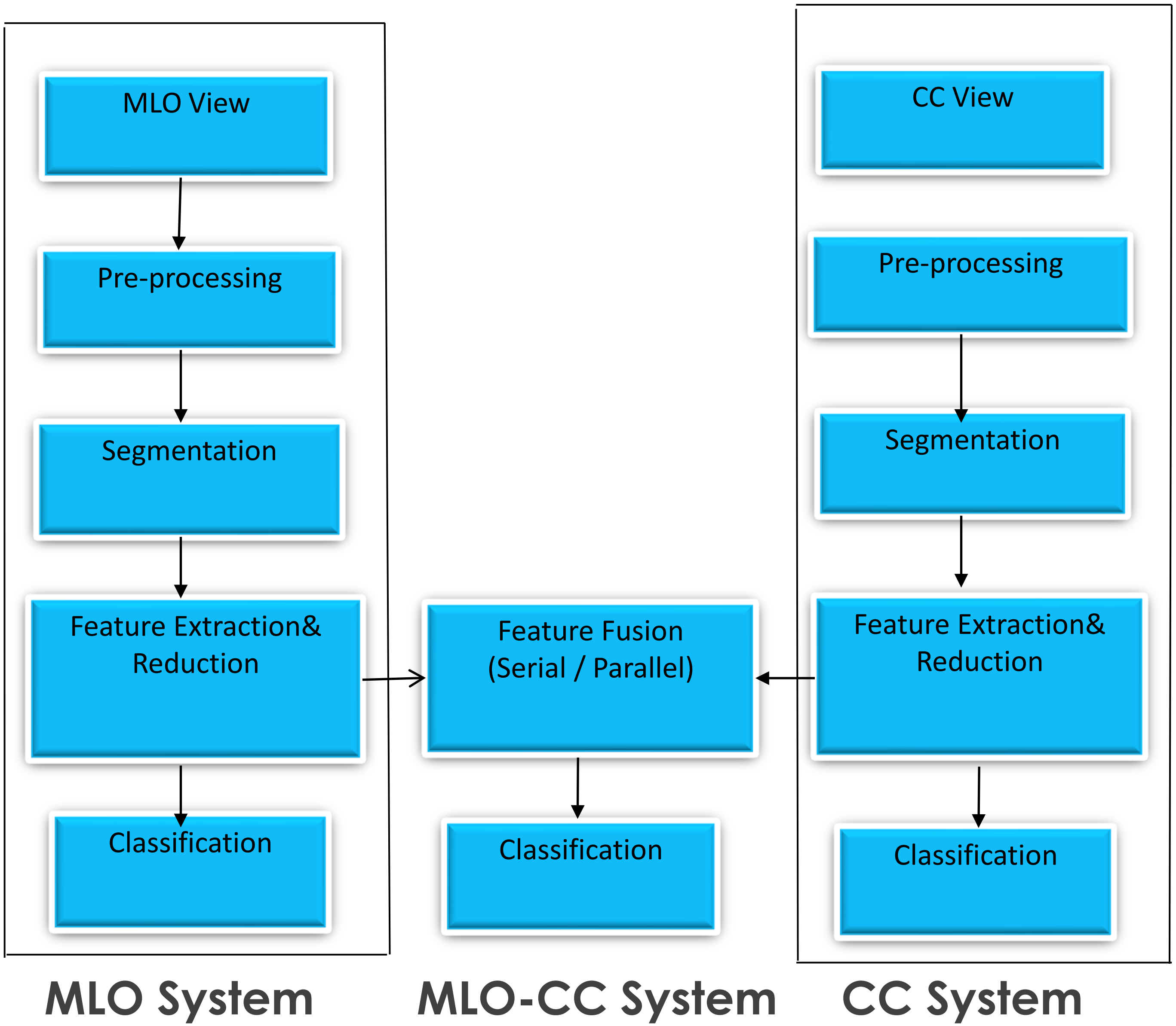
(b)

Conventional US **Elastography**

Need for both MLO & CC view information

- Radiologists use MLO view and CC for detection
- Two view screening improves the visibility and detection accuracy
- Lesions hidden by glandular tissue in one view might be visible in another view
- To mimic Radiologists' perception, information from both views could be used

Block Diagram



Textures in CAD System

- Texture is a quantitative measure of the spatial arrangement of intensities in an image
- Provides a value at each pixel, describing the texture in a neighborhood of that pixel
- The luminance characteristics of a mass can be represented by texture features
- Texture analysis plays a vital role in decision making for medical diagnostic problems - CAD
- Hypothesis - a malignancy would cause changes in the texture of nearby tissue
- CAD schemes usually focused on extracting texture features from ROI

Texture Features

- Gray Level Co-occurrence Matrix (GLCM)
- Gray Level Run Length Matrix (GLRLM)
- Gray Level Difference Method (GLDM)
- Laws Texture Energy Measures (LAWs)
- Local Binary Pattern (LBP)

Feature Fusion

- Feature Fusion is a method of integrating related information extracted from a group of Training and Testing images without losing any data

- Feature fusion is the process of combining two or more feature vectors to obtain a single feature vector, which is more discriminative than any of the input feature vectors

Feature Fusion

- **The main aim of feature fusion is feature reduction and removal of noisy features**

- **Also it can merge two or more features of different domains and reduce the "curse of dimensionality" problem**

- **The main essence of feature fusion lies in the feature selection process**

Feature Selection

- “Curse of dimensionality” is a big motivation for feature selection

- Too many features increase the computational time without any significant change in the performance during the testing phase

Feature Level Fusion

Principal Component Analysis (PCA)

- Projecting the feature on the eigenvectors corresponding to the largest M eigen values of its covariance matrix

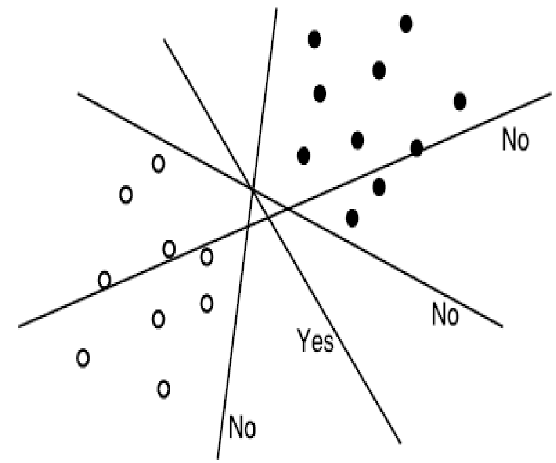
Canonical Correlation Analysis (CCA)

- Cross correlation between the input feature sets x and y is used to get new feature sets $\dot{x} = w_x^T x$ and $\dot{y} = w_y^T y$
- The transformations w_x & w_y are obtained in such a way that $\dot{x}$ and $\dot{y}$ maximize their cross correlations and minimize the auto correlation between them
- Maximization is performed by using Lagrangian multipliers subject to the constraints, variances of ($\dot{x}$) and ($\dot{y}$) set to unity

Classification

Support Vector Machines (SVMs)

- SVM is characterized by a splitti hyperplane or decision boundary. algorithm tries to minimize the g between current position and the d points.
  SVM learns to find the ideal separat hyper-plane, thereby maximizing the margins between the two different classes.
  An undefined/unknown samples class may be readily determined by examining the side where it lies, after finding the boundary.

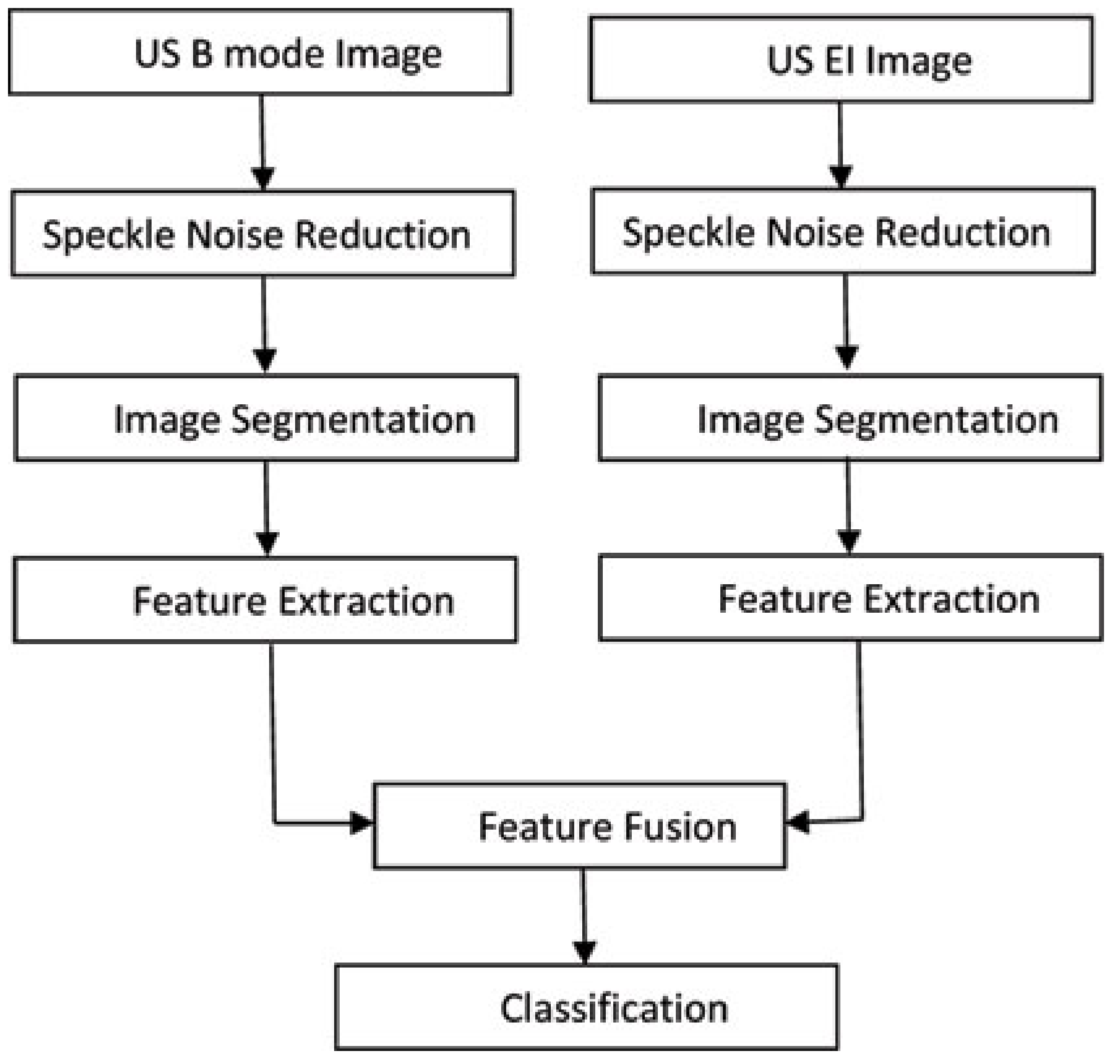


Choosing the best plane for classification

Performance Metrics

Sl.No	Measure		Formula
1	**Accuracy** :	% of correct classifications of all classes	$\frac{TP+TN}{FP+FN+TP+TN}$
2	**Sensitivity** :	Proportion of actual positives correctly identified as such	$\frac{TP}{P} = \frac{TP}{FN+TP}$
3	**Specificity** :	Proportion of actual negatives correctly identified as such	$\frac{\mathrm{TN}}{\mathrm{N}} = \frac{TN}{FP+TN}$
4	**Precision** :	Proportion of actual positives in the population being tested as it is	$\frac{TP}{TP+FP}$
5	**F1score** :	More useful than accuracy, especially if you have an uneven class distribution	$2 \text{ x } \frac{precision \times recall}{precision + recall}$
6	**Matthews Correlation Coefficient :**	Suitable for unbalanced class settings	$\frac{TP.TN - FP.FN}{\sqrt{(TP+FP)(TP+FN)(TN+FP)(TN+FN)}}$
7	**Balanced Classification Rate** :	More suitable for imbalanced data classes	$\sqrt{Sensitivity \times Specificity}$

Flow Diagram



Speckle Reduction

- Speckle is a signal dependent, multiplicative & spatially correlated noise
- Despeckling without destroying important image features is essential
- Speckle Reducing Anisotropic Diffusion (SRAD) for speckle reduction
- It exploits the instantaneous coefficient of variation as a function of the local gradient magnitude and Laplacian operators.
- Mean-preserving behaviour in homogeneous regions & edge preserving and enhancement behaviour at edges.

Performance of single View Multiple Texture Feature Fusion

Table 1: Performance metrics computed for DDSM

Feature Extraction Technique	ACC	ERR	TPR/ SEN / REC	TNR/ SPC	FPR (1-SPC)	FNR (1-TPR)	PPV	NPV	FDR (1-PPV)	FOR (1-NPV)
Fractal	85.3	14.7	83.7	89.5	10.5	16.3	95.3	68	4.7	32
GLCM	88.2	11.2	90.7	84	16	9.3	90.7	84	9.3	16
Gabor	88.2	11.8	88.9	87	13	11.1	93	80	7.0	20
GLRLM	89.7	10.3	90.9	87.5	12.5	9.1	93	84	7.0	16
GLDM	89.7	10.3	90.9	87.5	12.5	9.1	93	84	7.0	16
Steerable Pyramid	89.7	10.3	90.9	87.5	12.5	9.1	93	84	7.0	16
Combined Features	92.6	7.4	93.2	91.7	8.3	6.8	95.3	88	4.7	12

Performance of LBP with Two view Feature Fusion

	ACC(%)	SEN(%)	SPC(%)	PRE(%)	F1	MCC	BCR(%)
PCA	96.1	98.1	94.1	94.3	95.09	0.929	97.09
CCA	97.5	100	95	95.3	96.23	0.952	98.74

Performance of LBP with Two US Mode Feature Fusion

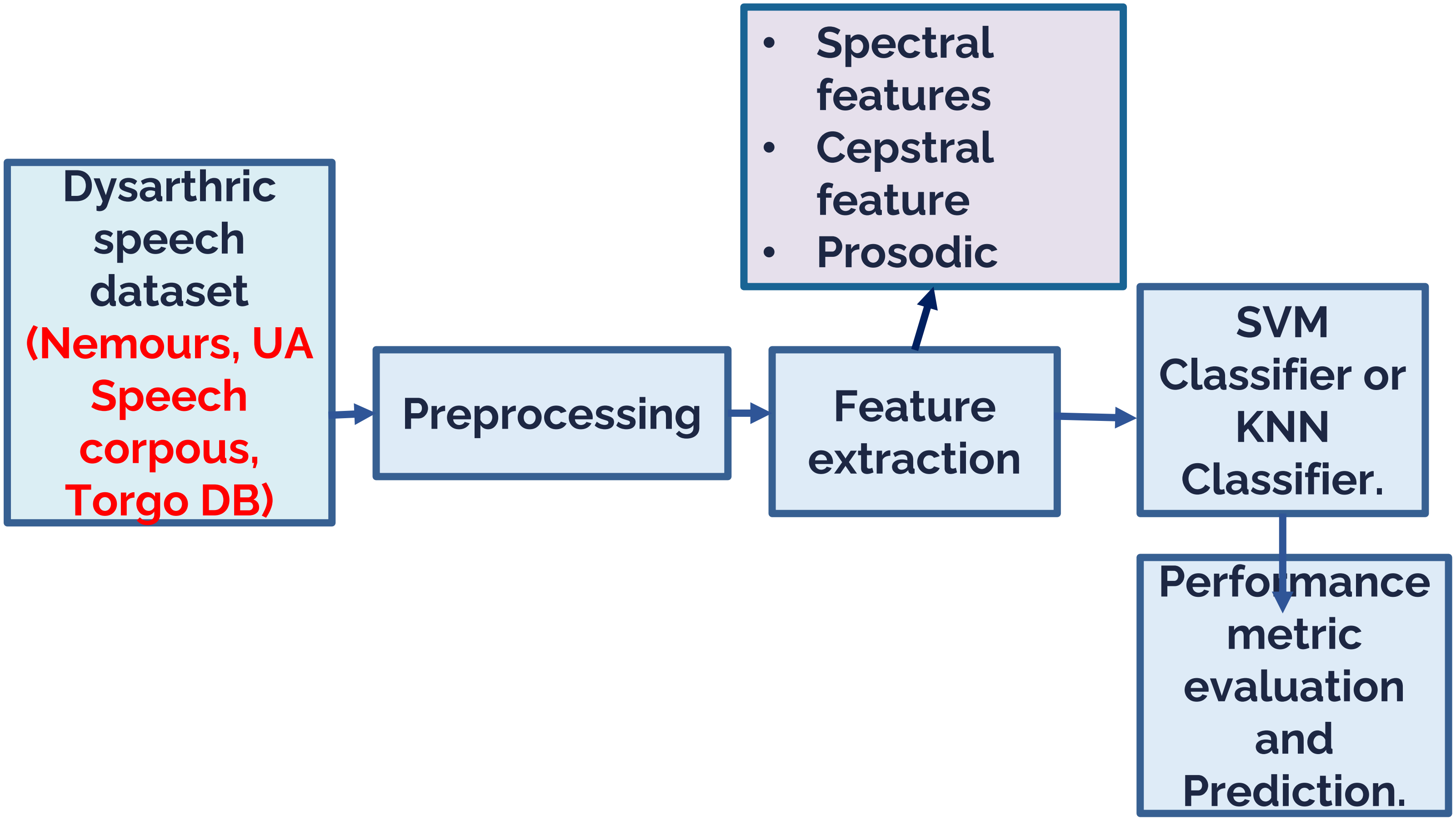
	ACC(%)	SEN(%)	SPC(%)	PRE(%)	F1	MCC	BCR(%)
PCA	97	100	94.9	93.1	96.43	0.94	97.42
CCA	97.7	94.4	100	100	97.12	0.954	97.12

Dysarthric Speech Severity Assessment

Dysarthric Speech Severity Assessment

- **Dysarthria is a speaking impairment due to the weak muscles of the patient due to brain injury. Dysarthria is loss of the ability to articulate words normally.**
- **About 8% to 60% of people with stroke have dysarthria.**
- **From the study of Tuzla university data from 936 acutes stroke patients speech problems were confirmed in 771 patients in which 57.69% (540 patients) were found to be Dysarthric.**
- **From the above data there is a necessity to help the Dysarthric people to feel comfortable with their speech and gradually develop confidence to speak more.**

Dysarthric Speech Severity Assessment



Dysarthric Speech Severity Assessment

Databases:

- **The TORGO dataset helps to build improved automatic speech classification models for the persons with dysarthria.**
- **A total of 600 dysarthric audio files are used in this study. The severity levels of low and medium (L and M) are chosen for the classification. 300 audio samples are taken from each severity level.**

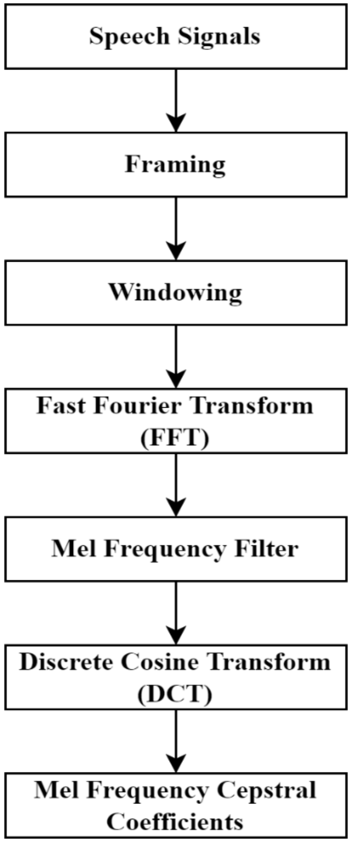
Dysarthric Speech Severity Assessment

Feature Extraction:

- To attain an improved classification accuracy, good audio features are required as, they can record the sequential and spectral aspects of audio.
- MFCC, Melspectrogram, ZCR, Spectral centroid, spectral rolloff are the feature extraction techniques that are experimented in this work..

Mel frequency Cepstral Coefficients (MFCC):

- MFCC offers the ability to capture important audio signal properties. Mel-frequency audio analysis relies on human perception tests.
- This has been proven that the auditory system of human is very sensitive and have a larger definition than to lesser frequency compared to a higher frequency.
- As a result, for feature extraction, an intuitive level of pitches equivalent in space, known as Mel-scale, is used.
- As human ears function in decibels, the logarithmic scale is used. Then the MFCC feature of the signal is obtained.



Melspectrogram:

- The Mel spectrogram is a type of spectrogram that converts frequencies to the Mel scale. Mel frequency has a non-linear connection with real frequency, which correlates to natural ear properties.
- Initially, the audio signals are framed and the windowing operation is done, then DFT is applied to the obtained frames. The computed frames are passed into Mel filter bank. Lastly, the log operation is computed to attain the Mel spectrogram of the audio.

Zero crossing rate:

- The frequency of a signal at which the transitions occur from positive to negative or vice versa is termed as the ZCR .
- For speech/non-speech categorization and detecting of the endpoint, the zero-crossing rate is a key parameter.

Spectral Centroid:

- The spectral centroid is a metric used to define a spectrum in signal processing. It specifies where the spectrum's center of mass is positioned.
- Initially, the signal is windowed along with FFT. The transformed frames are passed through filter banks and the spectral centroid extraction technique is computed, then the spectral centroid frequency is obtained.
- The signal from the filter banks is passed through spectral centroid magnitude extraction by taking log and DCT, the spectral centroid magnitude is obtained.

Spectral rolloff:

- Spectral rolloff is an evaluation of the signal's structure. It denotes the point at which high frequencies drop to zero.

Severity Classification:

- SVM and KNN are the ML algorithms that are used for severity classification of dysarthric speeches. These classification techniques will categorize the severity of the Dysarthric speaker based on the extracted features into required levels like low and medium generally.

K-NN classifier:

- The goal of the KNN classification is to locate the k data points in a data collection that are the closest to a particular query data point.
- The data points closest in distance with the unknown sample are referred to as nearest neighbors.
- The distance between an unknown sample and remaining data points in the collection must be computed, and this makes K-NN a computationally demanding classifier.

Results Obtained:

- Thus, the various features such as MFCC, ZCR, Spectral centroid, and Mel spectrogram are extracted and are fed to SVM and KNN classifier models to classify the Dysarthric voices with their respective severity level.

Support Vector Machine (SVM)			
Parameters	Features		
	MFCC	Mel spectrogram	ZCR + spectral centroid +spectral rolloff
Accuracy	0.93	**0.95**	0.75
Precision	**0.96**	0.88	0.587
Sensitivity	**0.93**	0.90	0.86
Specificity	**0.96**	0.87	0.66
F1-Score	**0.94**	0.89	0.69

Results Obtained:

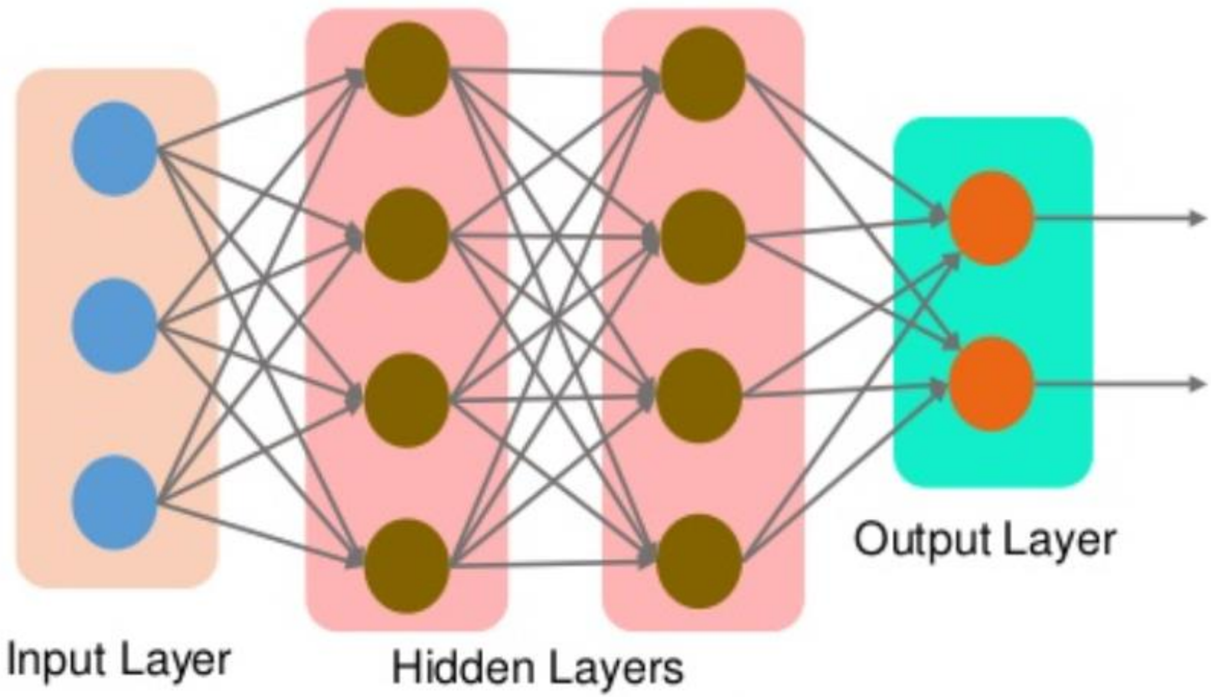
- From the results obtained, it is evident that the Mel spectrogram feature extraction technique has the highest accuracy with SVM classifier.
- From this Table , it is evident that the MFCC feature extraction technique has the highest accuracy in predicting the severity of the Dysarthric speech.

K-Nearest Neighbor (KNN)			
Parameters	Features		
	MFCC	Mel spectrogram	ZCR + spectral centroid +spectral rolloff
Accuracy	**0.975**	0.933	0.875
Precision	**0.96**	0.904	0.77
Sensitivity	**1**	0.86	0.90
Specificity	**0.96**	0.88	0.78
F1-Score	**0.98**	0.88	0.83

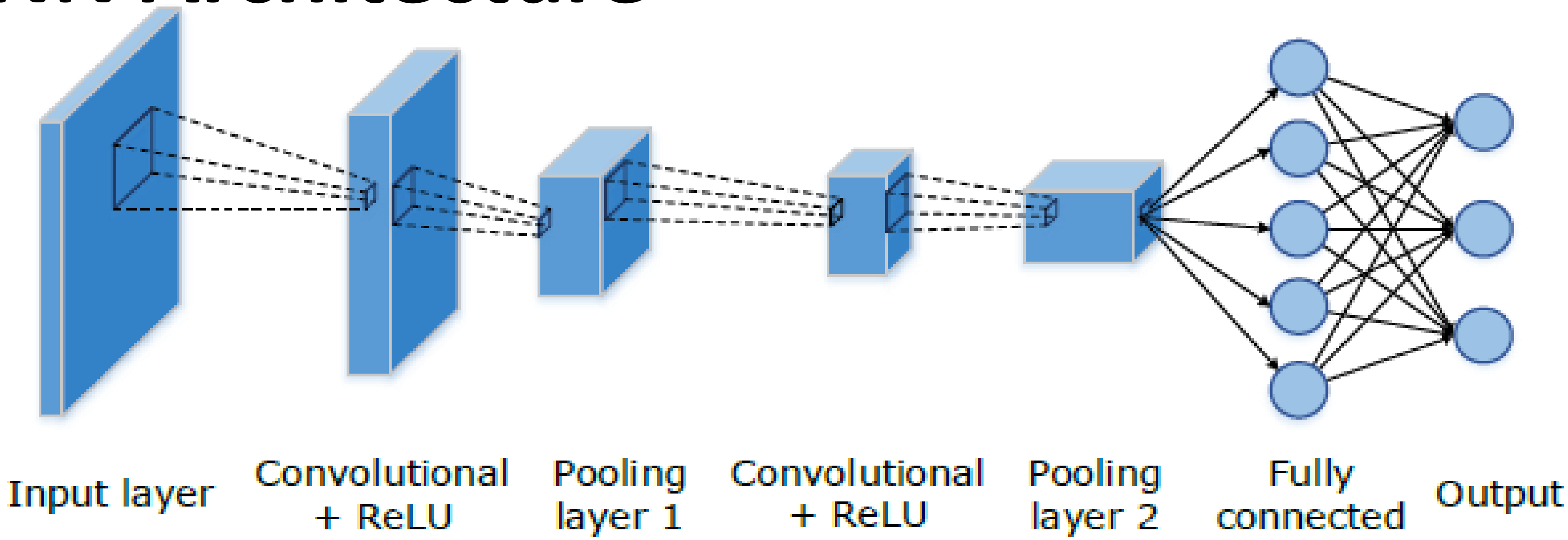
Deep Learning Based Systems

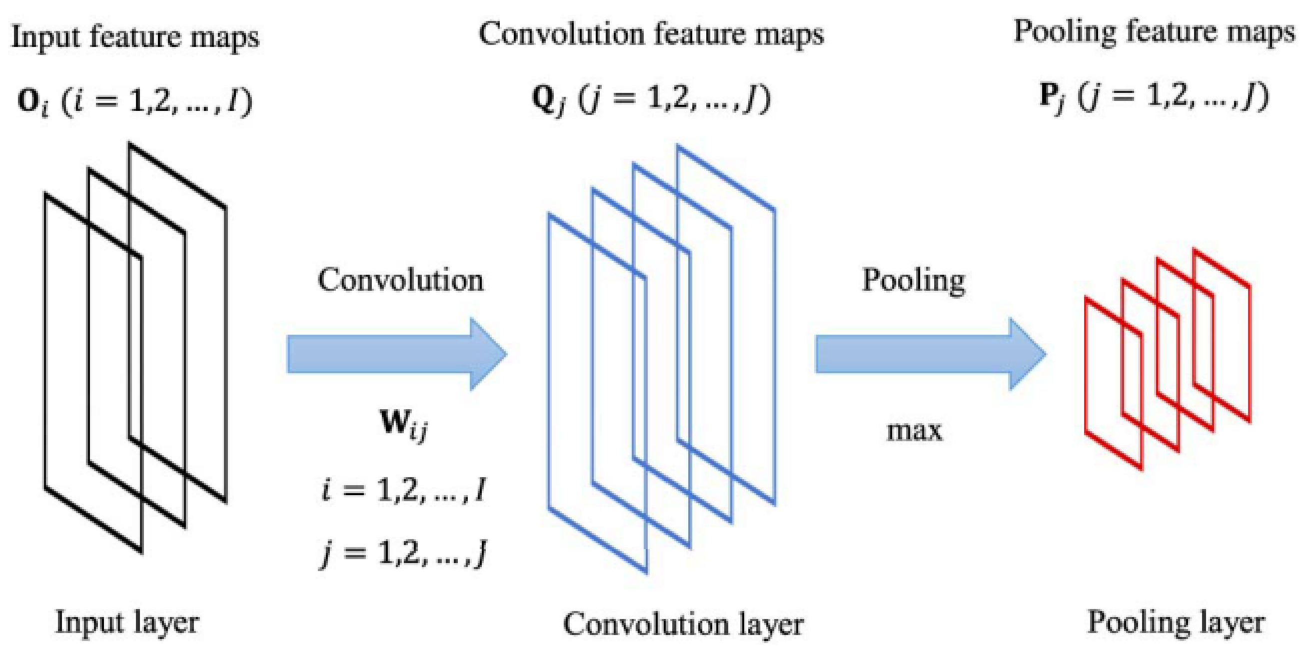
Deep Learning (DL)

- A subset of Machine Learning
- Hierarchical representations with deep architectures.
- HPC with Graphics Processing Units (GPUs).

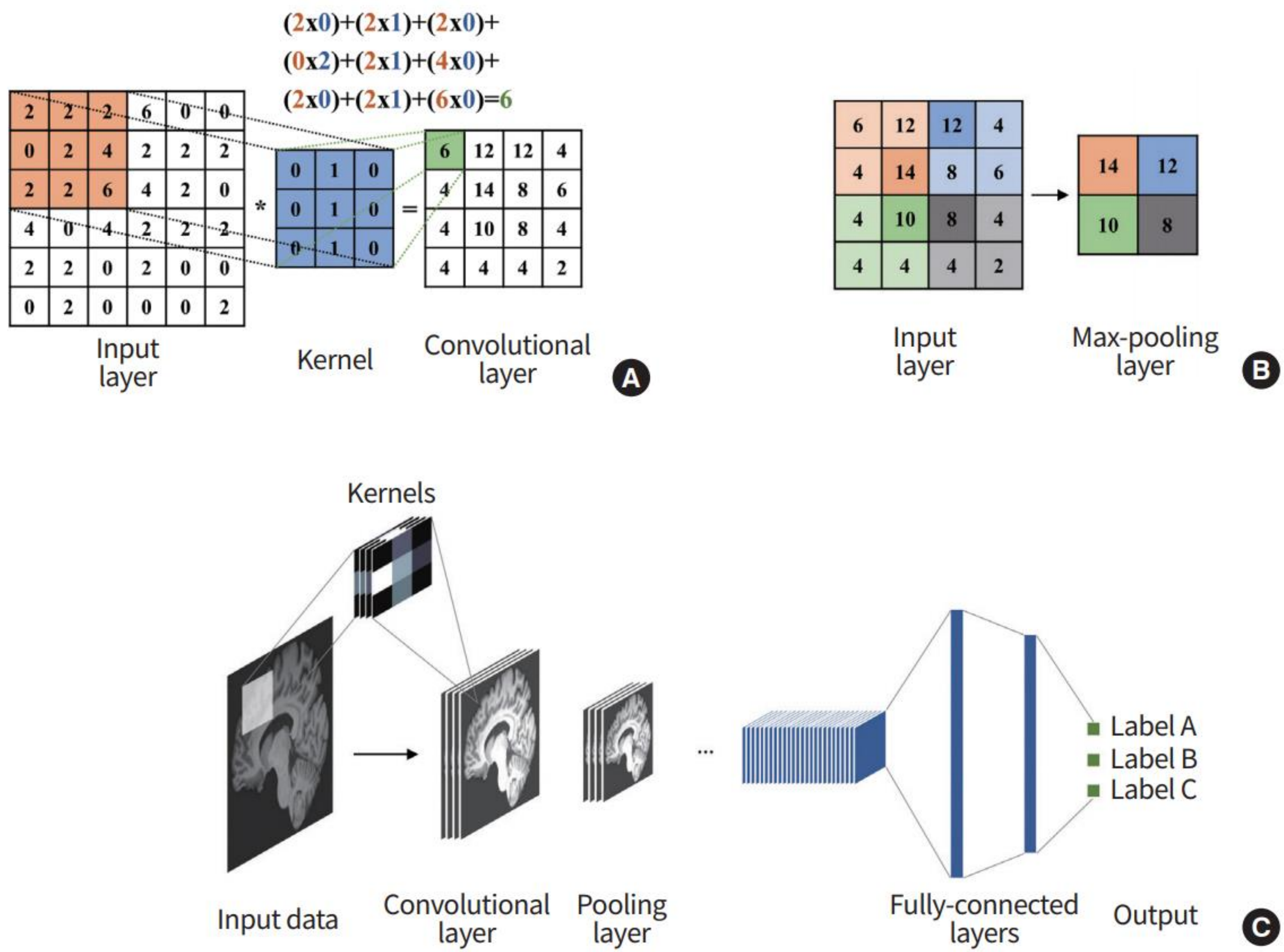


CNN Architecture





Simple Deep Learning Model



A convolutional layer

- Convolutional layer has a no. of filters that does convolutional operation
- **output size = [W1xH1xD1]** ⟶ **output size = [W2xH2xD2]**
  - ❖ W2 = (W1 – F + 2P)/S + 1
  - ❖ H2 = (H1 – F + 2P)/S + 1
  - ❖ D2= K (No. of filters)

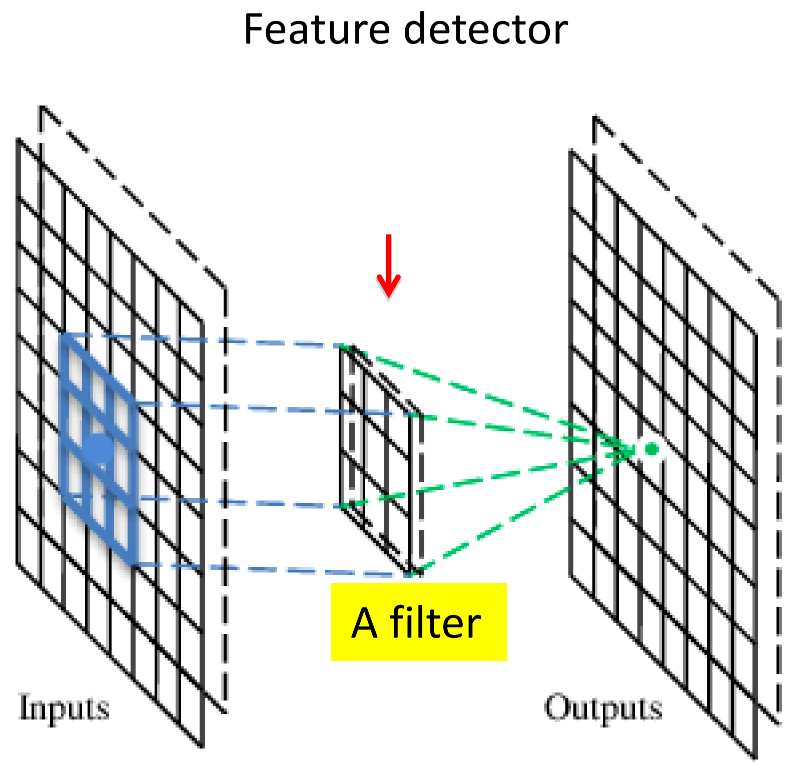
where:

•F: receptive field size

•S: stride

•P: amount of zero padding used on the border.

•K: depth



Convolution

These are the network parameters to be learned.

1	0	0	0	0	1
0	1	0	0	1	0
0	0	1	1	0	0
1	0	0	0	1	0
0	1	0	0	1	0
0	0	1	0	1	0

6 x 6 image

Filter 1

1	-1	-1
-1	1	-1
-1	-1	1

Filter 2

-1	1	-1
-1	1	-1
-1	1	-1

⋮

Each filter detects a small pattern (3 x 3)

Convolution

Strides

- **Stride is the number of pixels shifts over the input matrix.**
- **When the stride is 1 then we move the filters to 1 pixel at a time.**
- **When the stride is 2 then we move the filters to 2 pixels at a time and so on.**

Convolution

1	-1	-1
-1	1	-1
-1	-1	1

Filter 1

stride=1

1	0	0	0	0	1
0	1	0	0	1	0
0	0	1	1	0	0
1	0	0	0	1	0
0	1	0	0	1	0
0	0	1	0	1	0

Dot product → 3 -1

6 x 6 image

Convolution

1	-1	-1
-1	1	-1
-1	-1	1

Filter 1

If stride=2

1	0	0	0	0	1
0	1	0	0	1	0
0	0	1	1	0	0
1	0	0	0	1	0
0	1	0	0	1	0
0	0	1	0	1	0

6 x 6 image

3 -3

Convolution

Filter 1

1	-1	-1
-1	1	-1
-1	-1	1

stride=1

1	0	0	0	0	1
0	1	0	0	1	0
0	0	1	1	0	0
1	0	0	0	1	0
0	1	0	0	1	0
0	0	1	0	1	0

6 x 6 image

3	-1	-3	-1
-3	1	0	-3
-3	-3	0	1
3	-2	-2	-1

Convolution

-1	1	-1
-1	1	-1
-1	1	-1

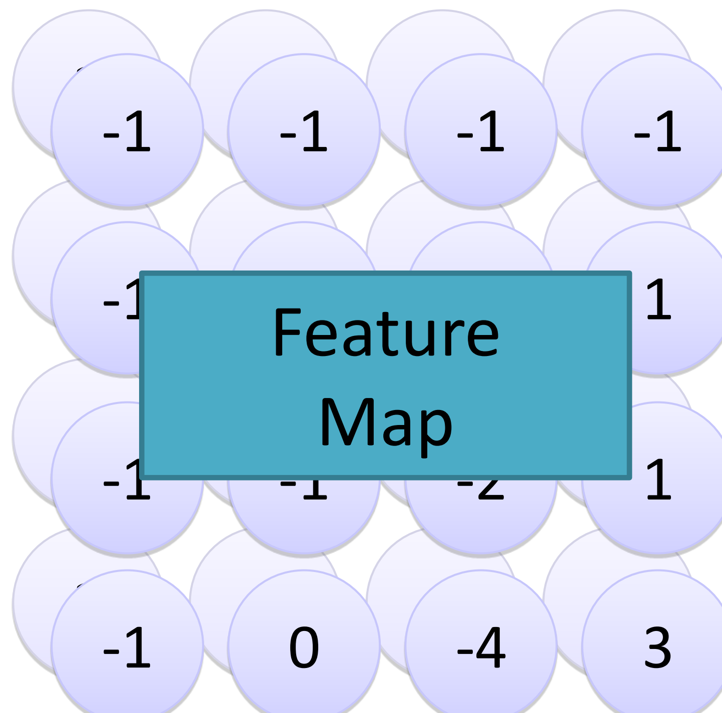
Filter 2

stride=1

1	0	0	0	0	1
0	1	0	0	1	0
0	0	1	1	0	0
1	0	0	0	1	0
0	1	0	0	1	0
0	0	1	0	1	0

6 x 6 image

Repeat this for each filter



Two 4 x 4 images
Forming 2 x 4 x 4 matrix

Convolution

Color image: RGB 3 channels

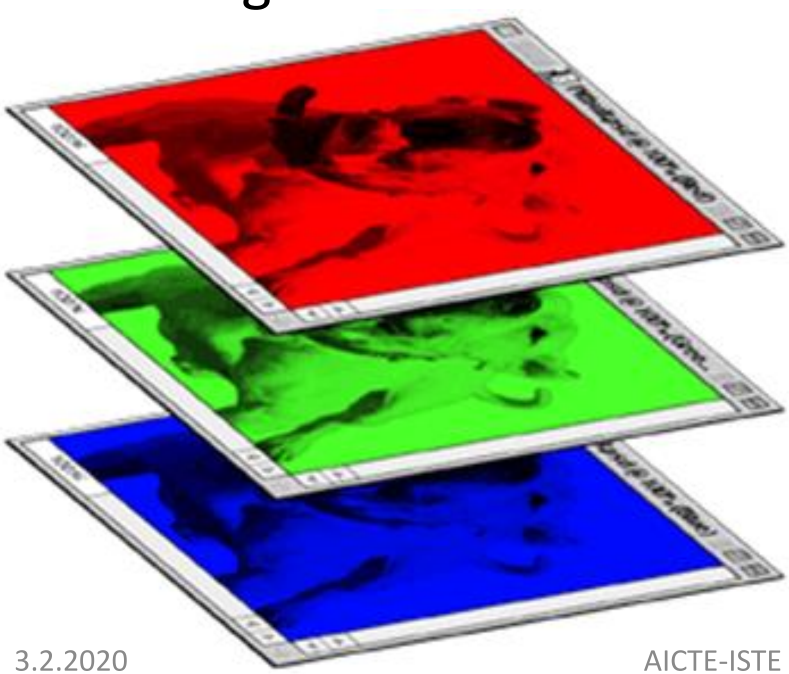
1	-1	-1
-1	1	-1
-1	-1	1

Filter 1

-1	1	-1
-1	1	-1
-1	1	-1

Filter 2

Color image



1	0	0	0	0	1
0	1	0	0	1	0
0	0	1	1	0	0
1	0	0	0	1	0
0	1	0	0	1	0
0	0	1	0	1	0

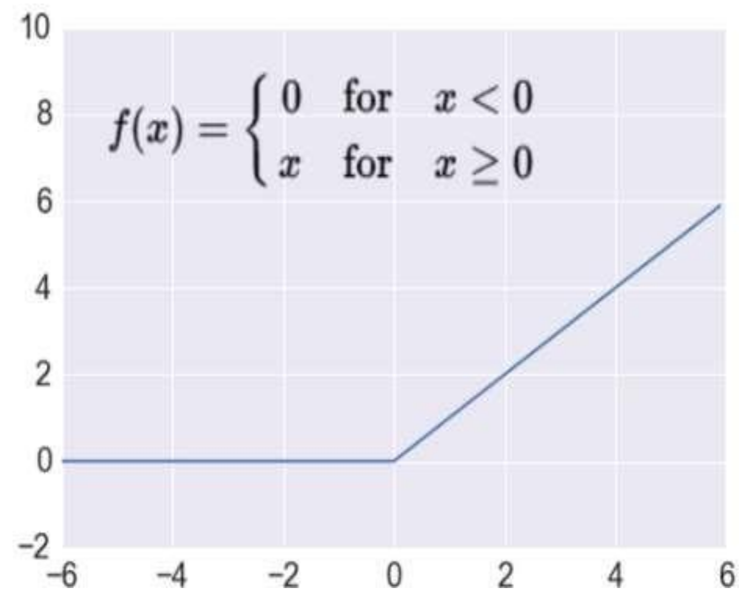
Convolution

Padding

- Sometimes filter does not fit perfectly to the input image.
- Pad the picture with zeros (zero-padding) so that it fits
- Drop the part of the image where the filter did not fit. This is called valid padding which keeps only valid part of the image.
- Padding preserves the edges

Rectified Linear Unit(ReLU)

- **ReLU stands for Rectified Linear Unit for a non-linear operation.**
- **The output is *ƒ(x) = max(0,x)*.**
- **Why ReLU is important :**
  - ➢ **ReLU introduces non-linearity in CNN**
  - ➢ **Real world data would want CNN to learn would be non-negative linear values**



RECTILINEAR ACTIVATION

1	14	-9	4
-2	-20	10	6
-3	3	11	1
2	54	-2	80

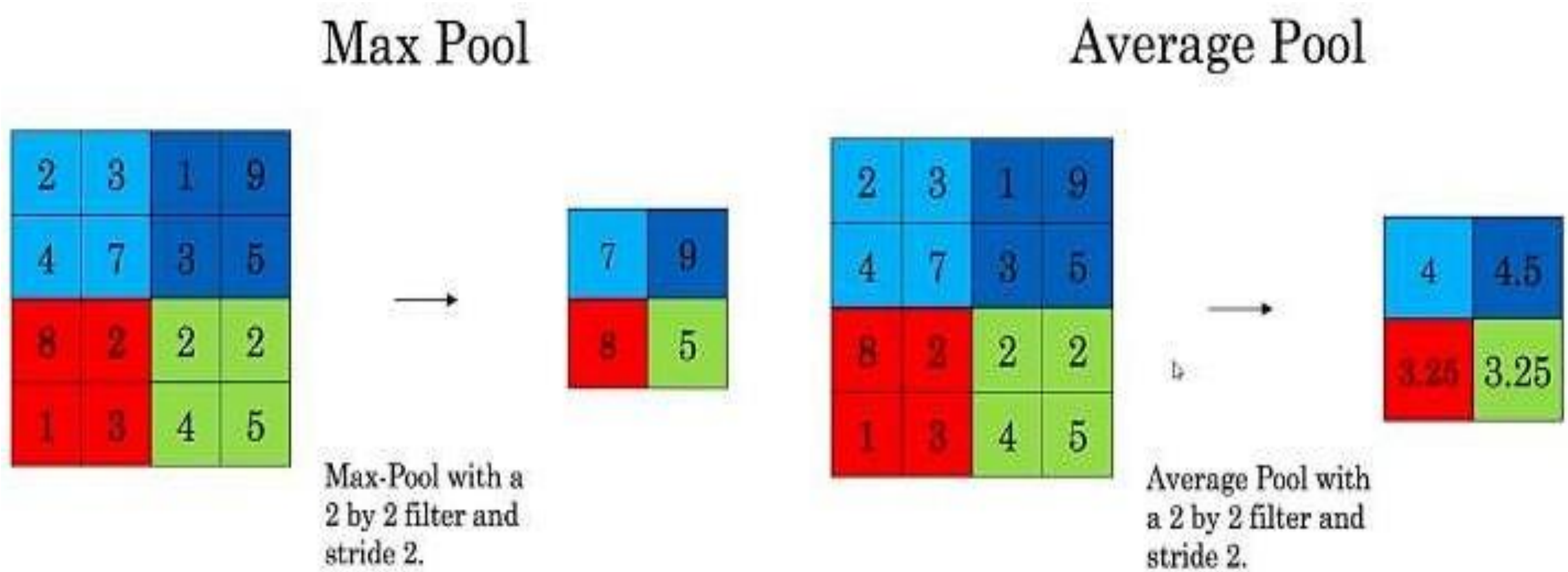
ReLU

1	14	0	4
0	0	10	6
0	3	11	1
2	54	0	80

Pooling Layer

- Reduce the number of parameters when the images are too large.
- Spatial pooling also called subsampling or downsampling
- Reduces the dimensionality of each map but retains important information
- It also Avoids over fitting problem
- Spatial pooling can be of different types:
  - Max Pooling- Takes the largest element from the rectified feature map.
  - Average Pooling- Taking the average of element
  - Sum Pooling- Sum of all elements in the feature map

POOLING


Max Pool
2 3 1 9
4 7 3 5
8 2 2 2
1 3 4 5
7 9
8 5
Max-Pool with a 2 by 2 filter and stride 2.
Average Pool
2 3 1 9
4 7 3 5
8 2 2 2
1 3 4 5
4 4.5
3.25 3.25
Average Pool with a 2 by 2 filter and stride 2.

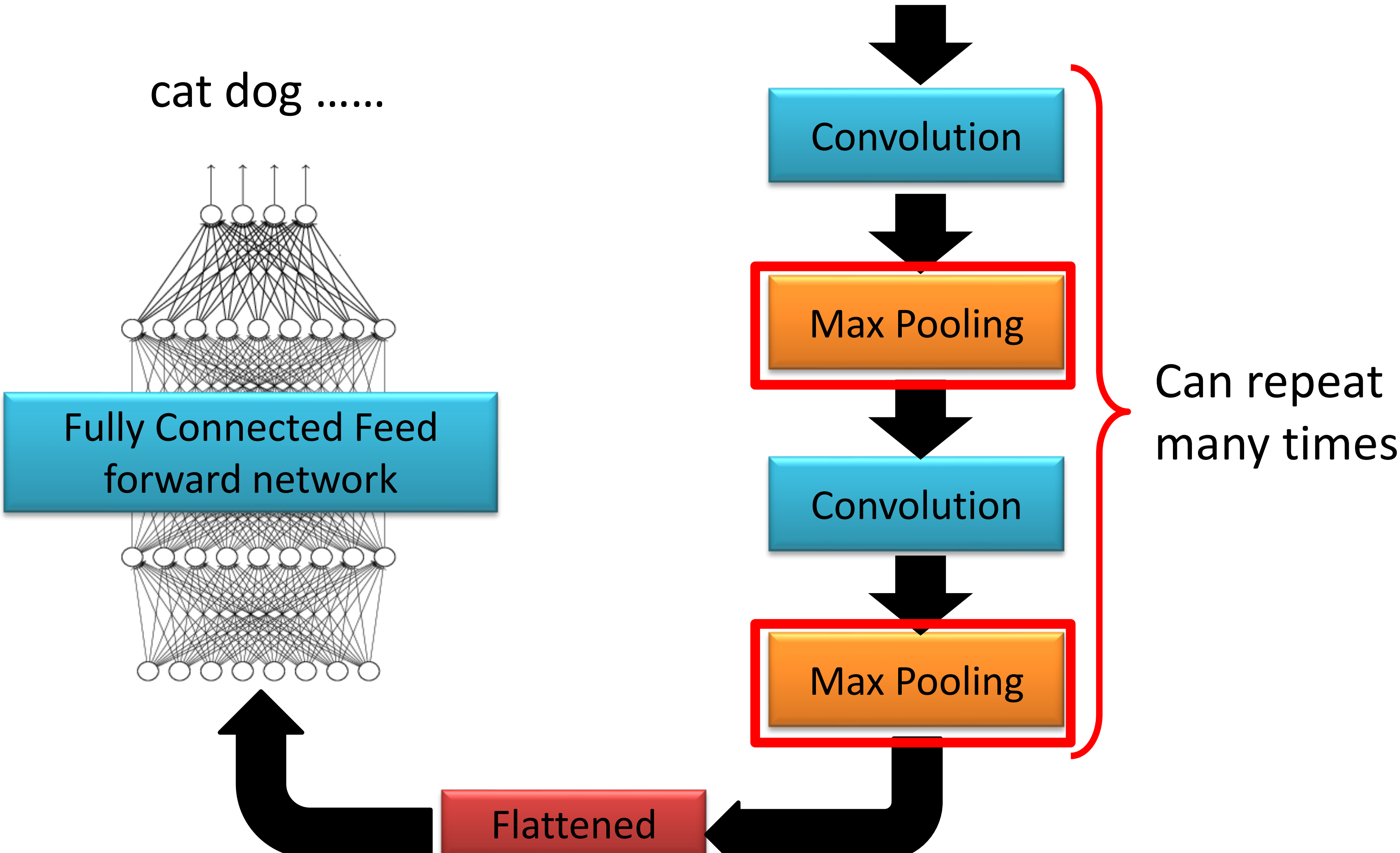
Fully Connected Layer

- **Flattened our matrix into vector**
- **Feed it into a fully connected layer like a neural network.**
- **The feature map matrix will be converted as vector (x1, x2, x3, …).**
- **With the fully connected layers, we combined these features together to create a model.**
- **Finally, we have an activation function such as softmax or sigmoid to classify the outputs as cat, dog, car, truck etc.,**

Summary of CNN

- Provide input image into convolution layer
- Choose parameters, apply filters with strides, padding if requires.
- Perform convolution on the image and apply ReLU activation to the matrix.
- Perform pooling to reduce dimensionality size
- Add as many convolutional layers until satisfied
- Flatten the output and feed into a fully connected layer (FC Layer)
- Output the class using an activation function and classifies images.

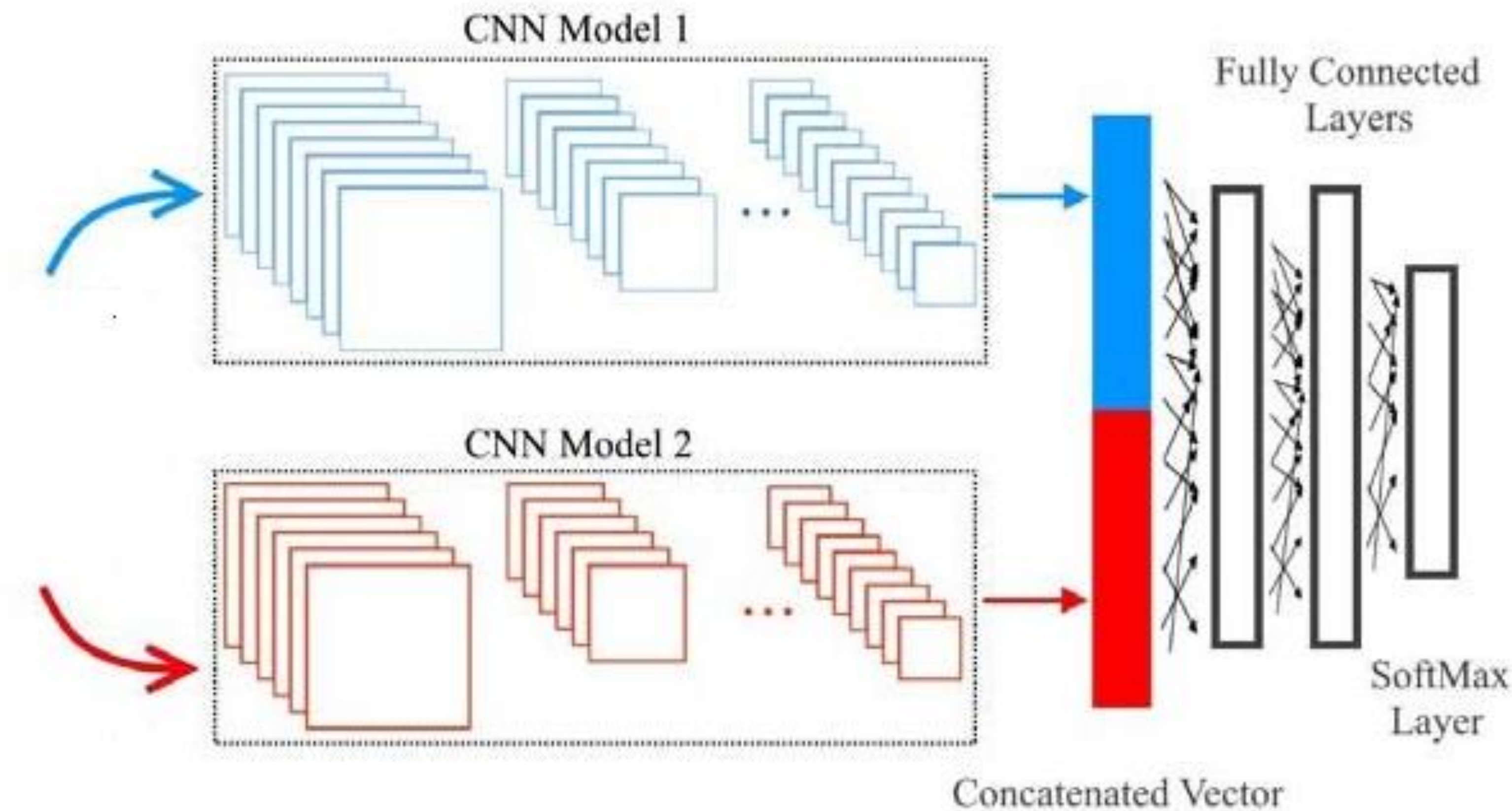
The whole



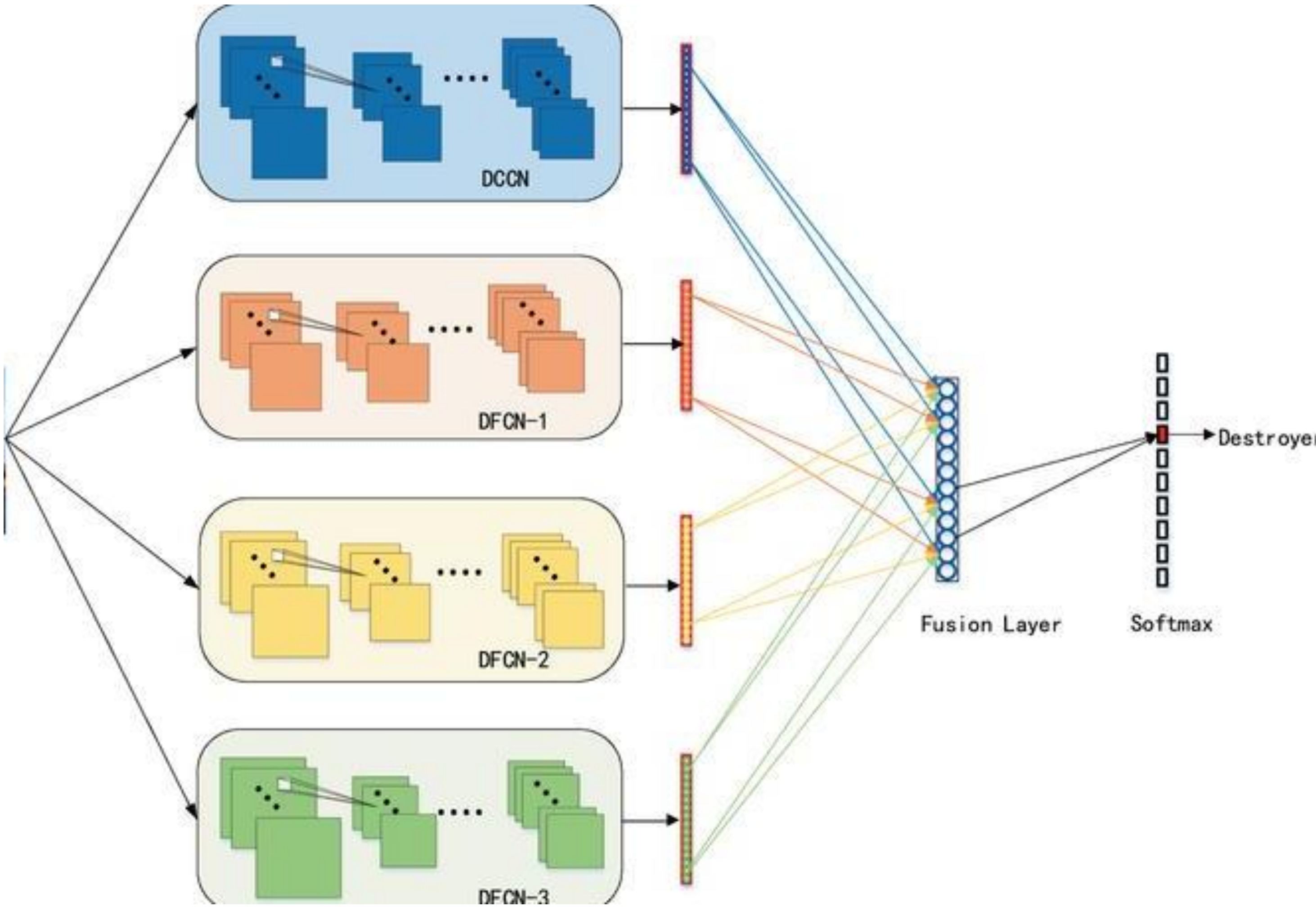
cat dog ......
Convolution
Max Pooling
Convolution
Max Pooling
Can repeat many times
Fully Connected Feed forward network
Flattened

Feature Fusion through Deep Learning Models

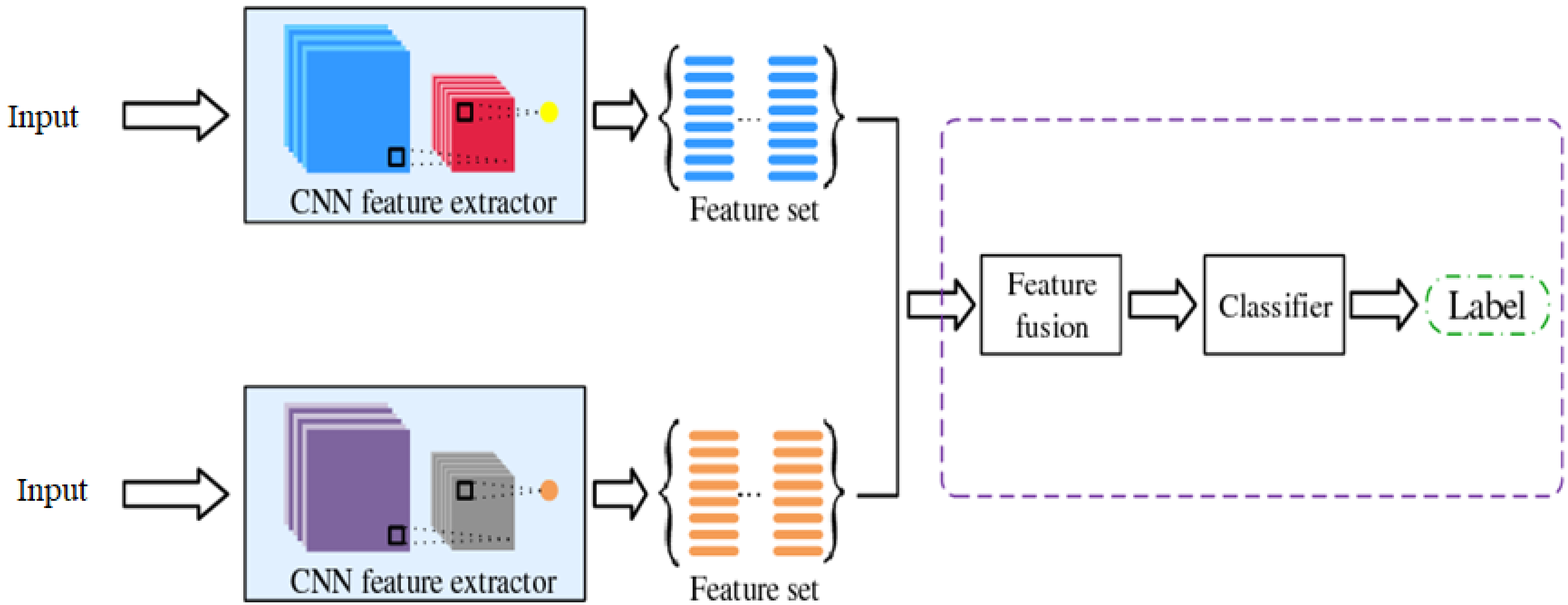
Illustration of Two CNN Model Fusion



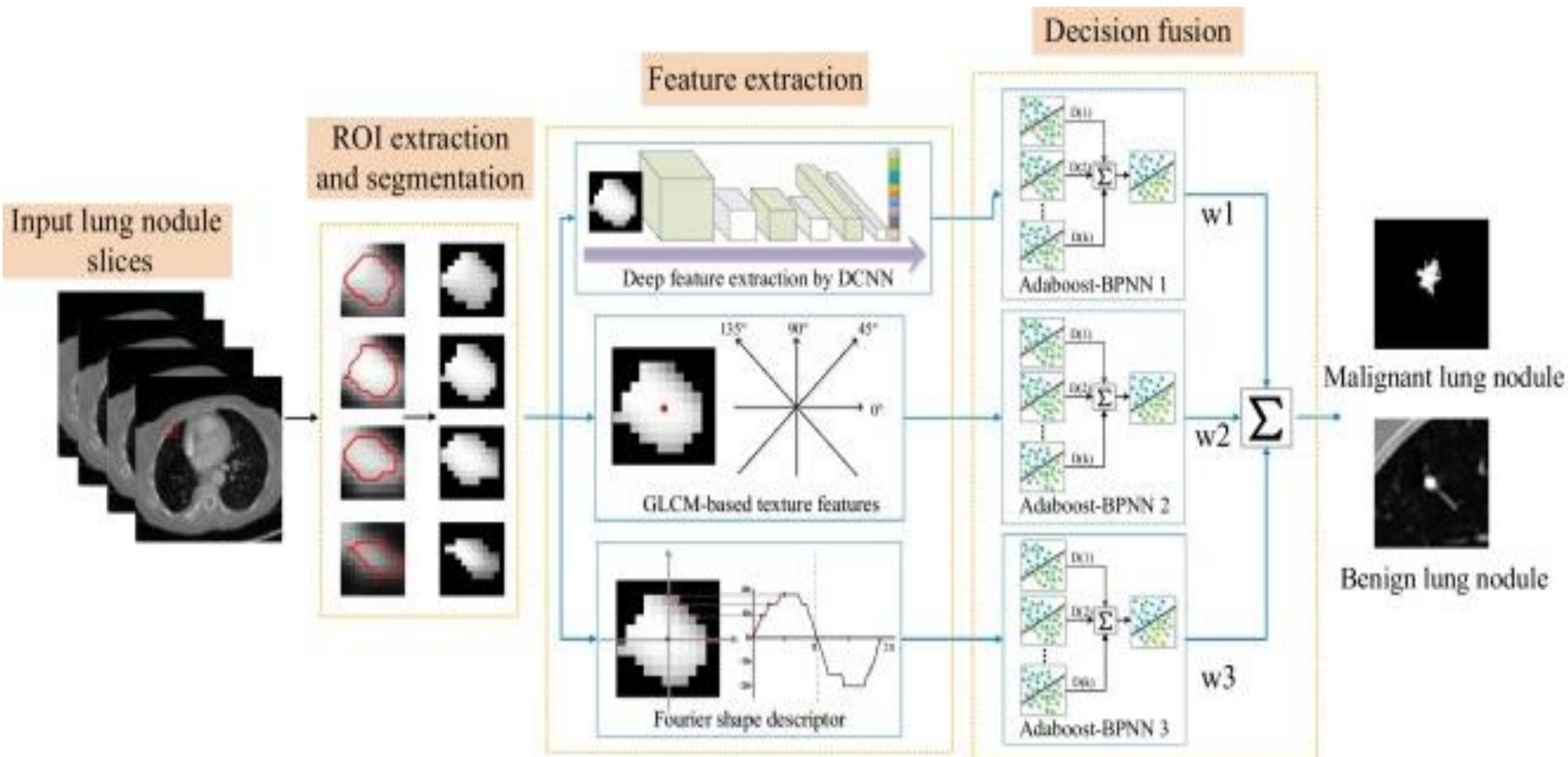
Multi Feature Fusion of CNN



Dense Connectivity Based Two-Stream Deep Feature Fusion

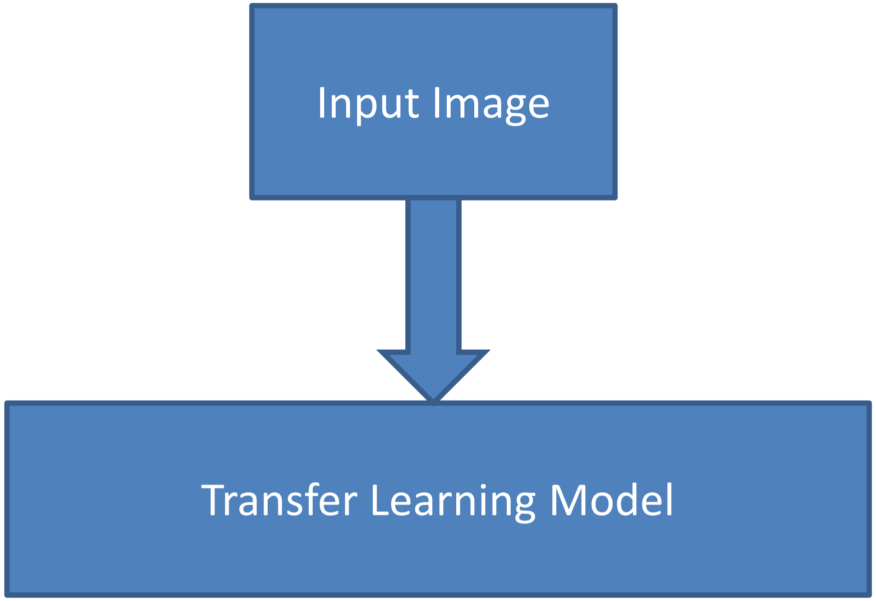


Fusing Texture, Shape and Deep Model-learned Information At Decision Level



Breast Cancer Detection through Deep Learning Models

Transfer Learning Methods



Classification Results With And Without Data Augmentation For Different Models For The DDSM

Classification results with and without data augmentation										
Model	Accuracy %		AUC %		Sensitivity %		Precision %		F1-score %	
	Without augmentation	With augmentation	Without augmentation	With augmentation	Without Augmentation	With Augmentation	Without augmentation	With augmentation	Without Augmentation	With Augmentation
DDSM Database										
InceptionV3	88.87	93.85	87.99	92.99	88.74	93.54	88.59	93.19	87.99	93.23
DenseNet121	85.97	91.57	84.99	90.89	85.89	91.49	85.84	91.52	85.85	91.35
ResNet50	84.54	89.58	83.99	88.99	83.94	89.84	84.12	90.23	84.21	90.32
VGG16	82.81	85.98	81.99	84.88	82.74	85.94	82.43	84.99	82.34	85.32
MobileNetV2	80.97	82.77	80.89	82.65	81.74	82.98	80.88	82.76	80.99	82.65

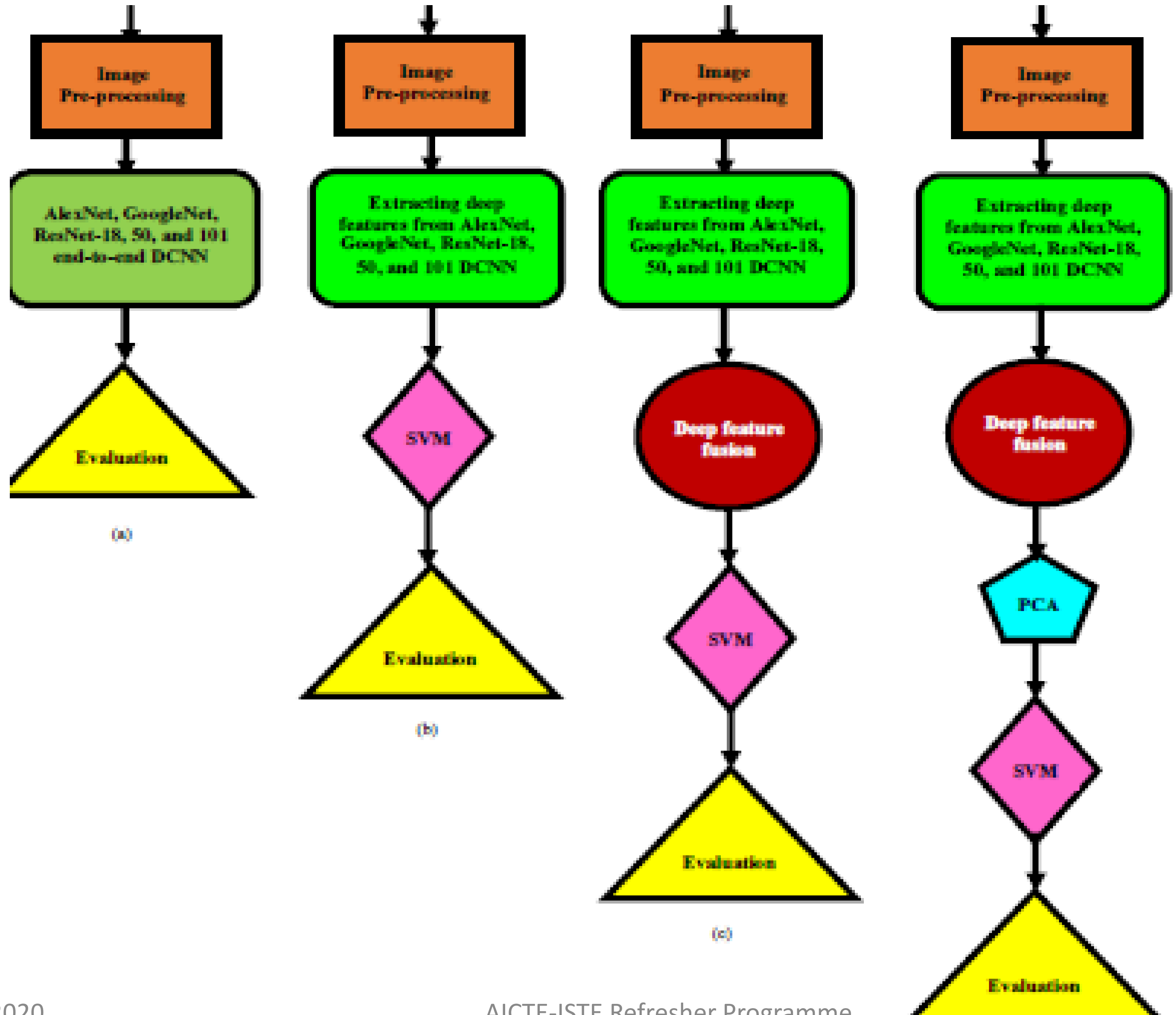


Image
Pre-processing
AlexNet, GoogleNet, ResNet-18, 50, and 101 end-to-end DCNN
Evaluation
(a)
Image
Pre-processing
Extracting deep features from AlexNet, GoogleNet, ResNet-18, 50, and 101 DCNN
SVM
Evaluation
(b)
Image
Pre-processing
Extracting deep features from AlexNet, GoogleNet, ResNet-18, 50, and 101 DCNN
Deep feature fusion
SVM
Evaluation
(c)
Image
Pre-processing
Extracting deep features from AlexNet, GoogleNet, ResNet-18, 50, and 101 DCNN
Deep feature fusion
PCA
SVM
Evaluation

The Accuracy And The Trained Time Of The Dcnn Architectures For The CBIS-DDSM Dataset.

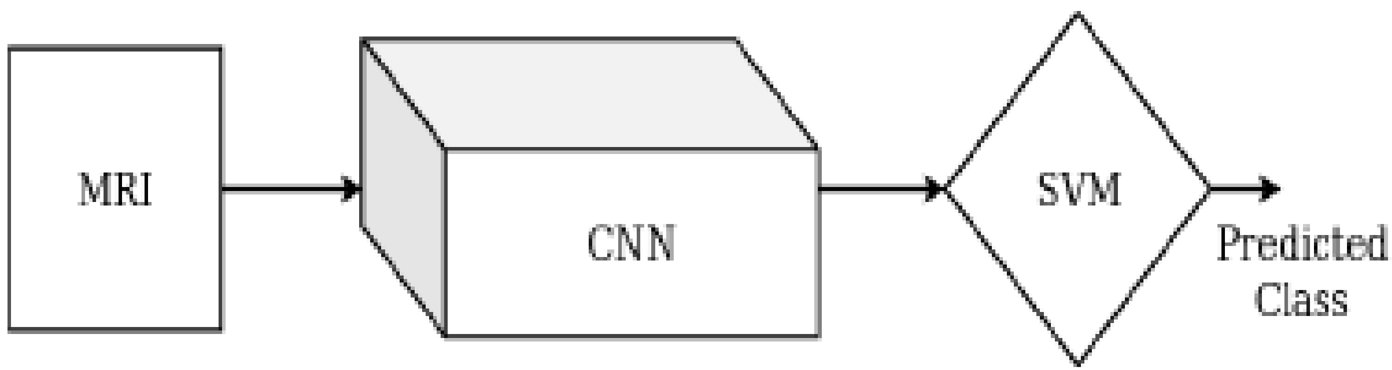
DCNN Architecture	DCNN Accuracy
AlexNet	74.68%
GoogleNet	76.01%
ResNet-18	72.23%
ResNet-50	71.09%
ResNet-101	71.47%

Calculated Scores Of The Different Svm Kernel Functions
for **AlexNet, GoogleNet, ResNet-18, 50, and 101 DCNN Features** for CBIS-DDSM Dataset.

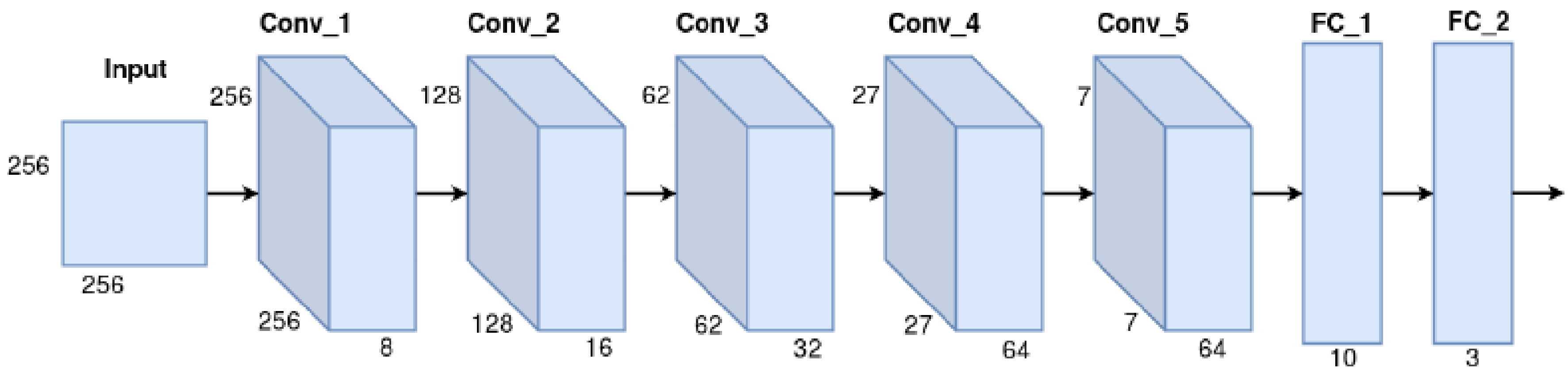
AlexNet, GoogleNet, ResNet-18, 50, and 101 DCNN Features				
	Accuracy (std)	AUC (std)	Sensitivity (std)	Specificity (std)
Linear	97.6% (0.001)	1.00 (0)	0.971 (0.001)	0.98 (0.001)
Quadratic	**97.9%** (0.001)	**1.00** (0)	**0.98** (0.003)	**0.98** (0.001)
Cubic	**97.9%** (0.001)	**1.00** (0)	**0.98** (0.001)	**0.98** (0.001)
Medium Gaussian	96.3% (0.001)	0.99 (0)	0.951 (0)	0.97 (0)
Coarse Gaussian	94.6% (0)	0.99 (0)	0.95 (0)	0.95 (0)

Categorization of Brain Tumor through Deep Learning Models

Model



CNN Model


Input
256
256
Conv_1
256
256
8
Conv_2
128
128
16
Conv_3
62
62
32
Conv_4
27
27
64
Conv_5
7
7
64
FC_1
10
FC_2
3

Performance Measures

Category	Precision	Recall	Specificity
Meningioma	94.4%	88.5%	98.4%
Glioma	95.5%	97.6%	97.9%
Pituitary Tumor	97.3%	98.6%	99.3%


WHY?
WHAT?
WHEN?
WHO?
HOW?
WHERE?
HOW?
WHAT? HOW? WHY?
WHAT?
WHO?
WHERE?
HOW? WHO?
WHAT? HOW? WHY?
HOW?


Thank
You!