1

Part 3
Lecture 1a: Image Recognition in Medical Imaging

Who I am…

Pascal Tyrrell, PhD *Associate Professor*

Department of Medical Imaging, Faculty of Medicine

Institute of Medical Science, Faculty of Medicine

Department of Statistical Sciences, Faculty of Arts and Science

Radiology Workflow

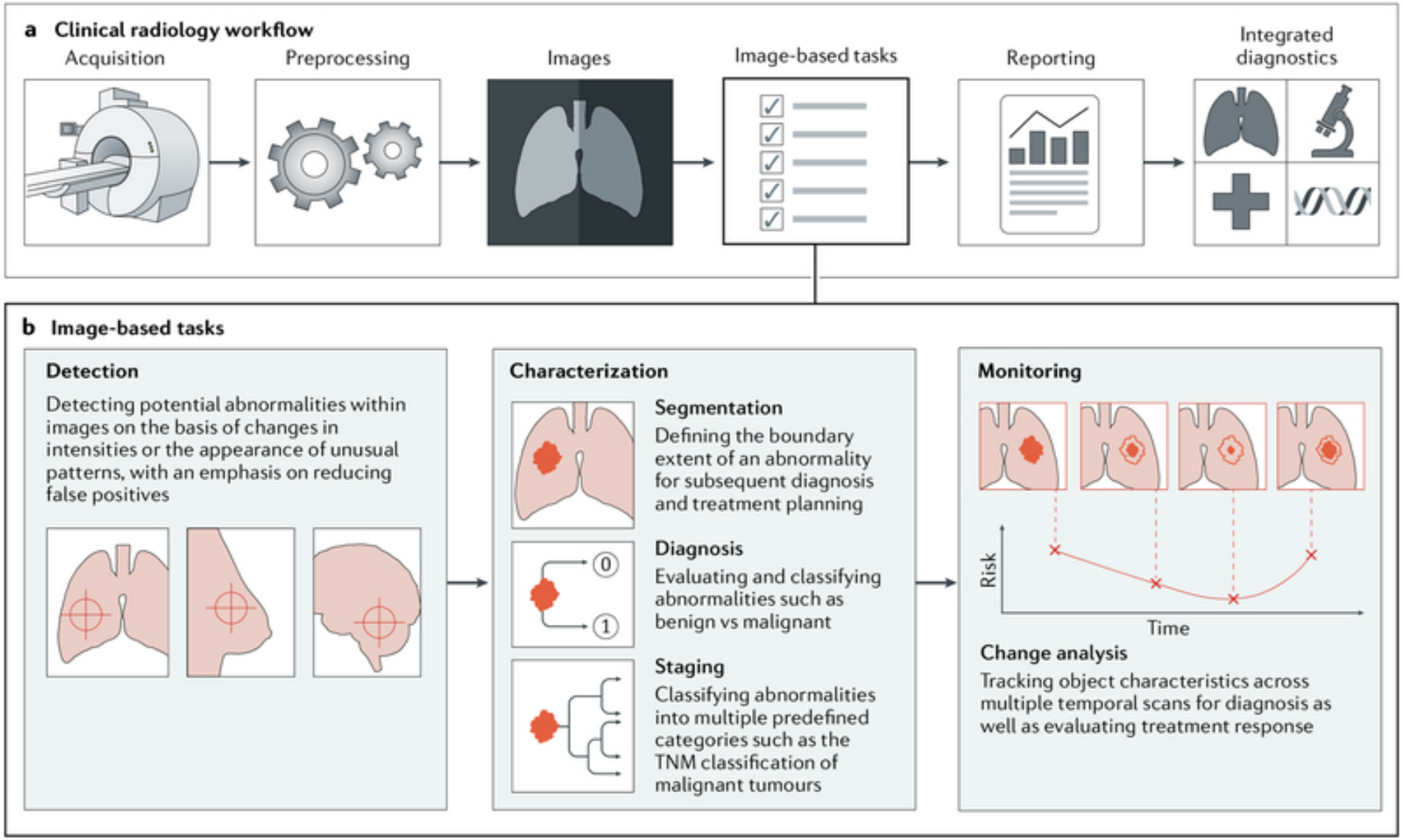


Image Based Tasks

- Detection
- Characterization
- Monitoring

Detection

Within the manual detection workflow, radiologists rely on manual perceptive skills to identify possible abnormalities, followed by cognitive skills to either confirm or reject the findings.

- Radiologists visually scan through stacks of images while periodically adjusting viewing planes and window width and level settings. This may become a subjective decision matrix.

What is CADe?

- Computer-aided **detection**
- Goal: **reduce false negatives**
- Pattern recognition software that identifies suspicious features on an image and brings them to the attention of the radiologist

What is CADx?

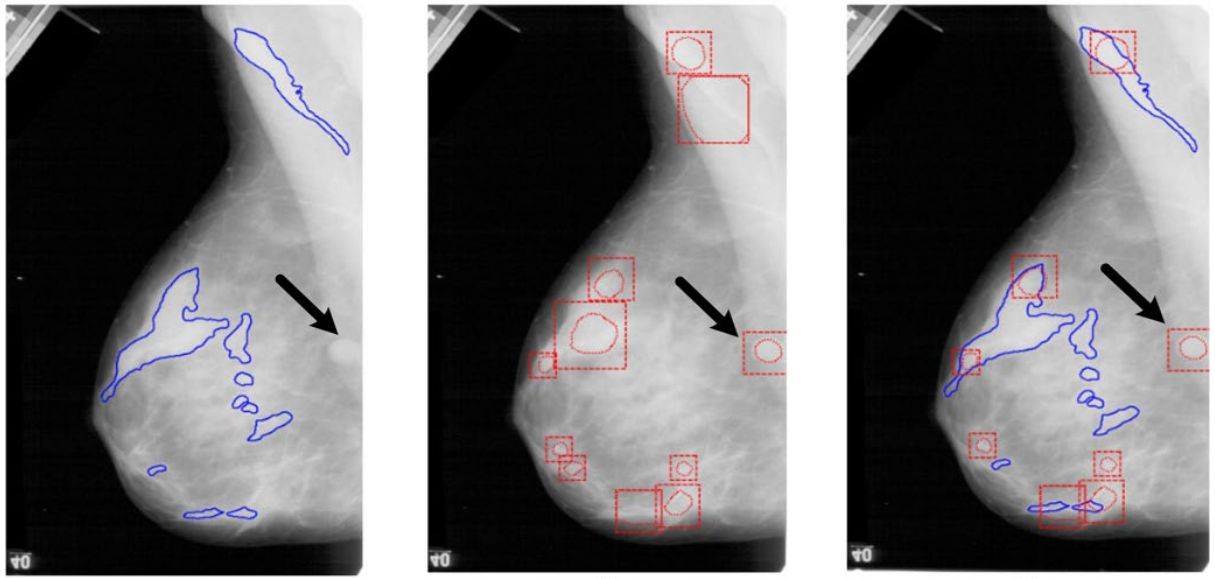
- Computer aided **diagnosis**
- Goal: analyze the likelihood that a feature in an image represents a specific disease process (ex. benign vs. malignant)
- The accuracy of traditional predefined feature-based CADx systems is contingent upon several factors, including the accuracy of previous object segmentations. It is often the case that errors are magnified as they propagate through the various image-based tasks within the clinical oncology workflow.

Machine Learning and CADe

- Traditional ML methods depend on explicit parameters based on expert knowledge
  - Machine learning models can build on this and identify potential imaging-based biomarkers
- Advances in deep learning AI means that we now have recognition techniques which do not require explicit feature definition
- Convolutional neural networks (CNNs) are the currently most prevalent deep learning architecture typologies in medical imaging
  - CNNs are generally well-suited for supervised learning tasks on labelled data
  - Other architectures such as deep autoencoders and generative adversarial networks are more well-suited for unsupervised learning tasks on unlabelled data

Using CADe for Detection

- As dependence on computers has increased, automated methods for the identification and processing of these predefined features
- Radiologist-defined criteria are distilled into a pattern-recognition solution where computer vision algorithms highlight objects within the image.



(a) (b) (c)

Using CADe for Detection

- Introduced as complementary tools that draw the radiologists' attention to certain image areas that need further evaluation.
- They do not detect all potential lesions, which would allow the radiologist only to focus on the areas identified by the CAD system.
  - It is necessary for the radiologist still to evaluate the whole image.
- The systems could detect additional lesions that might have escaped the radiologist's attention.

CADe and Image Recognition in Mammograms

In examining mammograms, some studies have reported that radiologists rarely altered their diagnostic decisions after viewing results from predefined, feature-based CADe systems and that their clinical integration had no statistical significance on the radiologists' performance.

Clinical Application using CADe

Recent efforts have explored deep learning-based CADe to detect pulmonary nodules in CT43 and prostate cancer in multiparametric imaging, specifically multiparametric MRI44.

In detecting lesions in mammograms, early results show that utilizing convolutional neural networks (CNNs; deep learning algorithms) in CADe outperforms traditional CADe systems at low sensitivity while performing comparably at high sensitivity and shows similar performance compared with human readers.

Room for Improvement...

- However, these algorithms are often task-specific and do not generalize across diseases and imaging modalities.
- These findings hint at the utility of deep learning in developing robust, high-performance CADe systems
- The accuracy of traditional predefined feature-based CADe systems remains questionable, with ongoing efforts to reduce false positives.

CADx Application:

Several systems are already in clinical use, as is the case with screening mammograms.

They usually serve as a second opinion in complementing a radiologist's assessment, and their perceived successes have led to the development of similar systems for other imaging modalities, including ultrasonography and MRI.

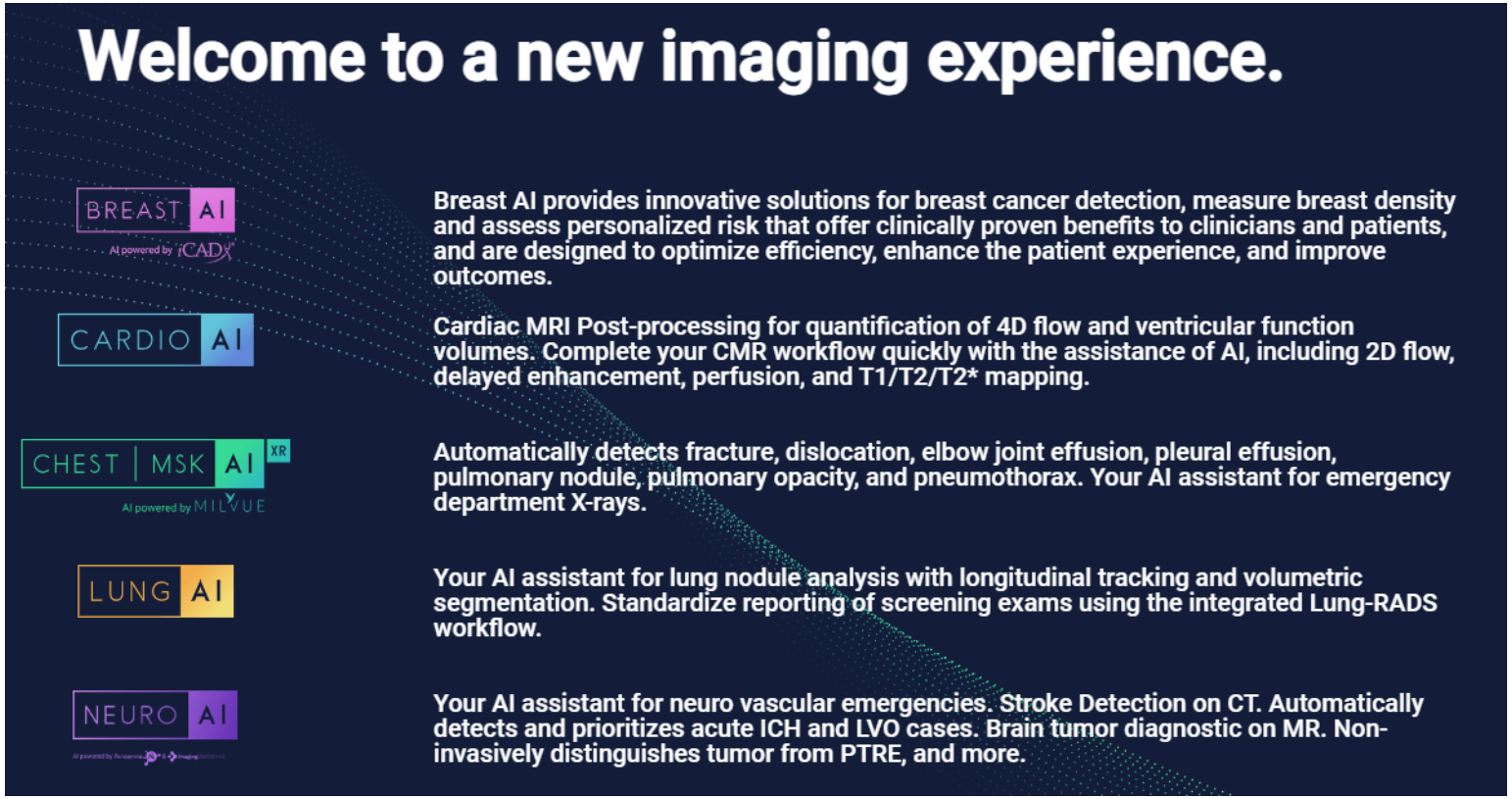
CADx Applications:

For both the breast lesion and lung nodule classification tasks, studies report a substantial performance gain of deep learning-based CADx methods — specifically those utilizing stacked denoising autoencoders — over their traditional state-of-the-art counterparts.

This is mainly owing to the automatic feature exploration mechanism and higher noise tolerance of deep learning.

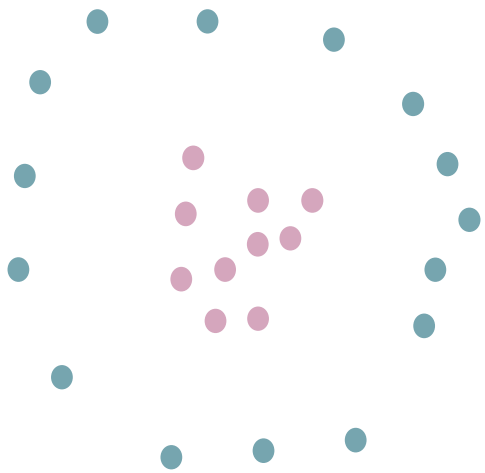
Introducing: Arterys (Tempus)

Automating the findings and results of diagnostic imaging



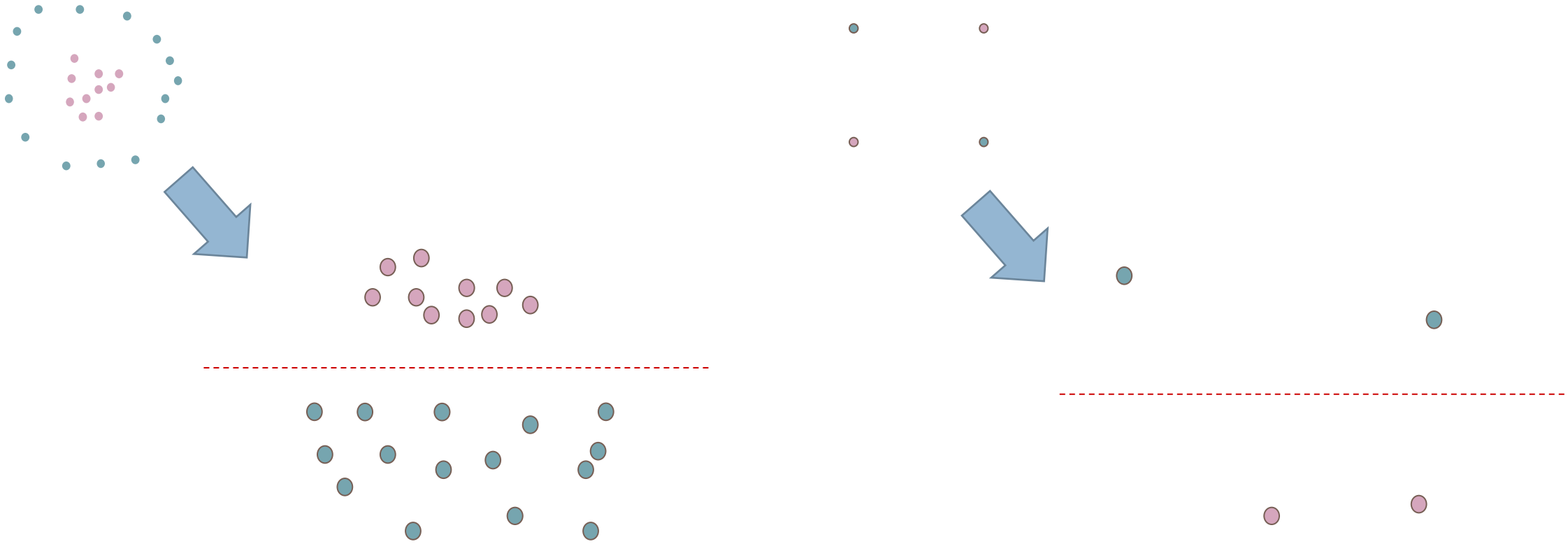
Traditional ML

Non-linear separable data



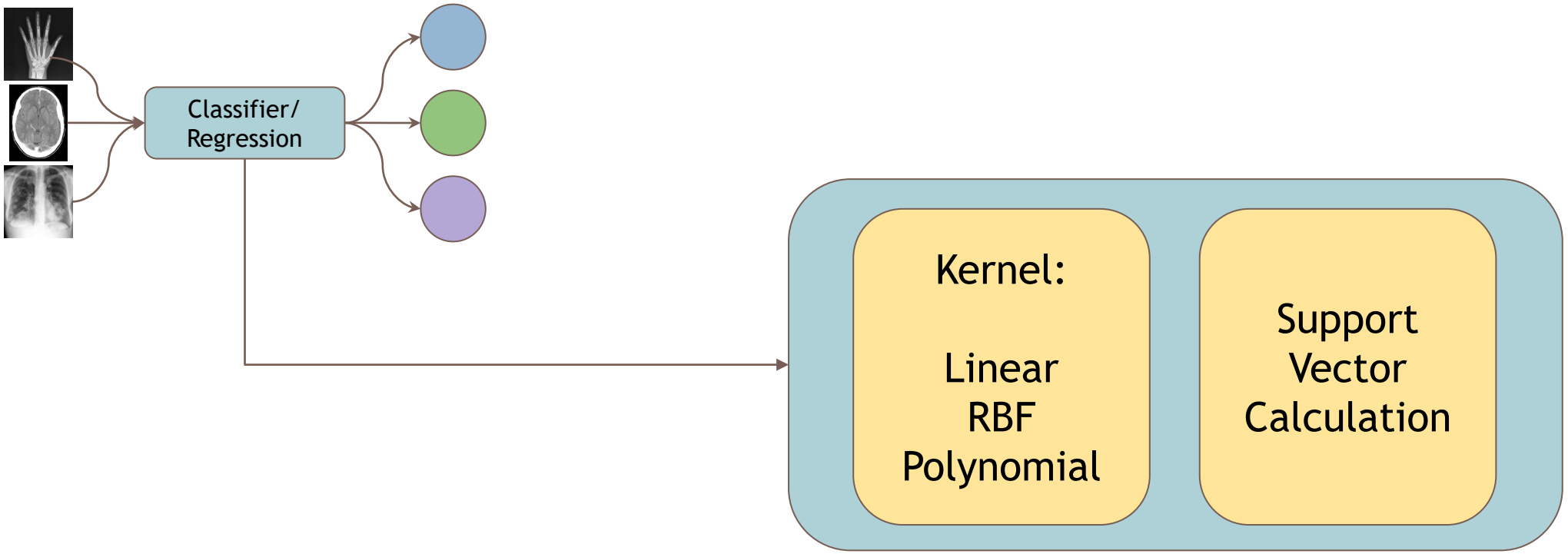
Inseparable with a straight line. More complex problems. Data in the real world.

Solution 1: Transforming the data -> SVM



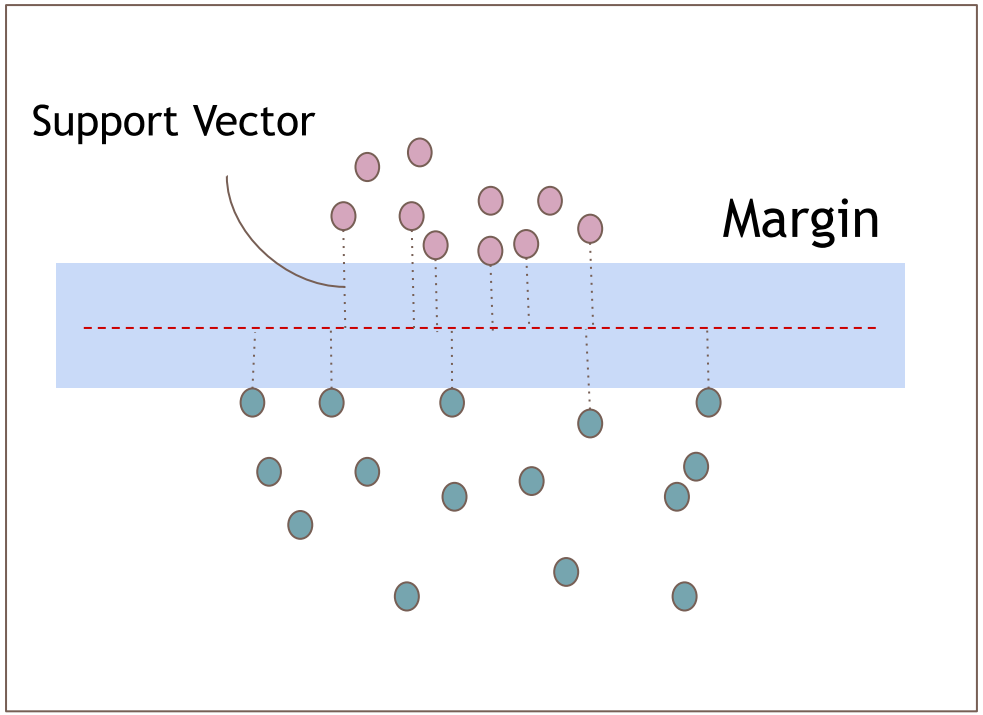
Transforming the data into a new space where is separable.

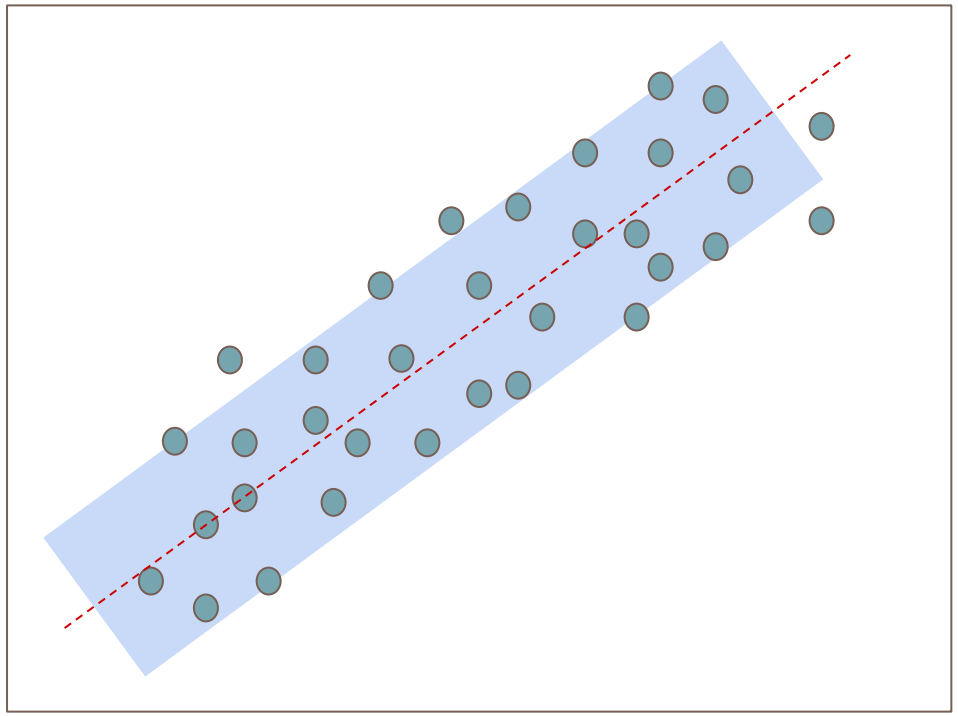
Support Vector Machines (SVM)



Has a kernel to transform the data. Maximize the distance between samples.

Support Vector Calculation: SVM



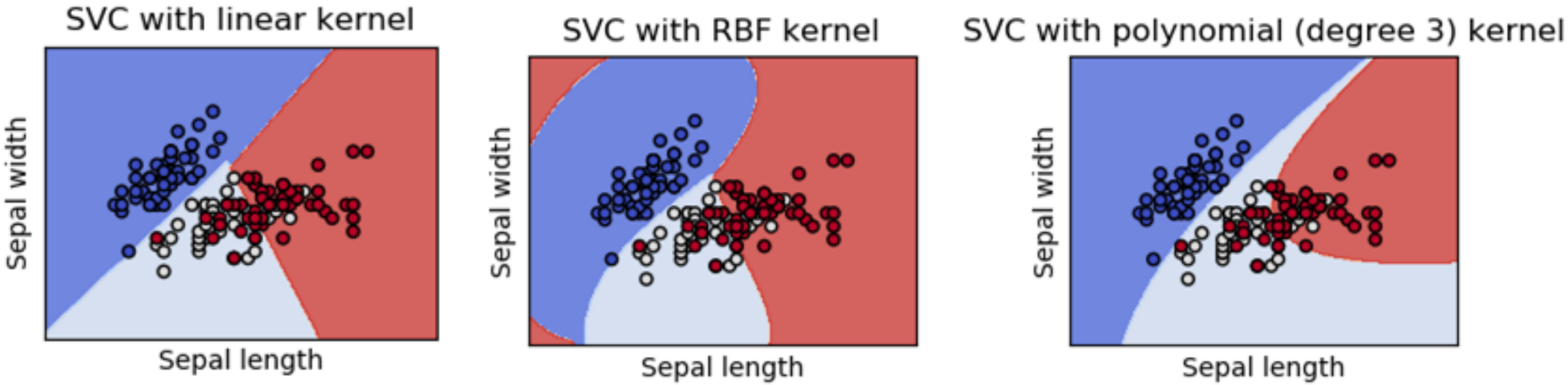


Parameters:

Regularization (C) and Gamma

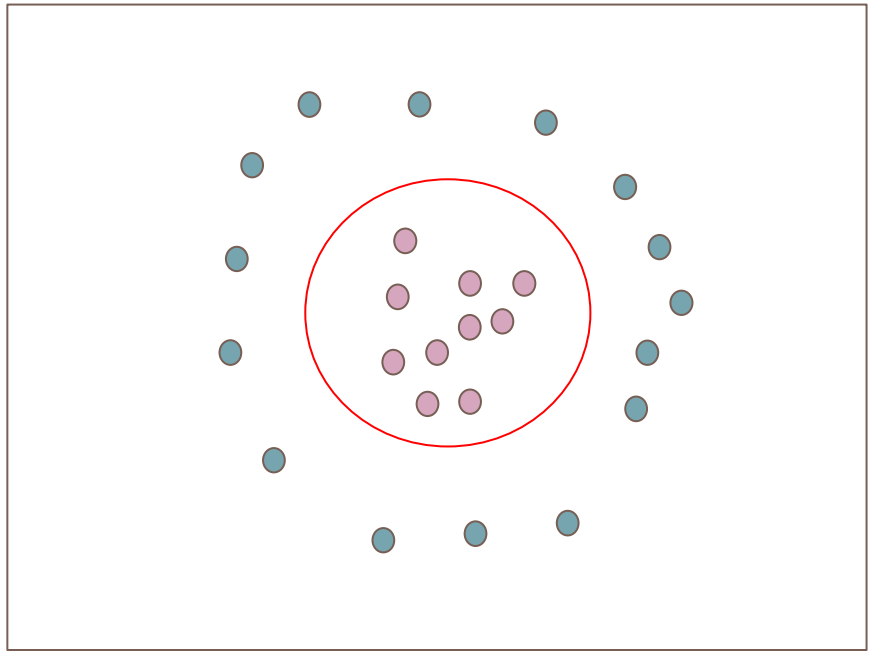
	Large Gamma	Small Gamma	Large C	Small C
Variance	Low	High	High	Low
Bias	High	Low	Low	High

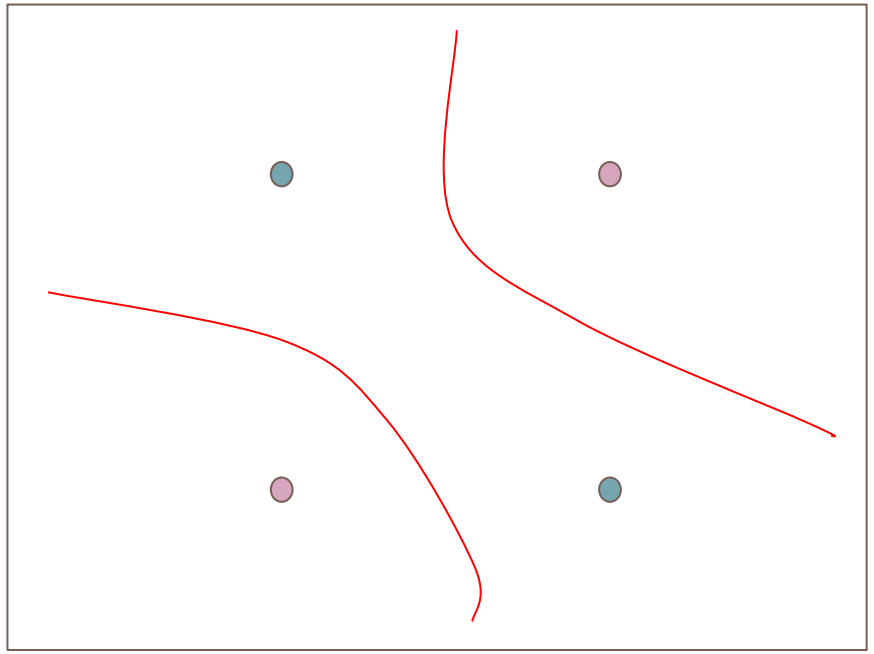
Kernel: SVM



Linear when you know the problem is linear separable.
Radius Basis Function (RBF) when you don't know the data distribution.

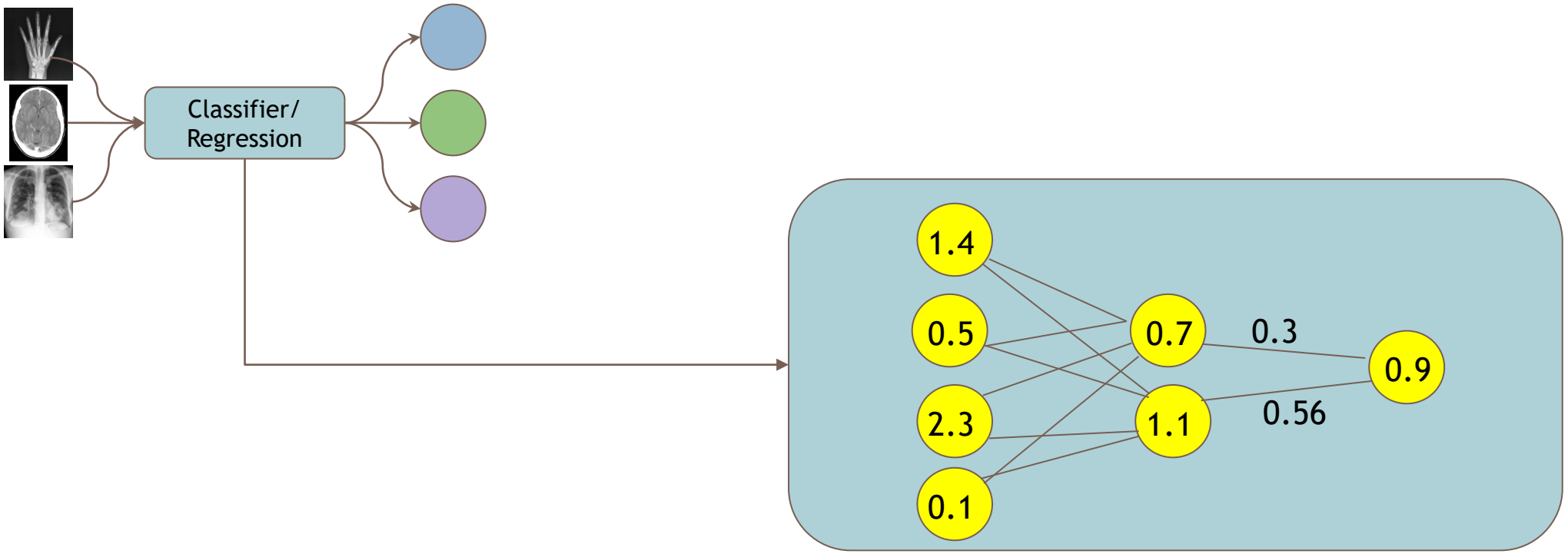
Solution 2: Non-linear functions





Modeling a non-linear function allows to predict division lines with all sorts of shapes.

Fully Connected Network (FCN)



Linear combination of weights and inputs (sum of multiplications)

Also known as Artificial Neural Network (ANN) or Dense Neural Network (DNN)

Differences:

1. SVMs only classify two categories
2. FCN are parametric, SVMs are non-parametric
3. SVMs are simpler but less typically powerful

End of Lecture 1a

Next up Part 3 Lecture 1b: Neural Networks