# Associating 3D Radiation Dose with Treatment Failure in Prostate Cancer Radiotherapy Patients

Presented by Marco Marcello

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# Acknowledgements

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# Breakdown

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1) Introduction

   ⇒ Cancer and radiotherapy basics

   ⇒ Research problem and aims

2) Aim 1: Locating Regions where Dose is Correlated with Failure

   ⇒ Using MATLAB for 3D visualisation

   ⇒ Using MATLAB for locating significant regions

3) Aim 2: Classification Modelling

   ⇒ What is classification modelling?

   ⇒ Live demo of MATLAB Classification Learner App

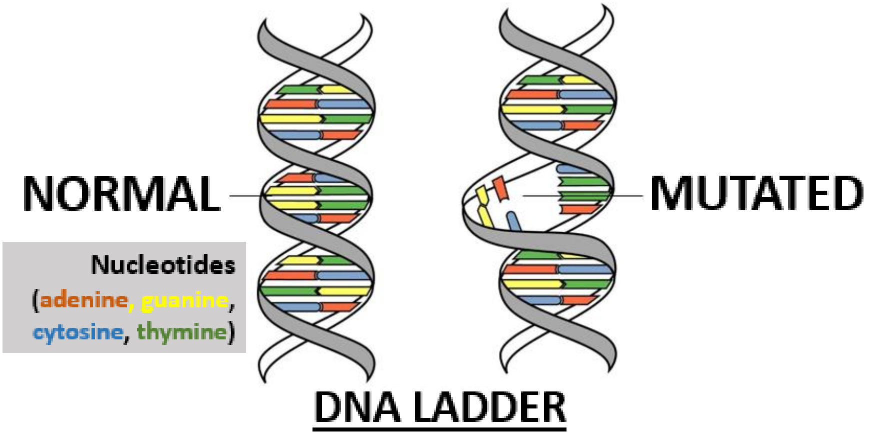
4) Potential Impact of Research

   ⇒ How MATLAB helps impact radiotherapy through this project

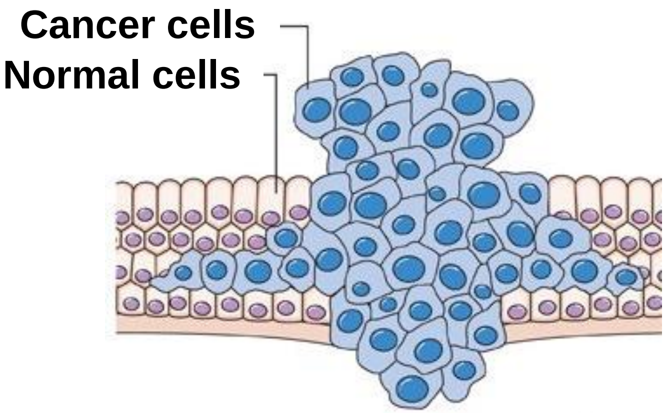
# Cancer and Radiotherapy Basics

↳ What is cancer?

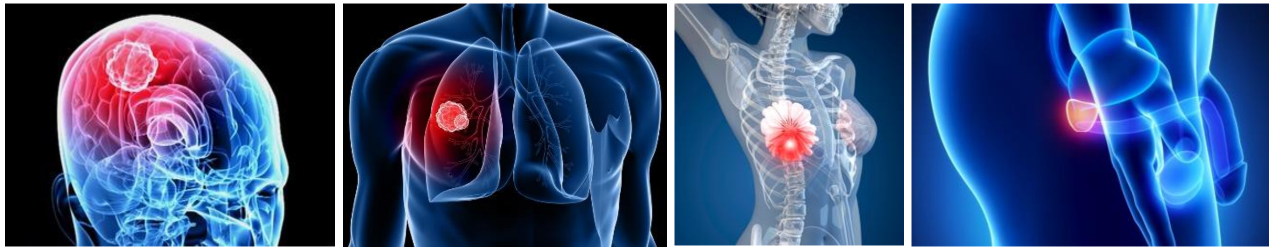
⇒ **Cancer results from genetic mutations that occur naturally or result from external influences.**




⇒ **Particular mutations stimulate out-of-control cell growth of cells without normal functionality.**




⇒ **Groups of these cells are what we call tumours, and can destroy healthy function in many crucial organs.**



# Cancer and Radiotherapy Basics

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↳ Is cancer prominent? How's it treated?

⇒ **Cancer is the leading cause of death in Australia, with 1 in 2 men and 1 in 3 women diagnosed by the age of 85**

⇒ **Prostate cancer is the most commonly diagnosed cancer in Australia, with 1 in 8 men diagnosed within their lifetime**

**Prostate cancer is typically treated with a combination of the following modalities:**

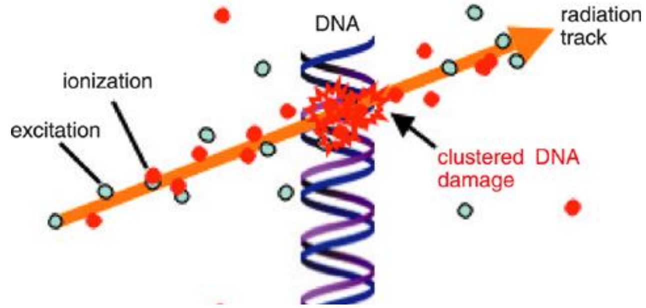
Treatment Modalities

Surgery

Chemotherapy

Hormone therapy

Radiotherapy



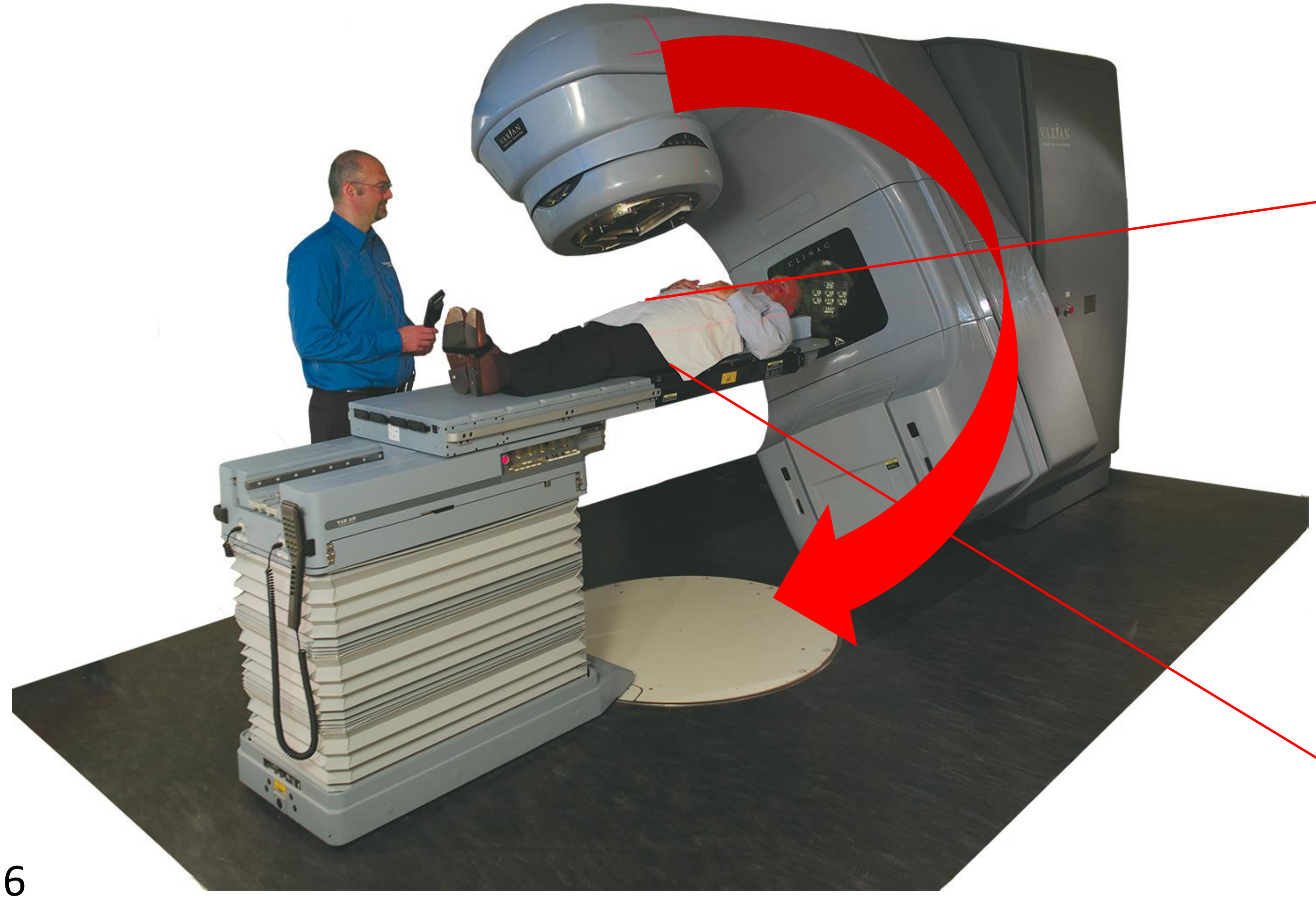

**Radiation kills cancer cells**

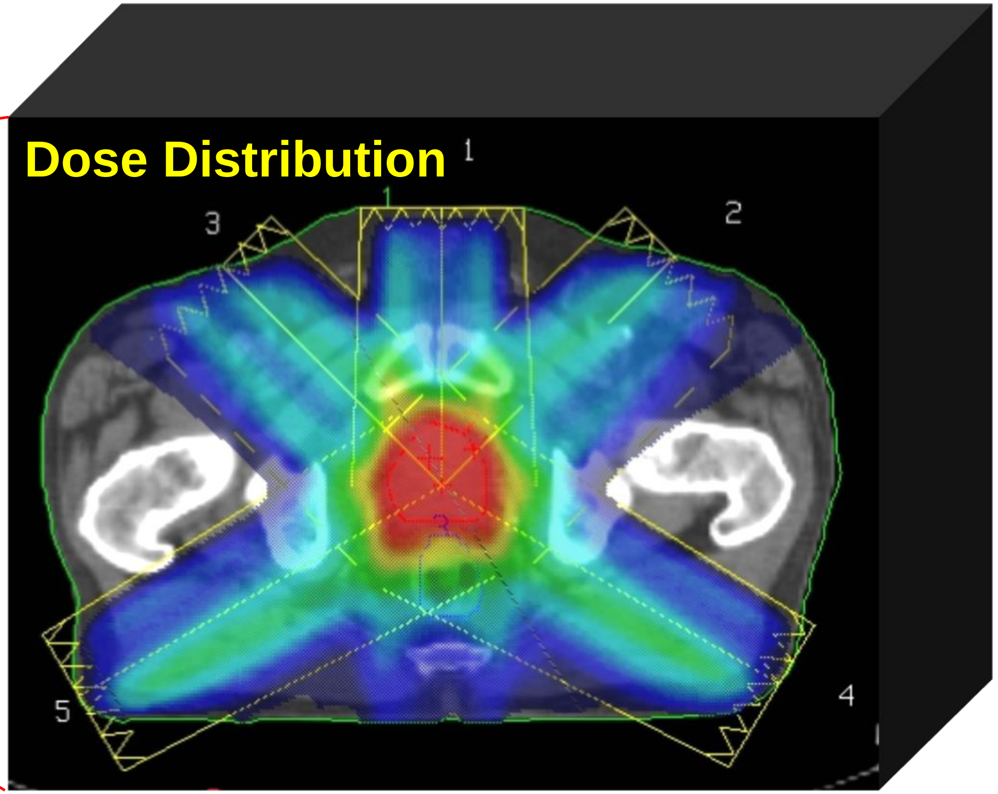
# Cancer and Radiotherapy Basics

↳ What's External Beam Radiotherapy (EBRT)?

**EBRT: radiation (high energy photons) externally delivered to tumour via linear accelerator.**

**'The Goal': to maximise dose (energy deposition) to tumour and minimise dose to healthy tissues.**





# Cancer and Radiotherapy Basics

↳ What's the EBRT process?

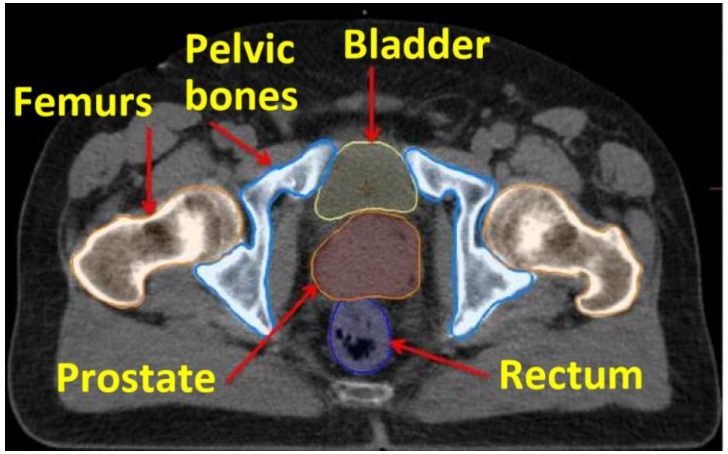
**Prostate cancer external beam radiotherapy (EBRT) involves three major stages:**

1) **Produce a high-quality 3D image of the treatment region.**

2) **Produce a treatment plan, including a 3D radiation dose distribution.**

3) **Accurately deliver the planned radiation dose via linear accelerator.**

1)

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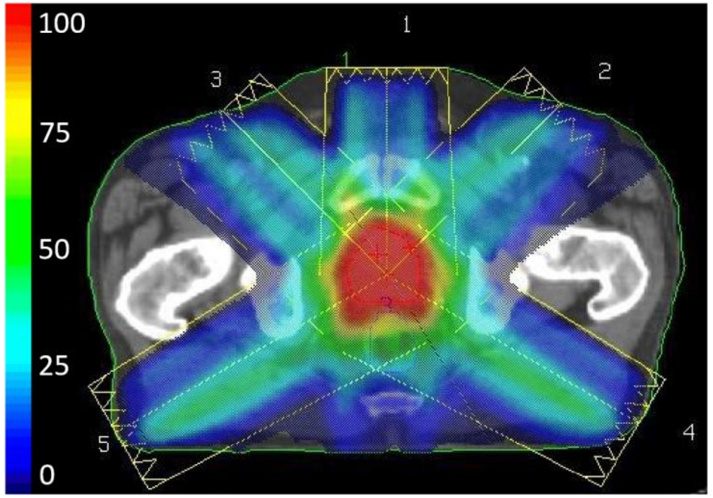


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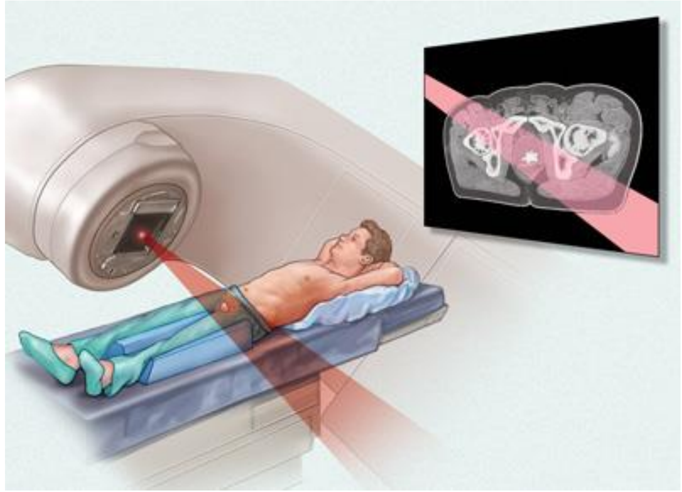


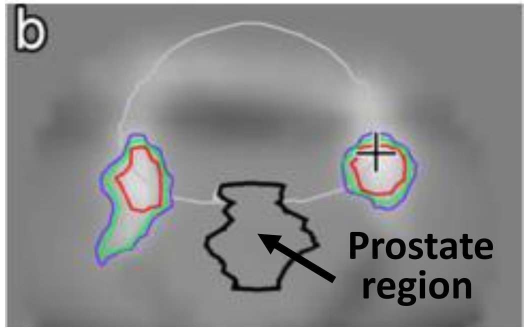
# Research Problem and Aims

↳ Issues addressed? Project aims?

**The project addresses a major unresolved issue in prostate EBRT:**

⇒ **The distribution of cancer around the prostate is difficult to locate due to potential microscopic disease spread.**

⇒ **Therefore, there could be regions that are under-dosed.**



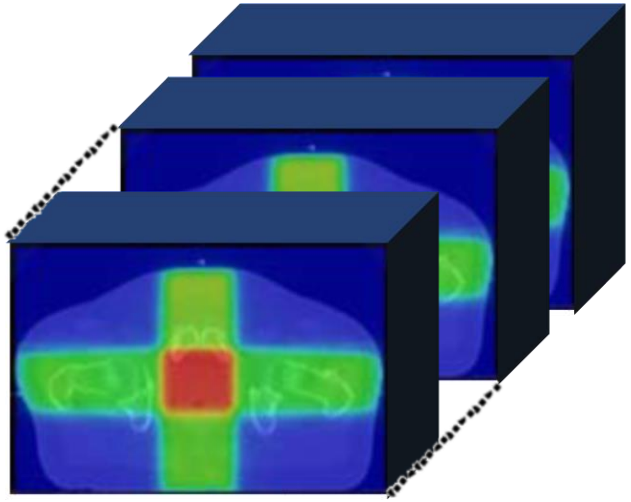

Witte, M. G. *et al.* Relating Dose Outside the Prostate With Freedom From Failure in the Dutch Trial 68 Gy vs. 78 Gy. *Int. J. Radiat. Oncol. Biol. Phys.* **77,** 131–138 (2010).

**Project aims:**

1) **To find regions where dose variation is correlated with treatment failure.**

2) **To produce a classification model capable of predicting failure based on a subject dose distributions.**

**RADAR trial subjects**



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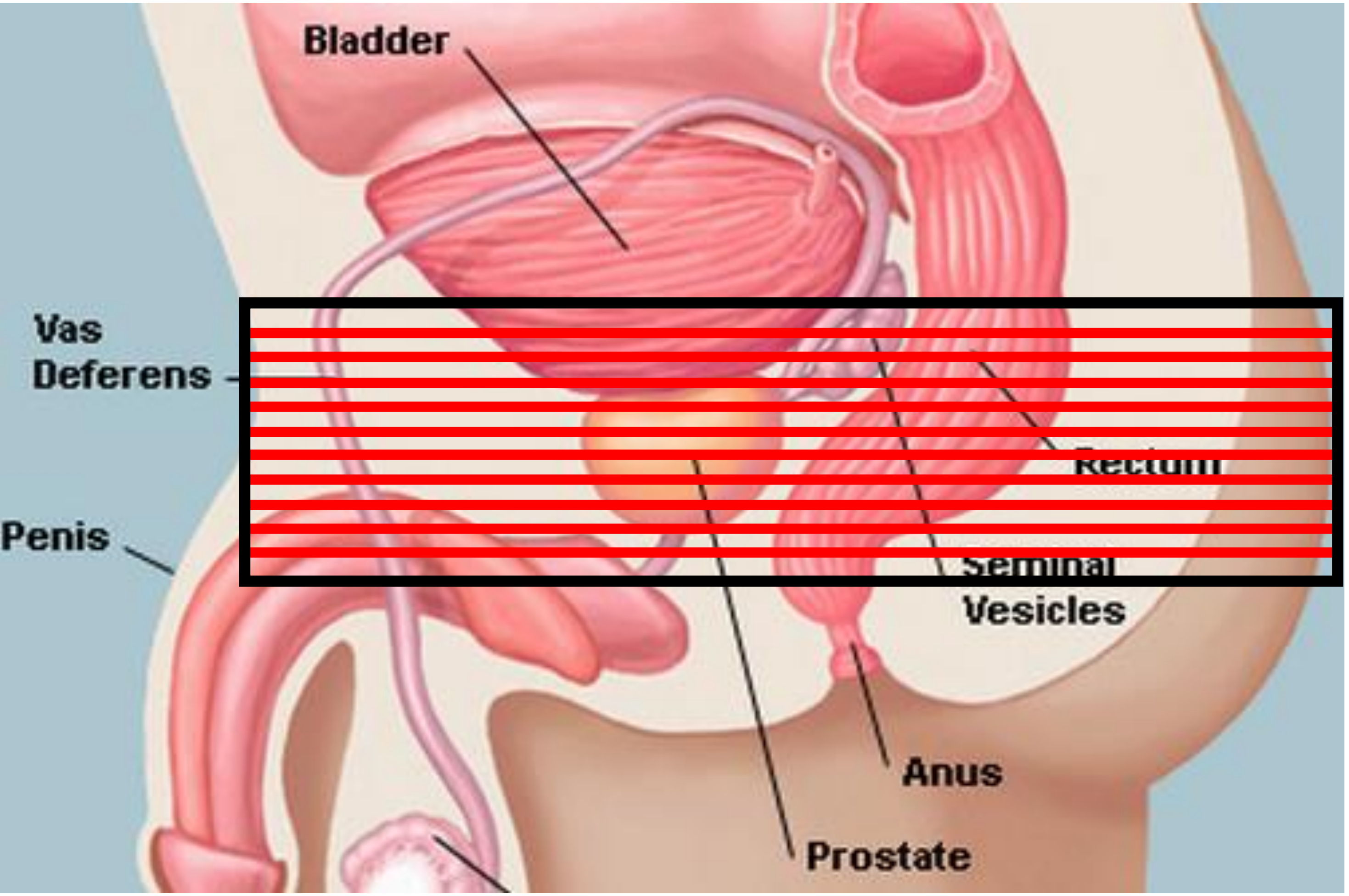
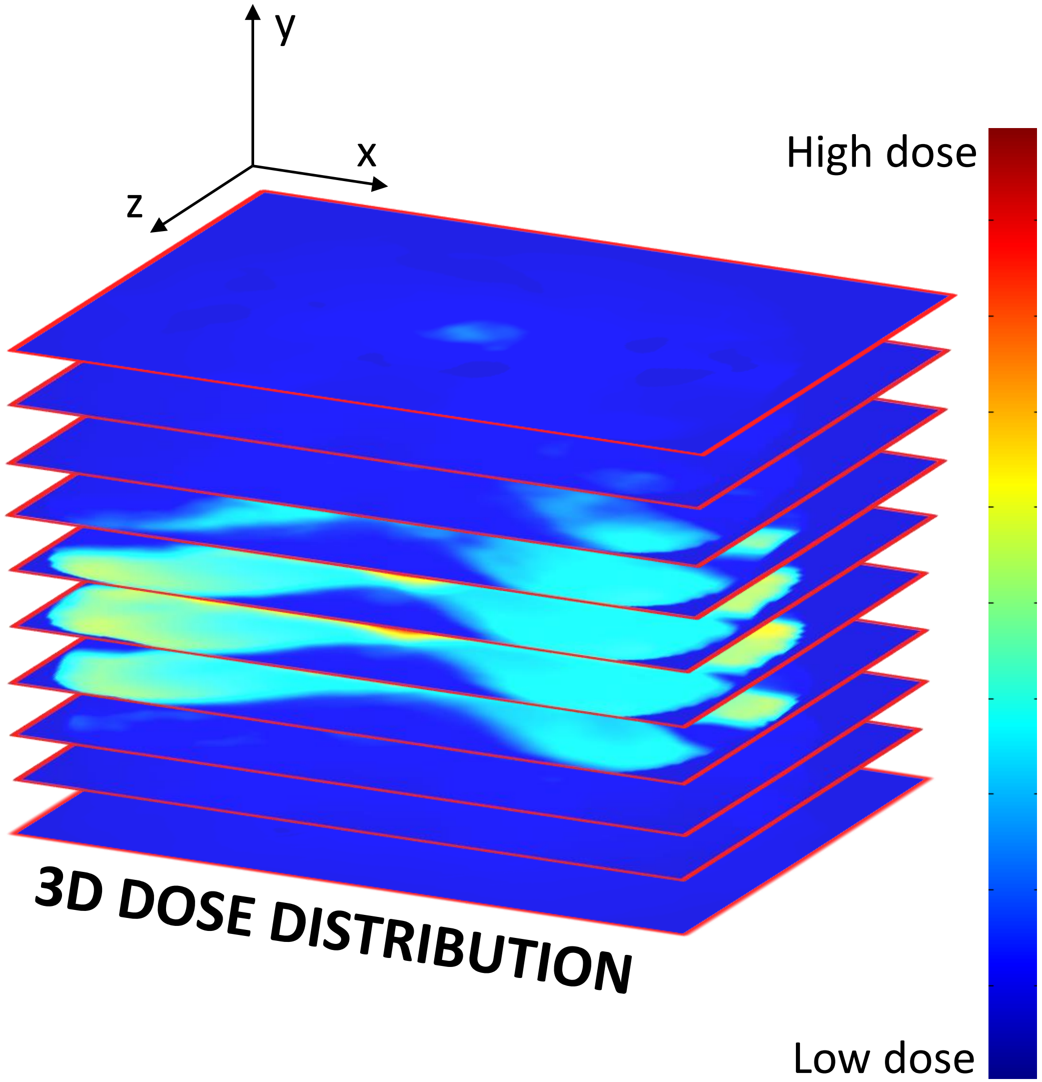
# Aim 1: Locating Significant Regions

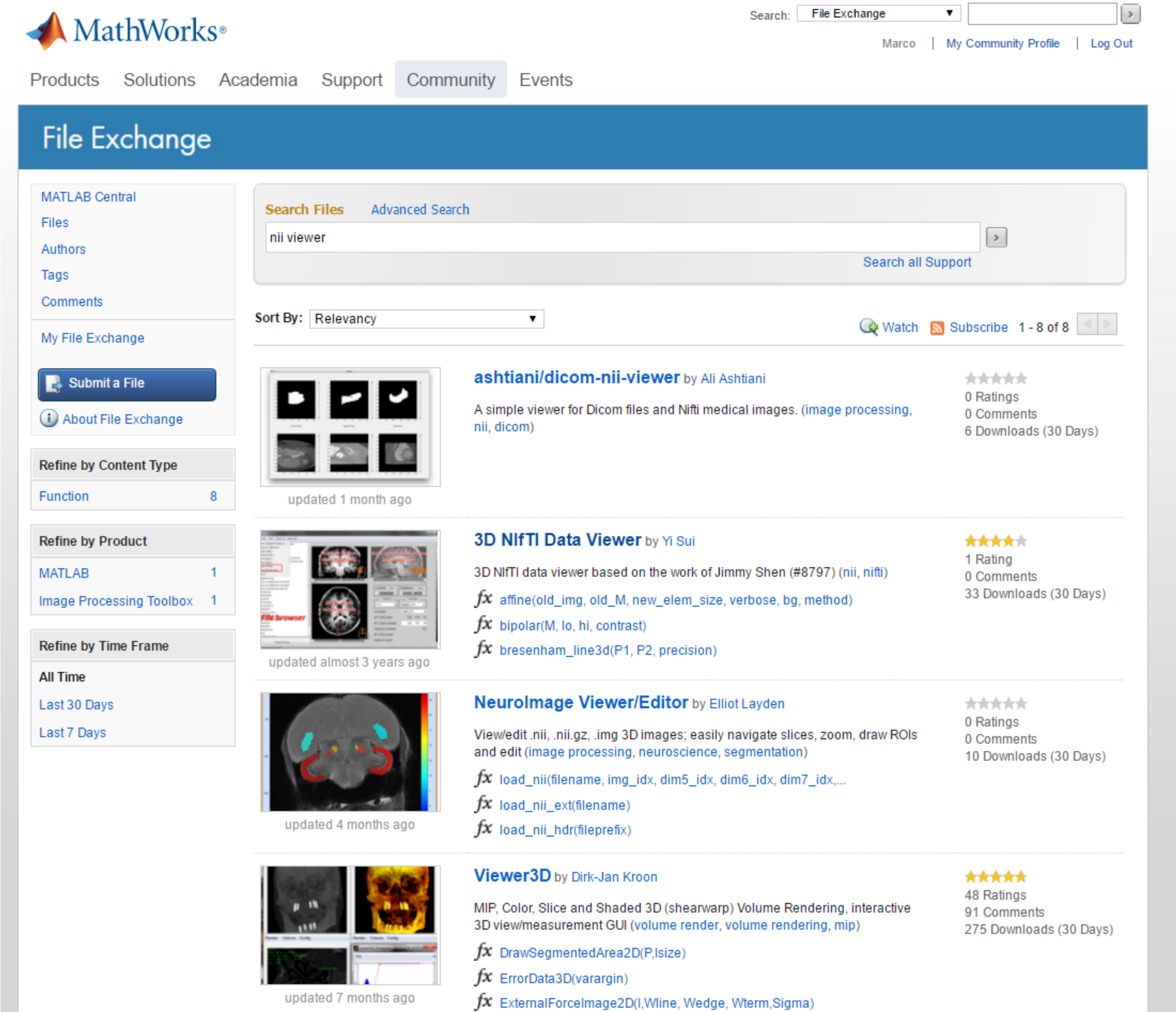
↳ What's a prostate EBRT 3D dose distribution?



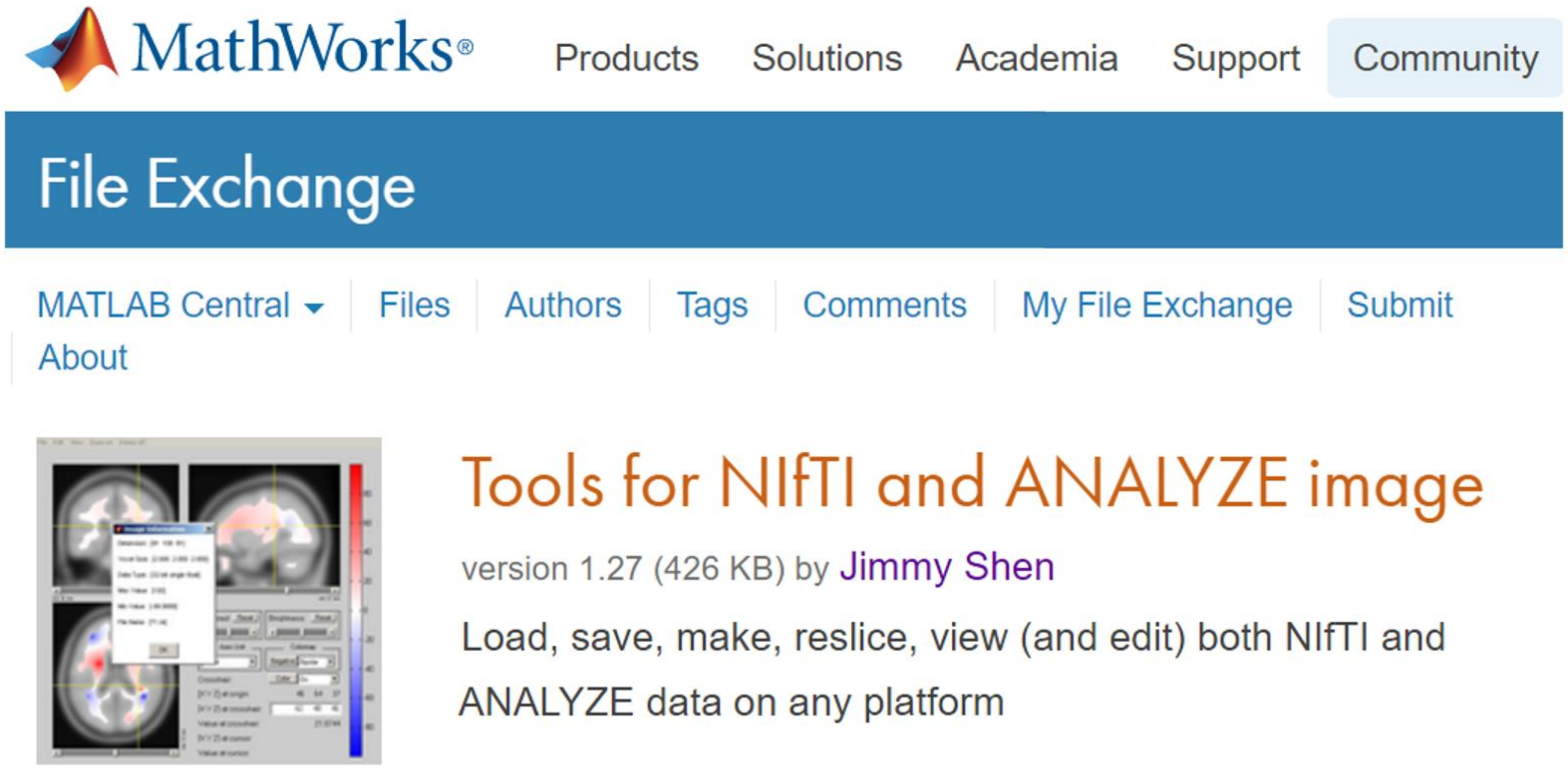
# Aim 1: Locating Significant Regions

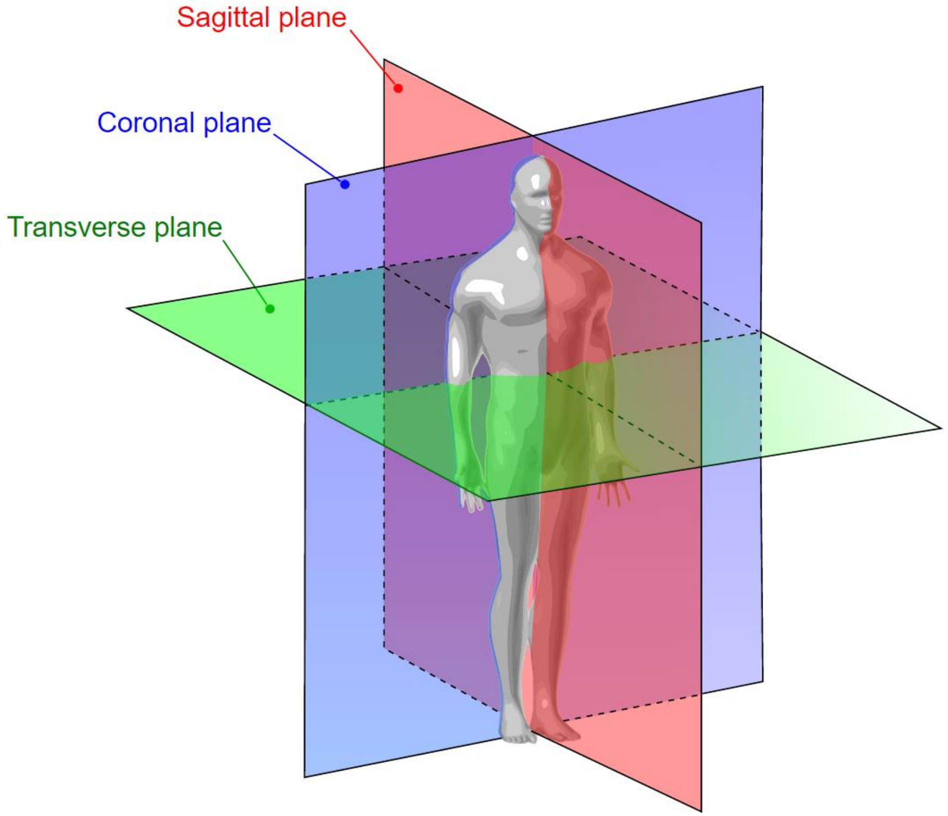
↳ 3D Visualisation on MATLAB?



# Aim 1: Locating Significant Regions

⮡ 3D Visualisation on MATLAB?



# Aim 1: Locating Significant Regions

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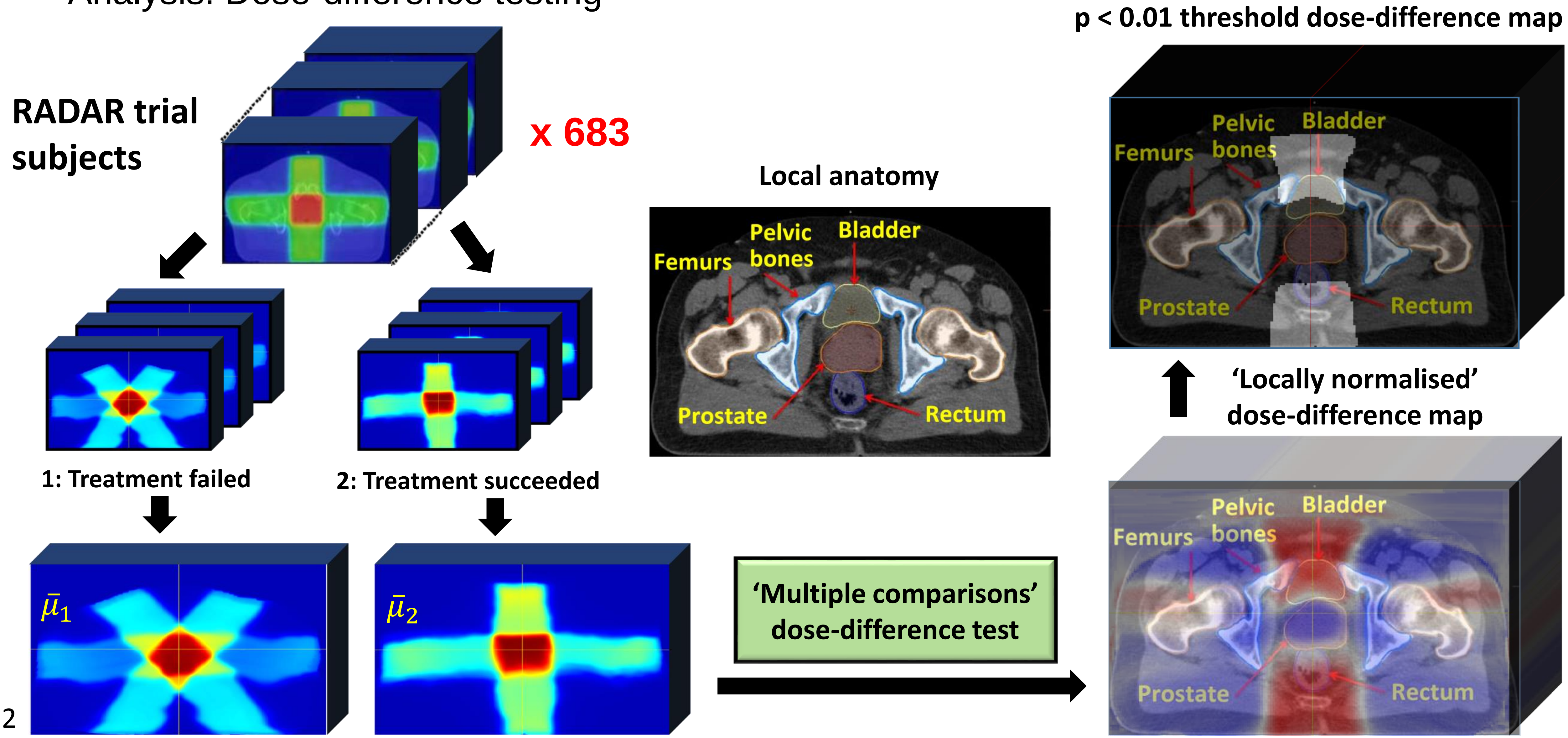
↳ Analysis: Dose-difference testing



# Aim 1: Locating Significant Regions

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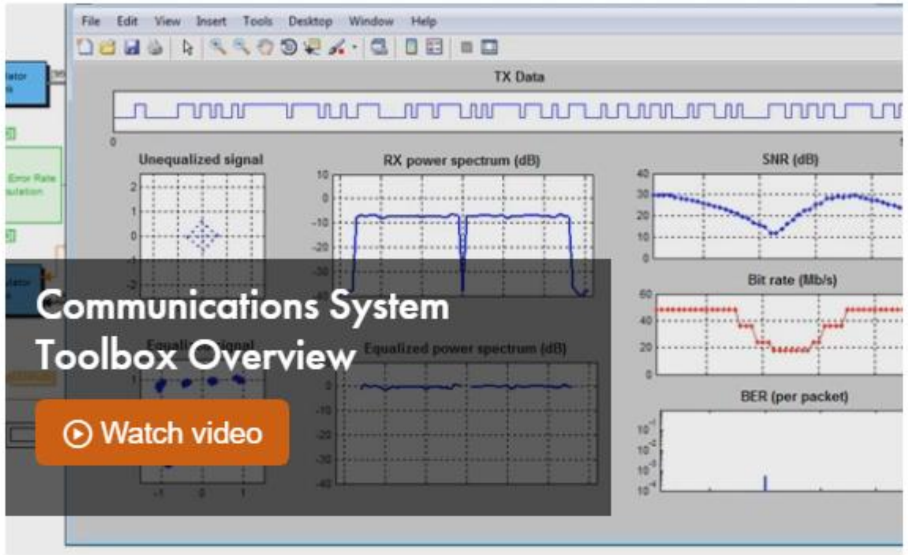
↳ Analysis: How did MATLAB help?

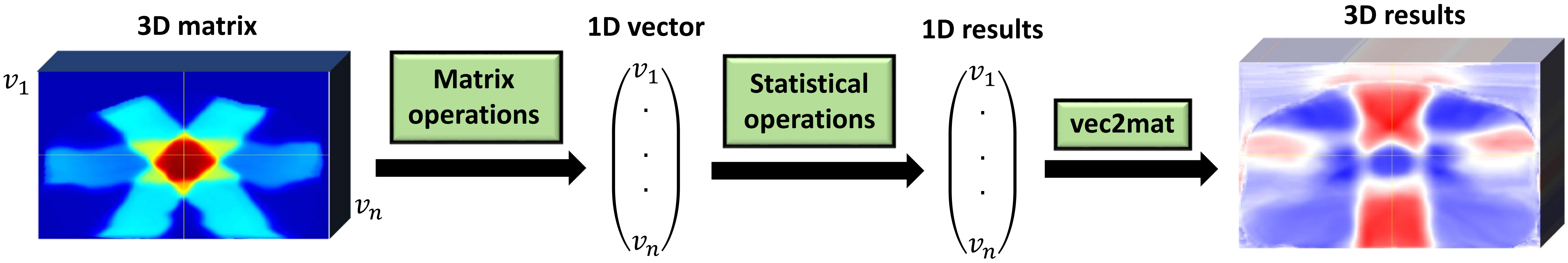
**The entire analysis was performed on MATLAB**

⇒ **All dose distributions are 3D matrices**

⇒ **MATLAB's matrix manipulation was very helpful**

⇒ **Using the 'vec2mat' function from the Communications System Toolbox**



# Aim 1: Locating Significant Regions

⮡ Analysis: How did MATLAB help?

**The analysis involved a lot of data crunching!**

$\Rightarrow$ **Each dose distribution is about 2.3 Mb**

$\Rightarrow$ **The analysis includes over 680 distributions**

**Parallel Computing Toolbox allows running multiple core's at once**

$\Rightarrow$ **Reduces processing time, very helpful!**

$\Rightarrow$ **Especially 'for loops', frequently used in code**

# Aim 2: Classification Modelling

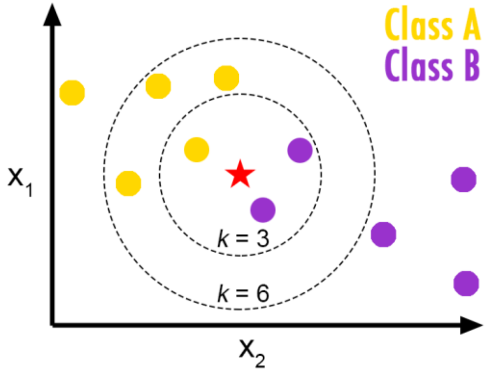
↳ What is 'machine learning' based classification?

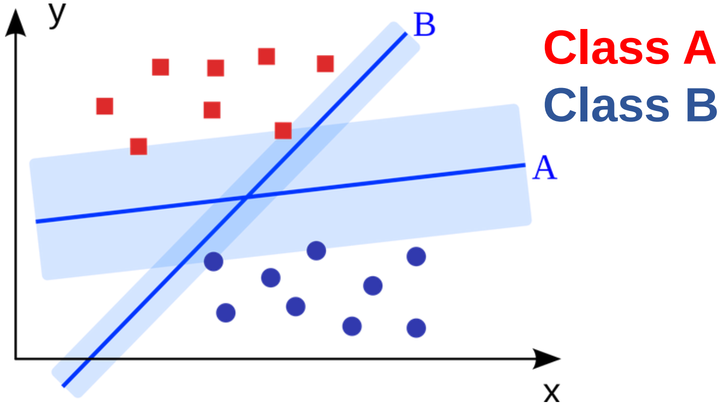
**A number of machine learning algorithms are used for classification:**

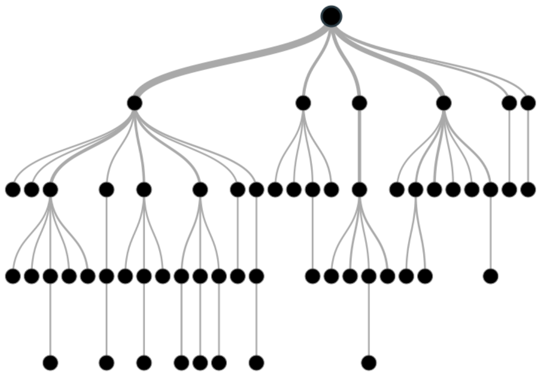
⇒ **K-nearest neighbour**

⇒ **Support vector machine**

⇒ **Decision tree**



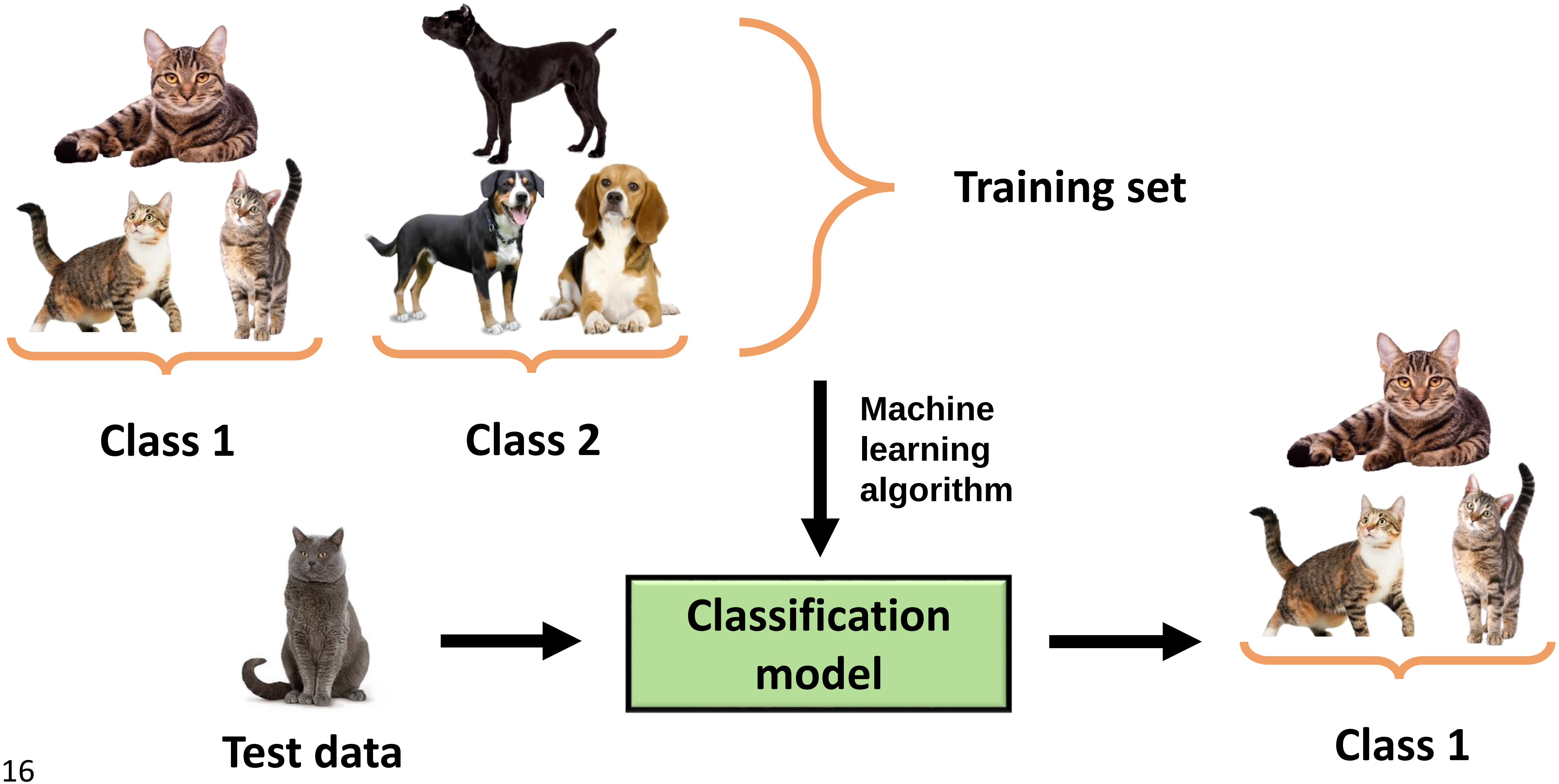



**Two major steps:**

1) **Use an algorithm to 'train' a model using a data set made up of classes (subgroups).**
2) **Classifying external data into a class of the training set.**

# Aim 2: Classification Modelling

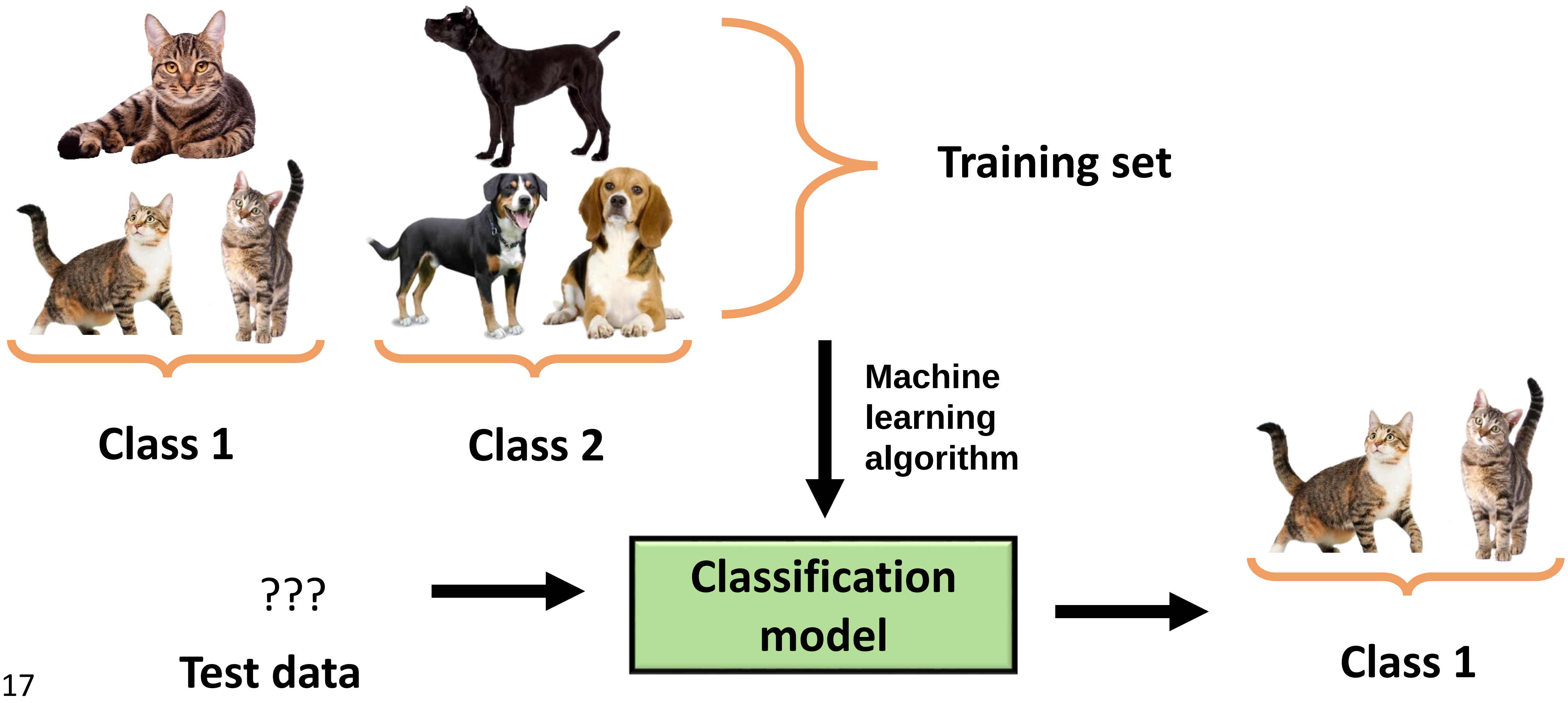
↳ What is ‘machine learning’ based classification?



# Aim 2: Classification Modelling

↳ What is 'machine learning' based classification?

**How do we test our model without test data?** **Can use cross-validation…**



# Aim 2: Classification Modelling

↳ What is 'machine learning' based classification?

## Testing the model…

**Three basic statistics help us test the model's per**

**Accuracy:**

$$Acc = \frac{\#\, correctly\ classified}{total\ number}$$

**E.g. 10 cats, 10 dogs**
**7 cats and 9 dogs correctly classified**

$$\Rightarrow Acc = \frac{7+9}{20} = 80\%$$

**Sensitivity:**

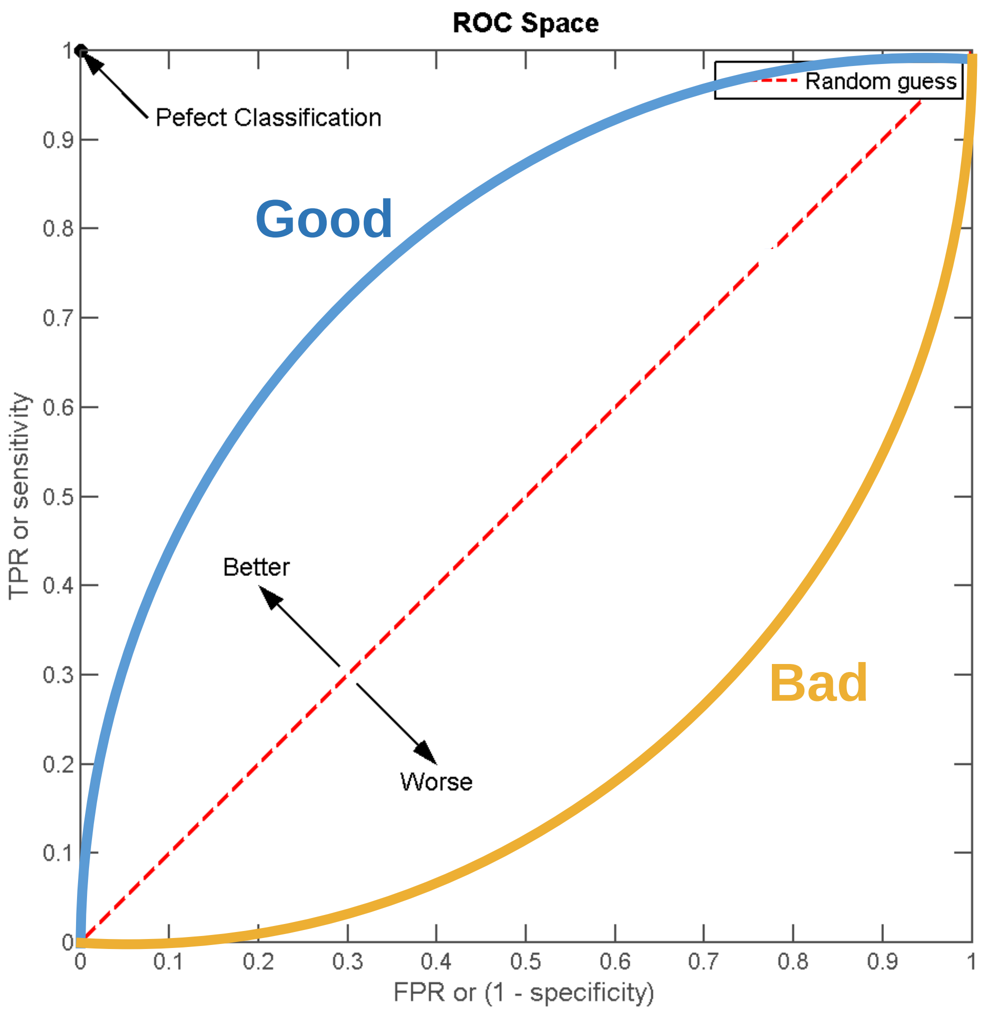
$$Sen = \frac{\#\, correctly\ classifie}{total\ number\ in}$$

$$\Rightarrow Sen = \frac{9}{10} = 90\%$$

**Specificity:**

$$Spe = \frac{\#\, correctly\ classifie}{total\ number\ in}$$

$$\Rightarrow Spe = \frac{7}{10} = 70\%$$



# Aim 2: Classification Modelling

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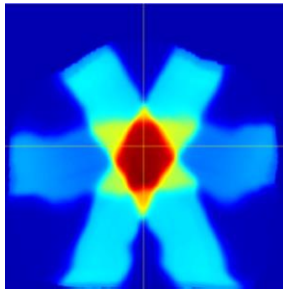
↳ Live demo example

**E.g. Classifying RADAR data according to number of beams:**

**Not 4 beams**



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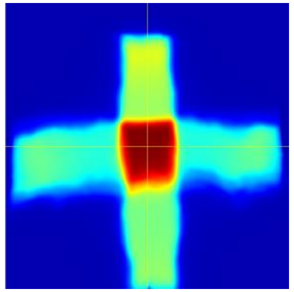
**Class 1**

**4 beams**



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**Class 2**

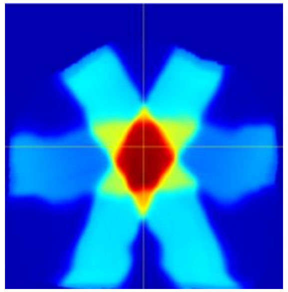
**Training set**

**Machine learning algorithm**

**‘15-fold’ cross validation**

**Classification model**

**Not 4 beams**



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**Class 1**

# Aim 2: Classification Modelling

⮡ Benefits of the MATLAB Classification Learner App

**Benefits:**

⇒ **Running multiple machine learning algorithms simultaneously is extremely powerful**

⇒ **Implement cross validation easily**

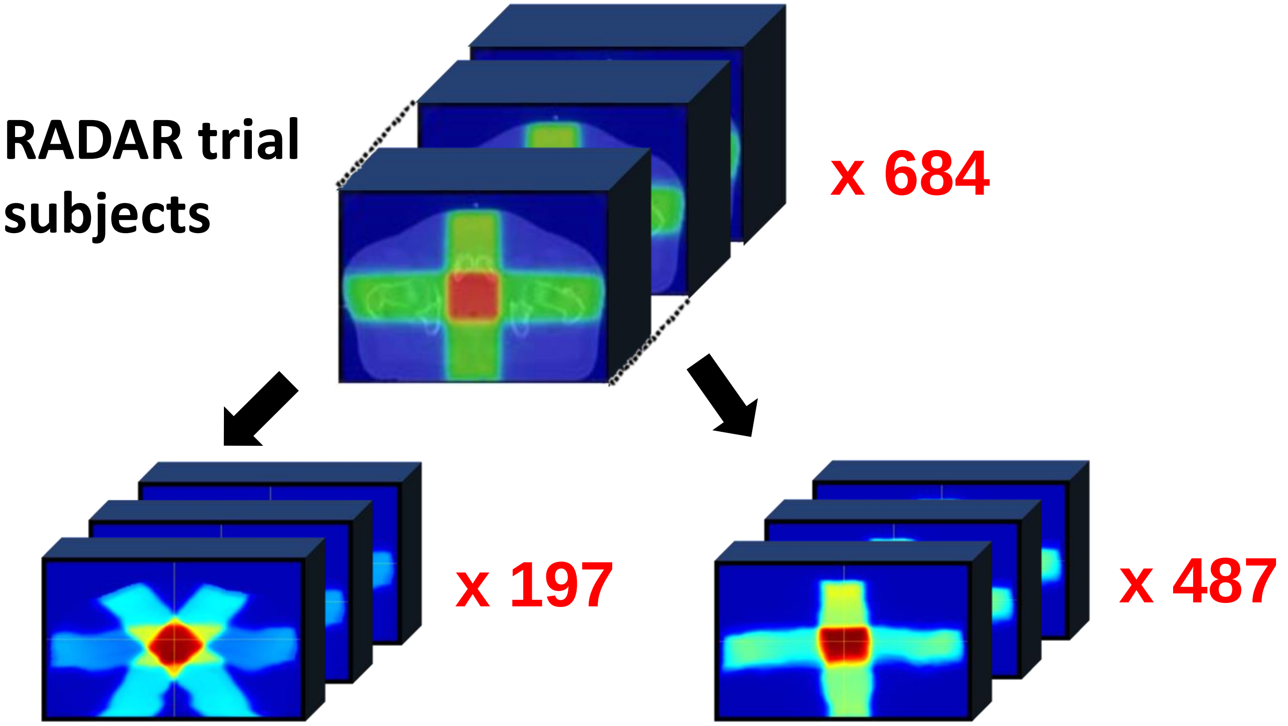
⇒ **Activate PCA easily**

⇒ **Generate performance statistics easily**

# Aim 2: Classification Modelling

↳ Classification to predict failure

**Goal: to build a model capable of predicting treatment failure in a patient based on their planned dose distribution**




**Class 1: Treatment 'failed' (passed away)**

**Class 2: Treatment 'succeeded' (survived)**

# Aim 2: Classification Modelling

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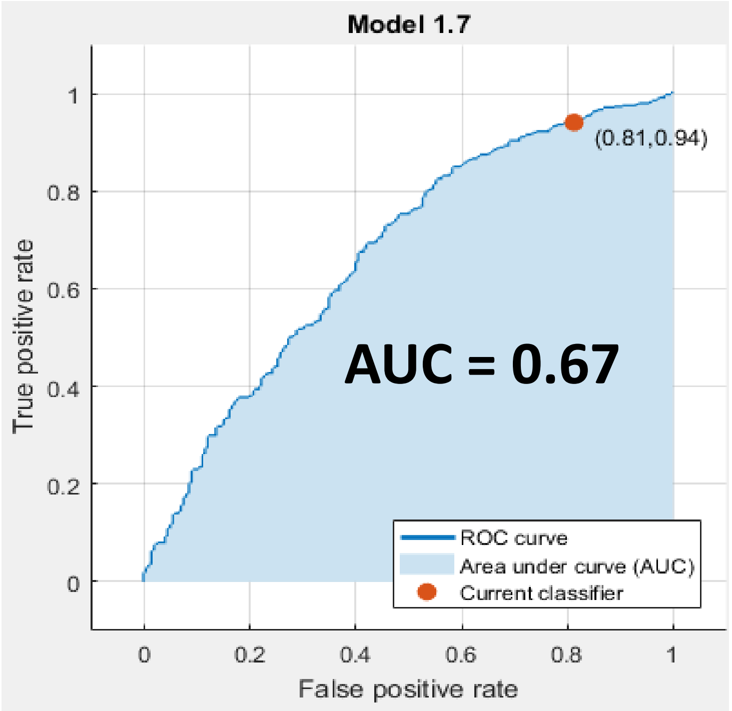
↳ Classification results

⇒ **Classified the two groups:**

- **197 died within 6.5 years**
- **487 death free**

⇒ **1 in 8 sampled data**

⇒ **15-fold cross validation**




| | | Last change | Accuracy | |
|---|---|---|---|---|
| 1.1 | Tree | Complex Tree | 68.4% | 10752/10752 features |
| 1.2 | Tree | Medium Tree | 70.8% | 10752/10752 features |
| 1.3 | Tree | Simple Tree | 71.9% | 10752/10752 features |
| 1.4 | Linear Discriminant | Linear Discriminant | 67.4% | 10752/10752 features |
| 1.5 | Quadratic Discriminant | Quadratic Discriminant | 67.4% | 10752/10752 features |
| 1.6 | Logistic Regression | Logistic Regression | 48.4% | 10752/10752 features |
| 1.7 | SVM | Linear SVM | 72.4% | 10752/10752 features |
| 1.8 | SVM | Quadratic SVM | 70.5% | 10752/10752 features |
| 1.9 | SVM | Cubic SVM | 69.2% | 10752/10752 features |
| 1.10 | SVM | Fine Gaussian SVM | 70.6% | 10752/10752 features |
| 1.11 | SVM | Medium Gaussian SVM | 72.4% | 10752/10752 features |
| 1.12 | SVM | Coarse Gaussian SVM | 71.1% | 10752/10752 features |
| 1.13 | KNN | Fine KNN | 65.8% | 10752/10752 features |
| 1.14 | KNN | Medium KNN | 71.3% | 10752/10752 features |
| 1.15 | KNN | Coarse KNN | 71.9% | 10752/10752 features |
| 1.16 | KNN | Cosine KNN | 71.1% | 10752/10752 features |
| 1.17 | KNN | Cubic KNN | 69.7% | 10752/10752 features |
| 1.18 | KNN | Weighted KNN | 70.5% | 10752/10752 features |
| 1.19 | Ensemble | Boosted Trees | 70.0% | 10752/10752 features |
| 1.20 | Ensemble | Bagged Trees | 72.1% | 10752/10752 features |
| 1.21 | Ensemble | Subspace Discriminant | 60.5% | 10752/10752 features |
| 1.22 | Ensemble | Subspace KNN | 63.9% | 10752/10752 features |
| 1.23 | Ensemble | RUSBoosted Trees | 66.5% | 10752/10752 features |

# Potential Impact of Research

↳ How can these MATLAB based analyses impact radiotherapy?

**Impact of these analyses:**

1) **Identifying anatomical regions prone to under-dosing is helpful because:**
   - ⇒ **Valuable for clinicians identifying the optimal treatment region**
   - ⇒ **It helps determine where and why the treatment is failing**
   - ⇒ **Correcting this can directly improve patient outcomes!**

2) **A robust model capable of predicting treatment failure is helpful because:**
   - ⇒ **It can help us determine particular geometric dose patterns associated with treatment failure**
   - ⇒ **Predicting treatment failure before treatment can indicate need for replanning and improvement**

# Questions…