Prediction of the lung capacity in patients with lung fibrosis

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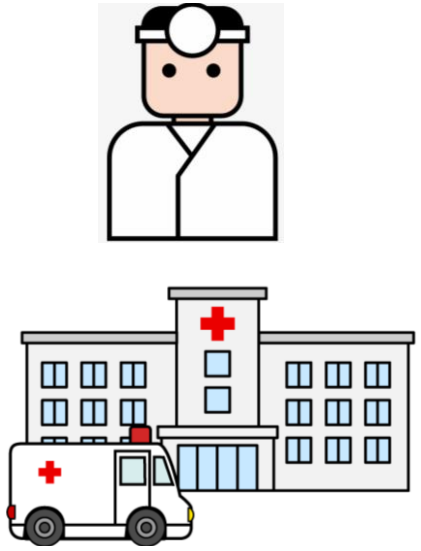
The Problem

- Respiratory failure is the 4th leading cause of death world-wide
- Pulmonary fibrosis is a chronic progressive with unpredictable prognosis.

- **Proposed solution**: deep learning-based algorithm that, based on patient general information and chest CT images predicts how patient's lung capacity will change in the future

Who Might Care?

Hospital & physician



Insurance Company

The patient

The patient's Family

The Data

- Data Source :

  - Kaggle: 176 patients gather from different public and private hospitals

- Data composition:

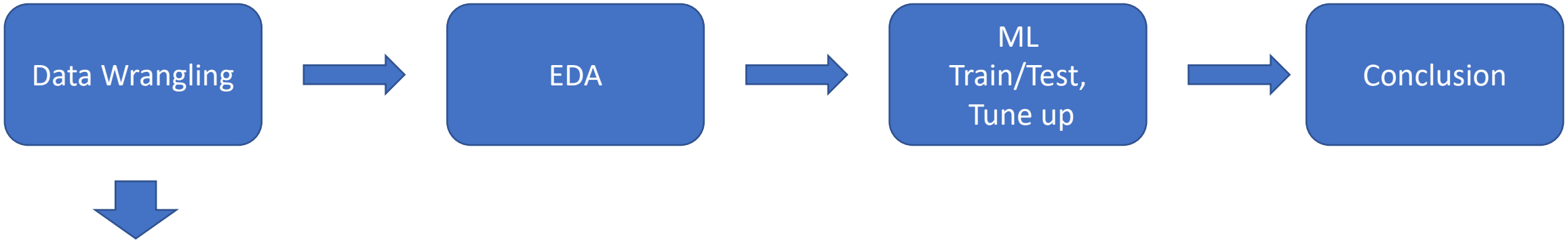
  - Age, Sex, Smoking status

  - Lung capacity measurements and their timeline: FVC (forced vital capacity)/weeks.

  - CT images (dcm format)

https://www.kaggle.com/c/osic-pulmonary-fibrosis-progression

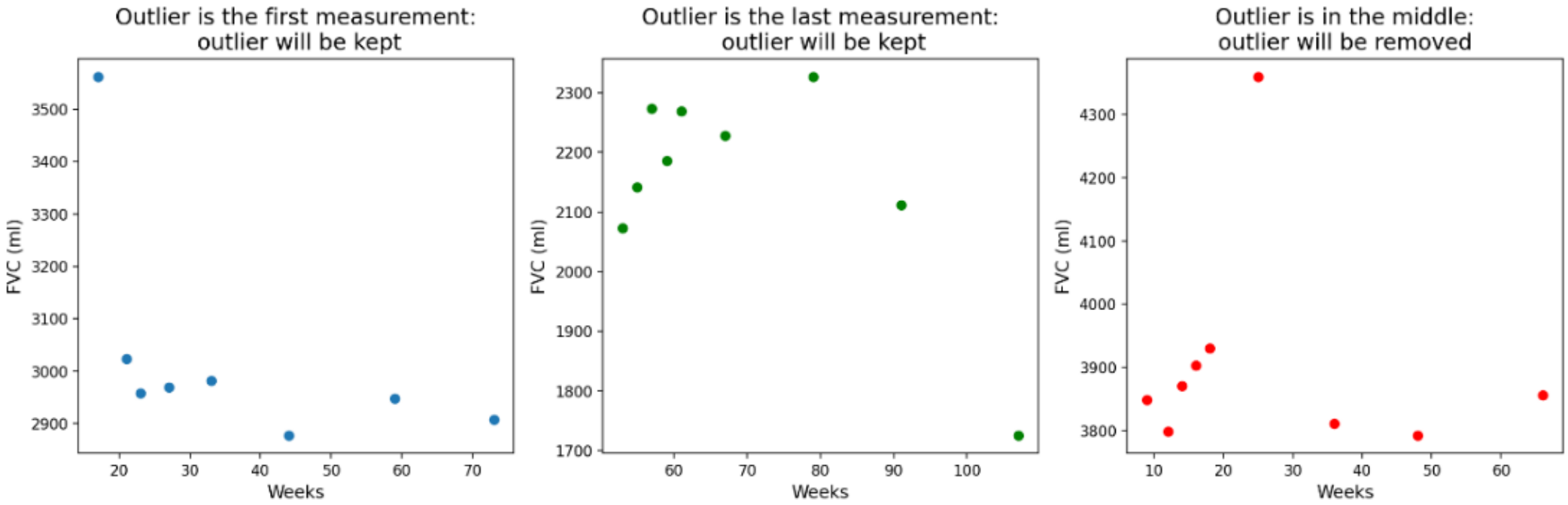
How the problem was tacked



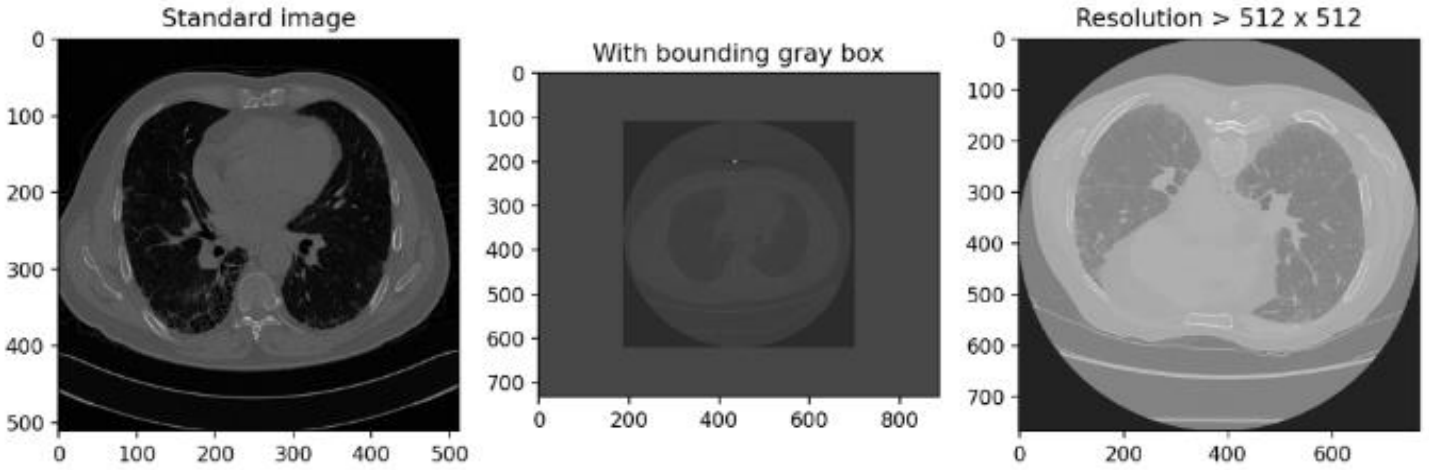
- **Patients medical information**
- **CT Images**

Data Wrangling – Sex, Age, Smoking status, FVC values

- **No missing values**
- **Outliers in the FVC measurements**



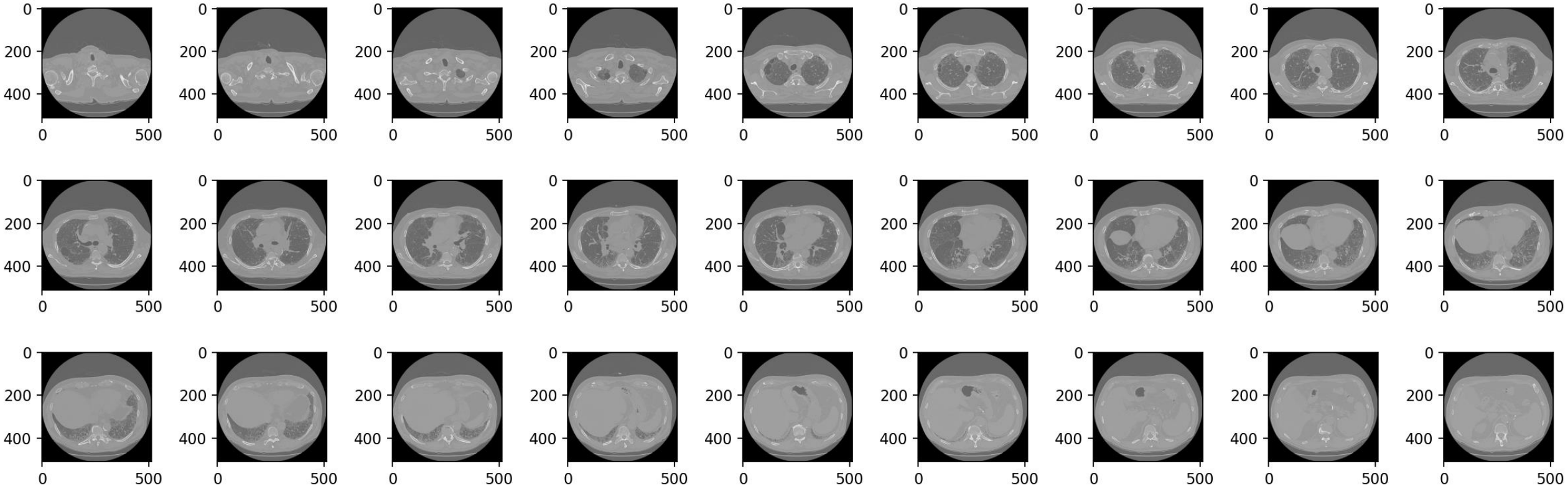
Data Wrangling - CT images (a)



Normalize Resolution

Remove bounding box

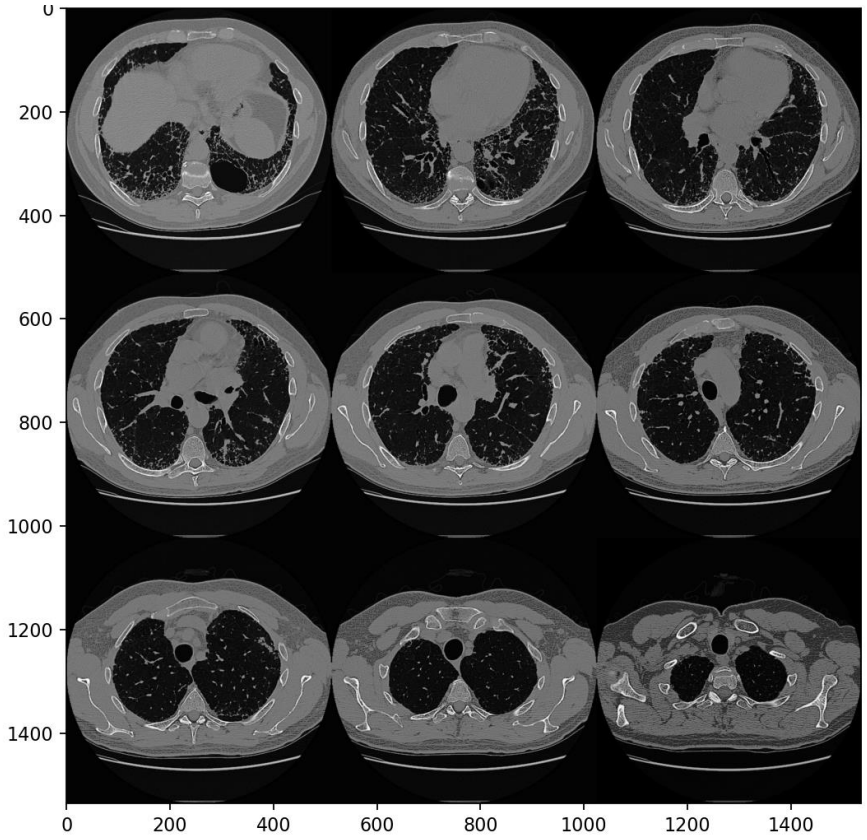
Data Wrangling - CT images (b)



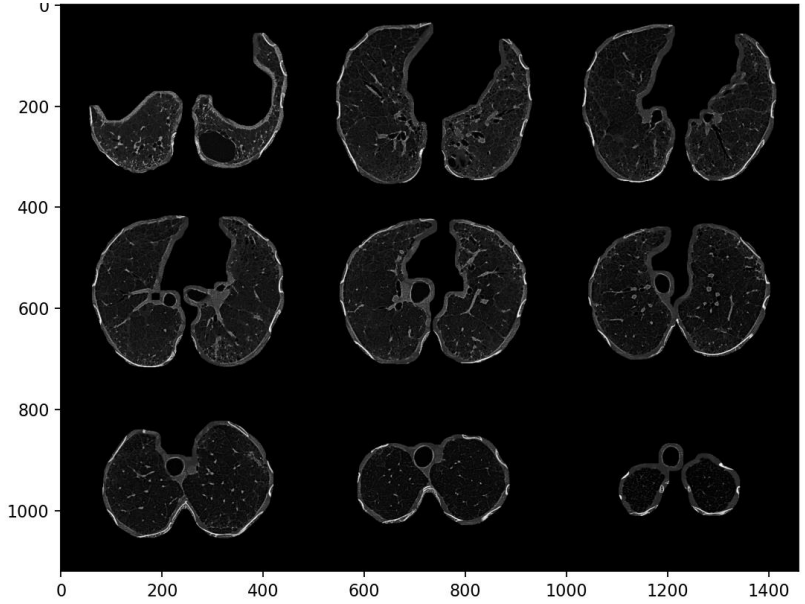
Mark the top and bottom images displaying the lung

Data Wrangling - CT images (c)

Preparing 3x3 grids:

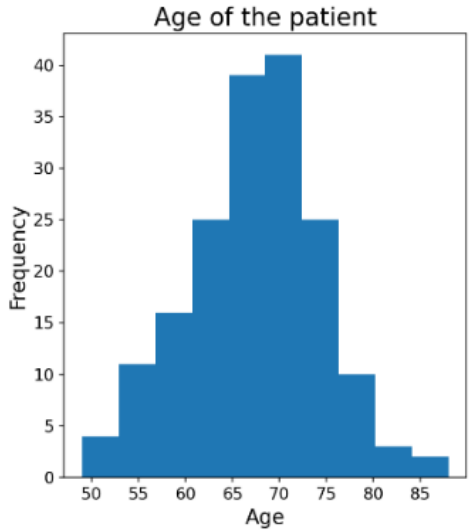


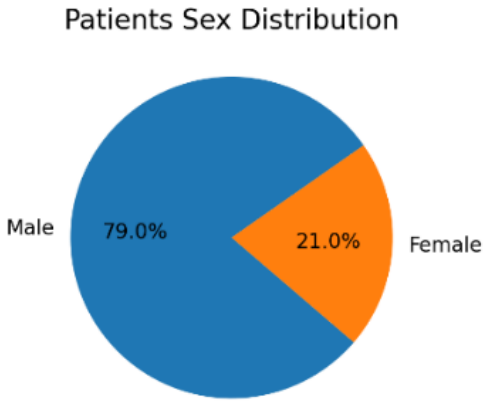
3x3 non-carved images

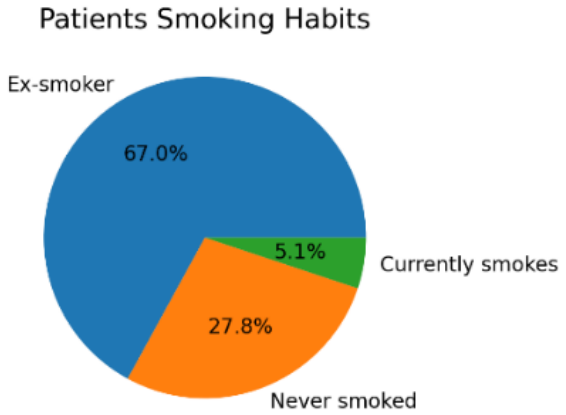


3x3 carved images

EDA – Age, Sex, Smoking Status

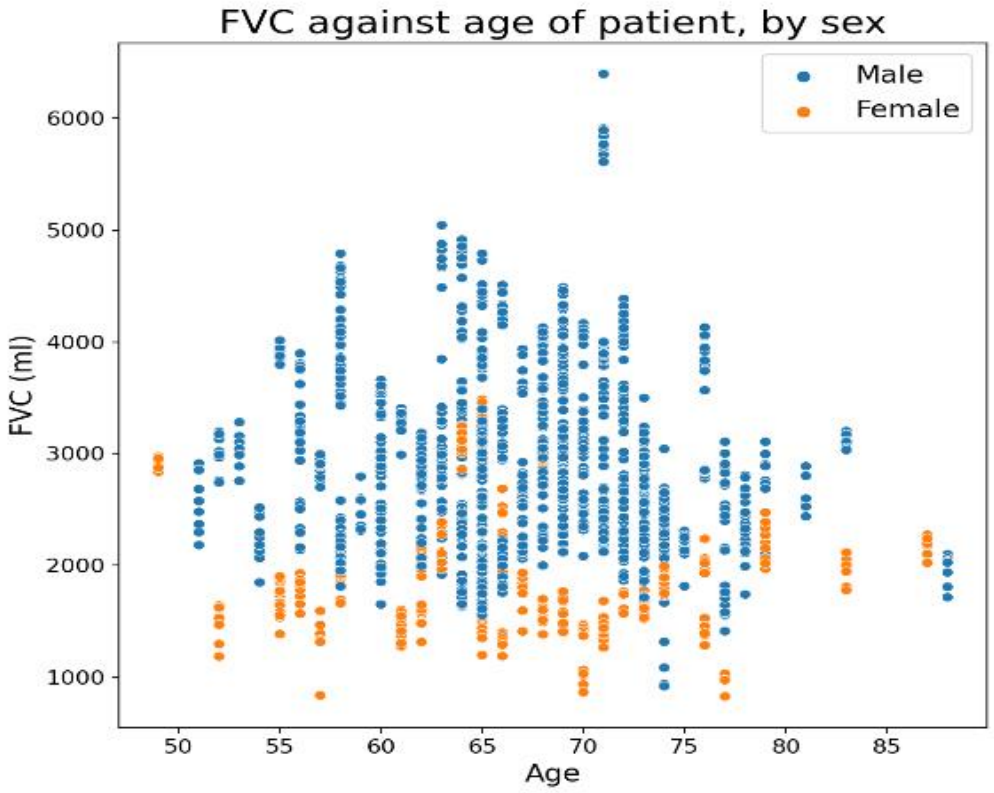






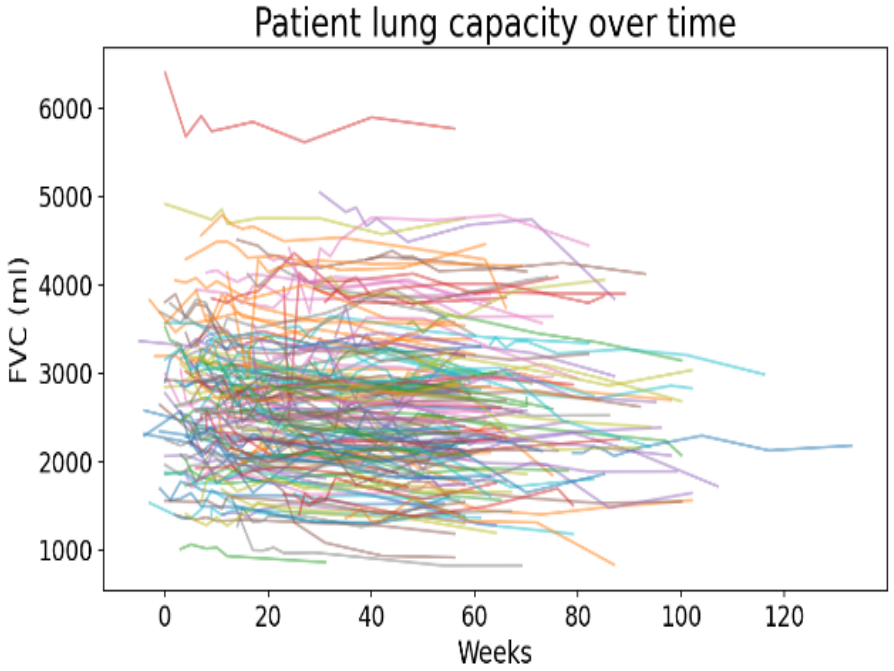
- Age normally distributed (mean 67.3 years)
- Majority of patients are men, ex-smokers

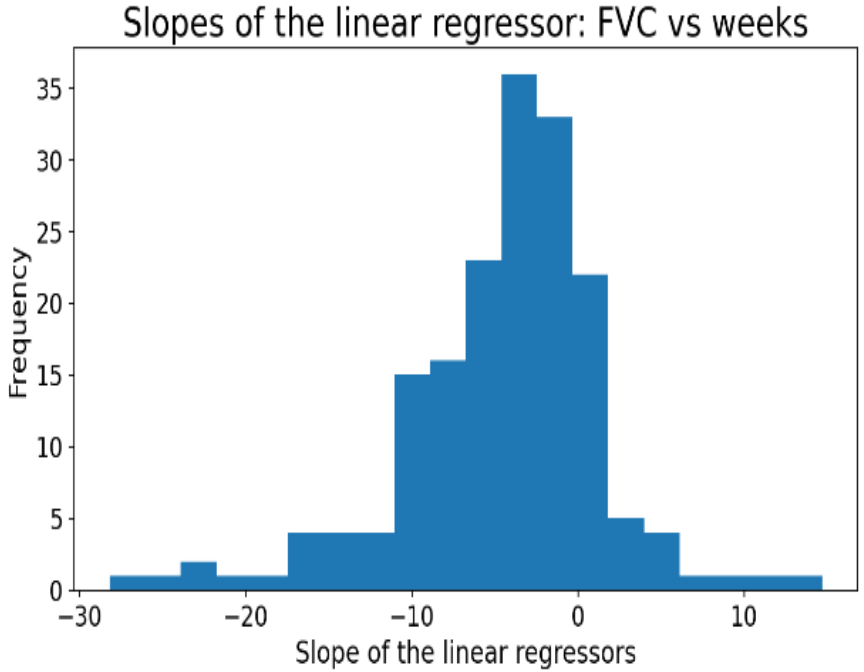
EDA – FVC



Males have higher lung capacity (bigger chest)

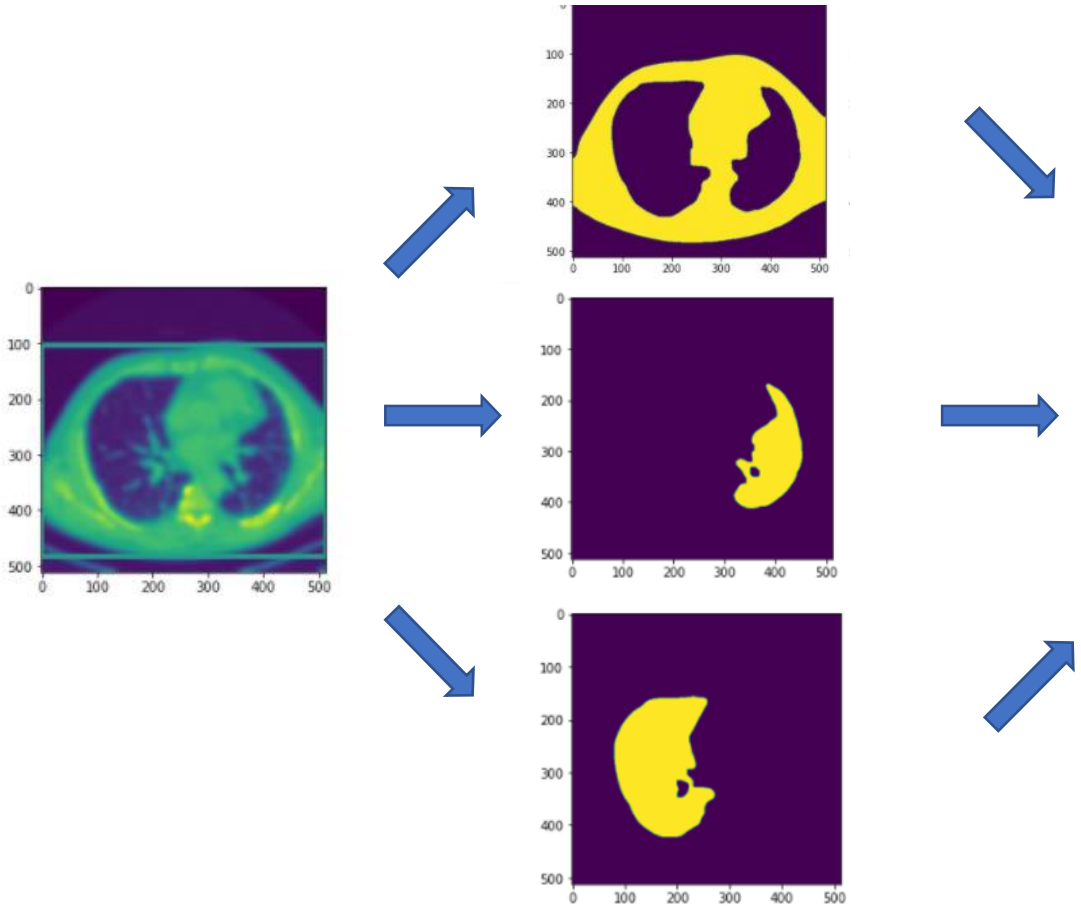
EDA – FVC decay

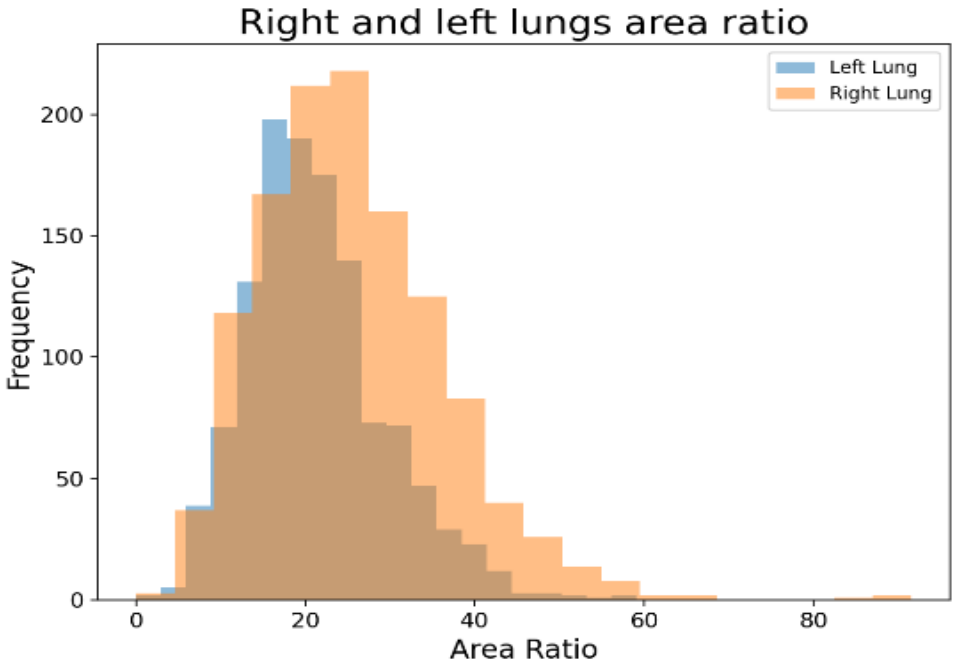




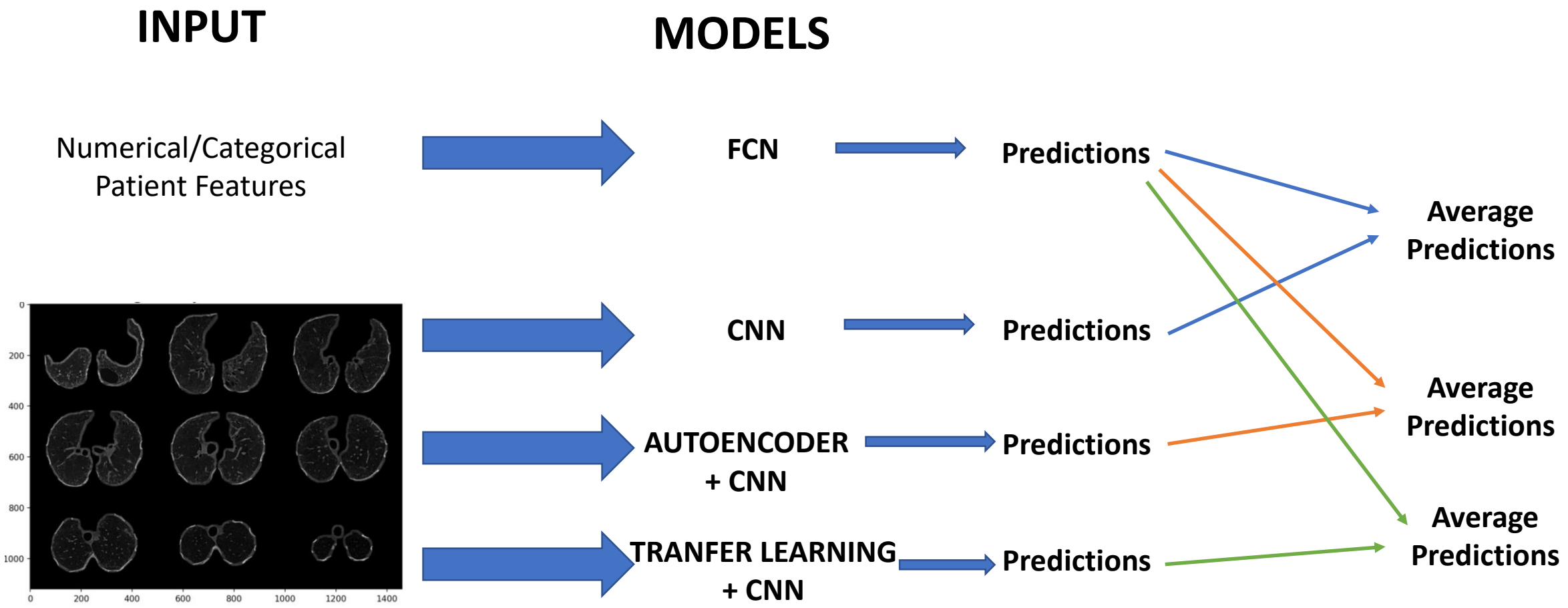
The lung capacity dropped for most of the patients

EDA – Area right and left lung





Modeling – Approaches

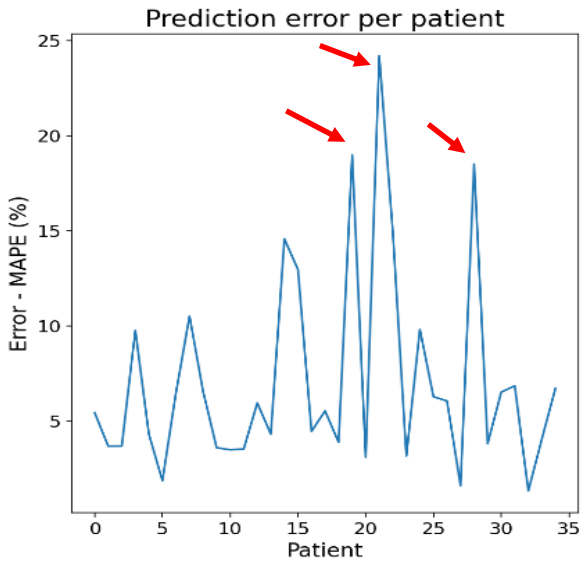


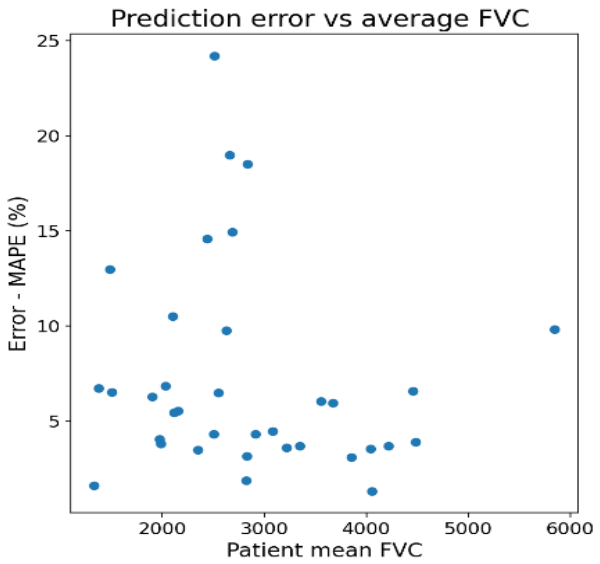
Modeling – Summary

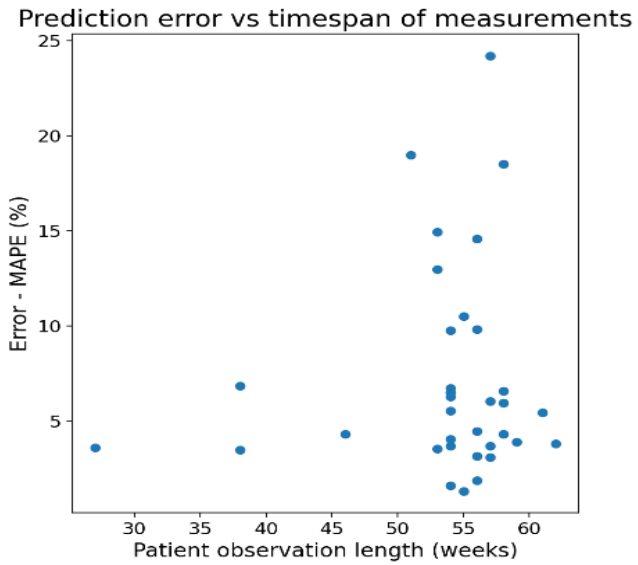
Model	Input	FVC prediction error: (MAPE)	FVC prediction error when ensembled with NN (MAPE)
NN	Numerical and categorical medical data	7.19%	N/A
CNN-1a	1536x1536 px, non-carved 3x3 images	Original contrast: 7.58% Normalized contrast: 7.33%	Original contrast: 7.33% Normalized contrast: 7.23%
CNN-1b	1120x1460 px carved 3x3 images	Original contrast: 7.34% Normalized contrast: 7.34%	Original contrast: 7.25% Normalized contrast: 7.24%
CNN-2 Encoder	1536x1536 px, non-carved 3x3 images	Enc 48x48, Norm. contrast: 7.24% Enc 96x96, Norm. contrast: 7.34% Enc 192x192, Norm. contrast: 7.44% Enc 384x384, Norm. contrast: 7.32%	Enc 48x48: 7.23% Enc 96x96: 7.22% Enc 192x192: 7.26% Enc 384x384: 7.22%
CNN-3 Transfer Learning	1024x1024 px RGB images 3x3 non-carved	Normalized contrast: 7.06%	Normalized contrast: 7.11%**

- Both patient medical data and chest CT images hold key information for the prediction of the future patient's lung capacity.
- Normalizing the contrast on the images consistently improve the model predictive power.
- Carving the lung out of the CT image does not improve the model performance.
- Transfer learning is the winning strategy.

Modeling – Analysis



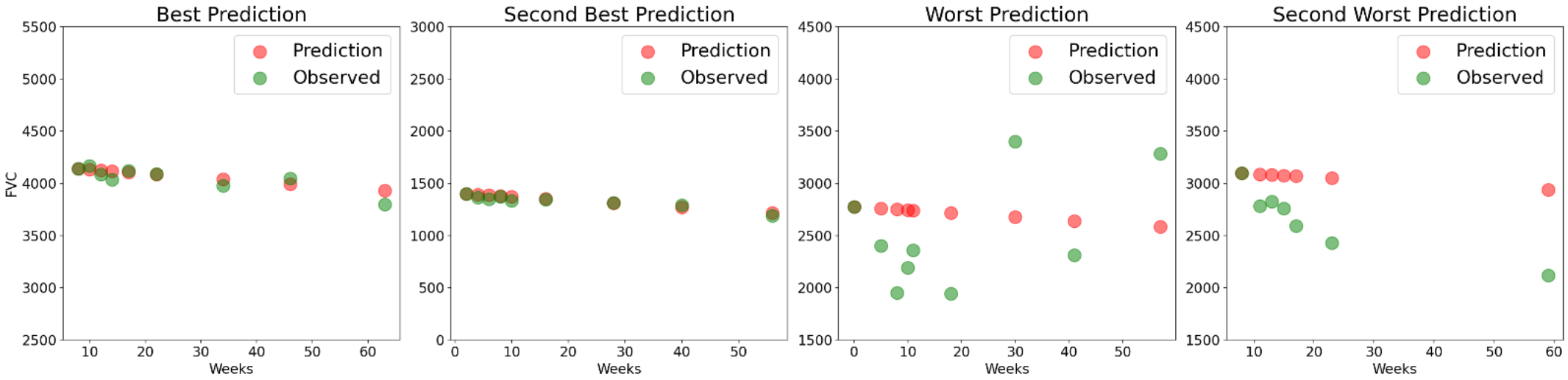




The error of the model is not correlated with the mean of the observed FVC measurements.

The longer the patient was enrolled in the study for, the higher the error of the model

Modeling – Analysis

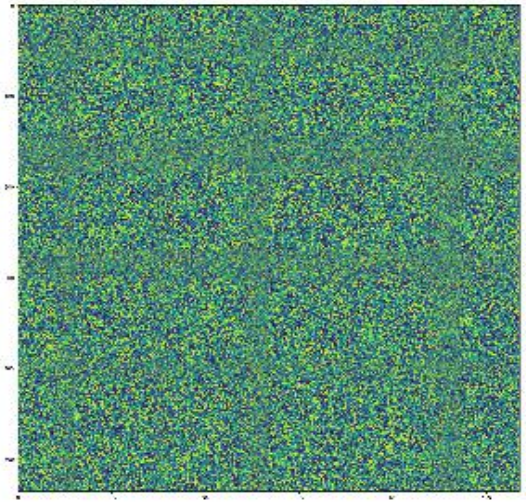
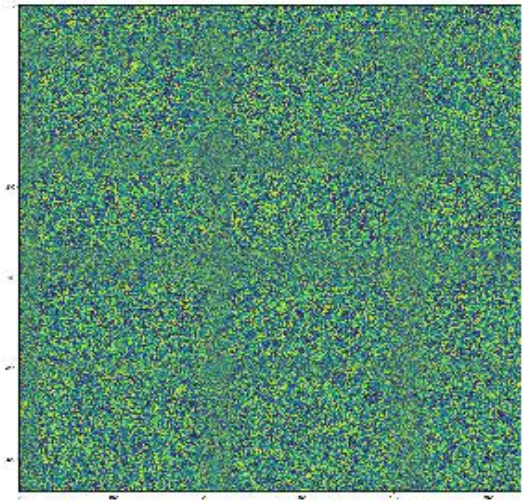
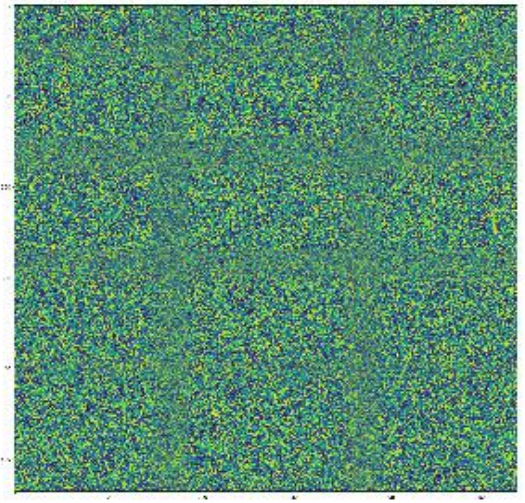
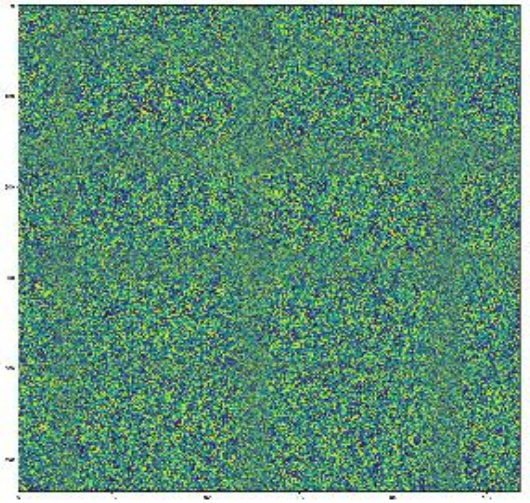


When the lung capacity of the patient drops linearly overtime, the model performs well

When lung capacity drops drastically, model overestimates FVC

Modeling – Analysis

What does the model “see”?

string-like patterns **?** shape of the scar tissue

Conclusion

- **Both the patient medical information** and **chest CT images** hold key insights for the prediction of the future patient's lung capacity.

- **Transfer learning** produced the best predictive models: MAPE **7.06%** (standalone) to **7.11%** (ensemble)

- The model performs well when lung capacity decays linearly but **underperforms otherwise**.
  → Utilize the last FVC measurement (or the average of last n measurements) as baseline value for the future predictions.

- **How to obtain better predictions:**
  - Information on the patients' pharmacological treatment (and when it was initiated),
  - Presence of comorbidities (such as diabetes, cardiovascular disease, other chronic diseases)
  - Other general information (blood pressure, weight, body mass index).
  - Increase the number of pictures