An automated and unobtrusive system for cough detection in COPD management

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What is COPD?

COPD
Chronic Obstructive Pulmonary Disease

COPD definition:

Chronic inflammation of the lung airways which results in airflow limitation

It is a global health problem:

- top three causes of mortality[1]
- Increasing incidence in the next years (6000 deaths each year in the Netherlands)
- Strong socio-economic impact

COPD & Cough:

- COPD patients complain of cough
- Cough is associated with an increased risk of hospitalizations

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[1] R. Lozano *et al.*, "Global and regional mortality from 235 causes of death for 20 age groups in 1990 and 2010: a systematic analysis for the global burden of disease study 2010," *The LANCET*

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Why cough monitoring?

"**COPD patients with chronic cough** may represent a **target population** for whom specific **cough monitoring** strategies should be developed"

Cough monitoring aims to:

- Assist the doctor in **patient management**
- **Identify** clinical deterioration
- **Prevent** hospital admission
- **Provide** early interventions
- **Education**: patient **learns** the **effects of his actions** on the disease

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Cough monitoring: existing methods

- **Questionnaire or manual counting**:
  - Time consuming
  - Laborious process
  - Not suitable for long term assessments

- **Worn devices (e.g. contact microphones, inertial sensors):**
  - Obtrusive
  - Patient might forget to wear it
  - Used only for short time monitoring periods
  - \+ Mobile

Hull Automatic Cough Counter (**HACC**)

There is **no standardized** cough monitoring **method** that is:

- Unobtrusive
- Automated
- Suitable for long-term assessment

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Goal and proposed solution

Goal:

Investigate whether it is possible to **correlate patients' symptoms** with the **coughs detected** by an automatic cough counter

Our Solution

Use of a **remote microphone** in conjunction with **machine learning algorithms** to design a **new cough monitoring system that is:**

- **Unobtrusive**
- **Automated**
- **Suitable for long term assessment**

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Experimental trial and Dataset

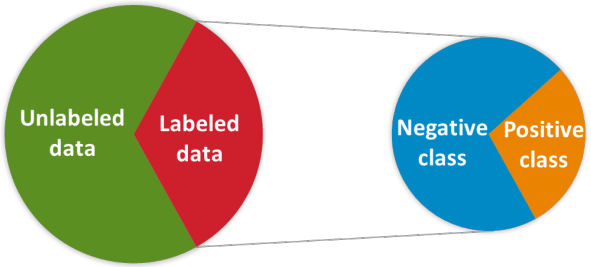
7 COPD patients monitored through a remote microphone for 90 days

Audio snippets collect

- Cough events
- Any other daily sounds (e.g. TV, speech)

Feature extraction

MFCCs (Mel Frequency Cepstral Coefficients)



Positive class: **patient** coughs

Negative class: any other sounds or partner coughs

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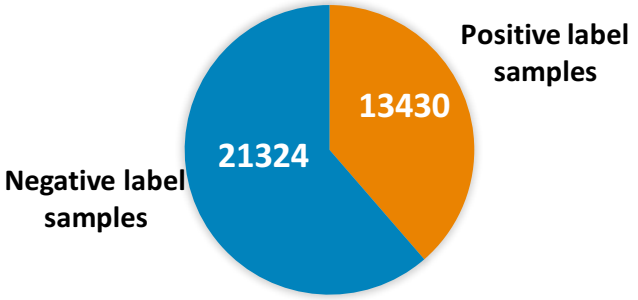
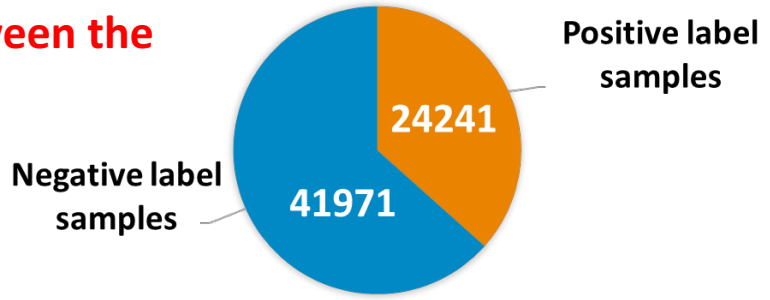
Two detection challenges proposed



Imbalance between the two classes



Challenge A:

- Cough monitoring system that aims to detect **coughs coming from any person in the environment**
- It can be used in medical environments where a COPD patient is living alone
- **Dataset:**
  - Old annotation for all the patients without coughing partner
  - New annotation made on the first 2 days for patients with partner
- **Labels:**

  Positive label: coughs regardless the person
  Negative label: any other sounds (e.g. TV, speech)

Challenge B:

- Cough monitoring system that aims to find out cough events of **COPD patients only**
- It would allow the medical doctor to remotely monitor the COPD patients
- **Dataset:**
  - Old annotation for all the patients made on 90 days
- **Labels:**

  Positive class: **patient** coughs
  Negative class: any other sounds or partner coughs

Machine learning algorithms used

One class approach

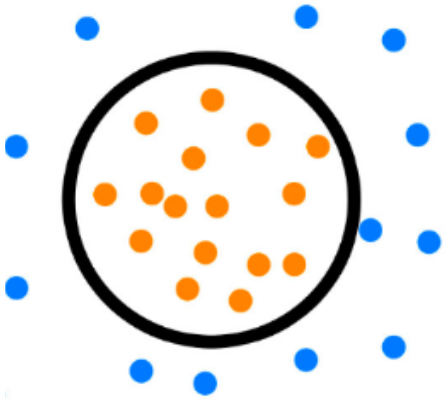
Binary class approach

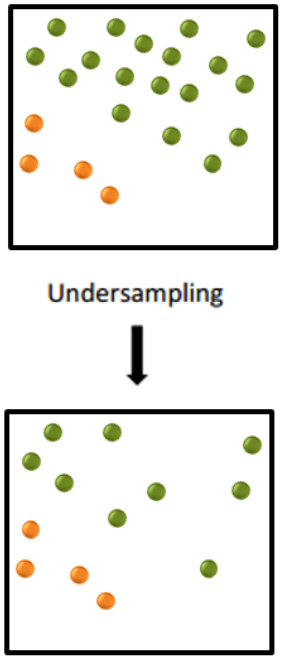
One class support vector machine (OC-SVM)

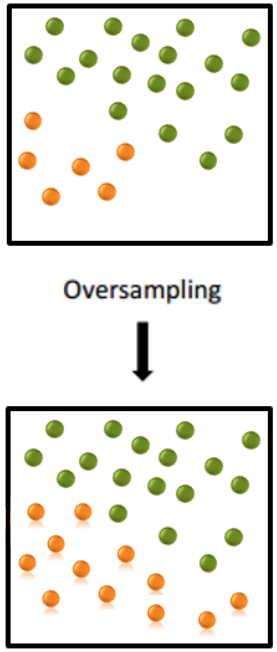
SVM with under-sampling method SVM-Allknn

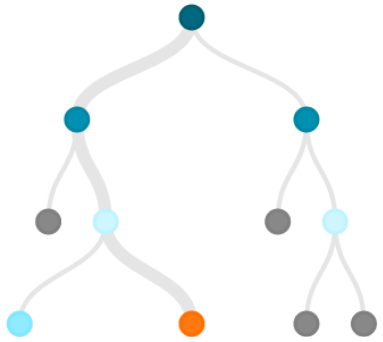
SVM with over-sampling method SVM-SMOTE

Ensemble method: XGBoost









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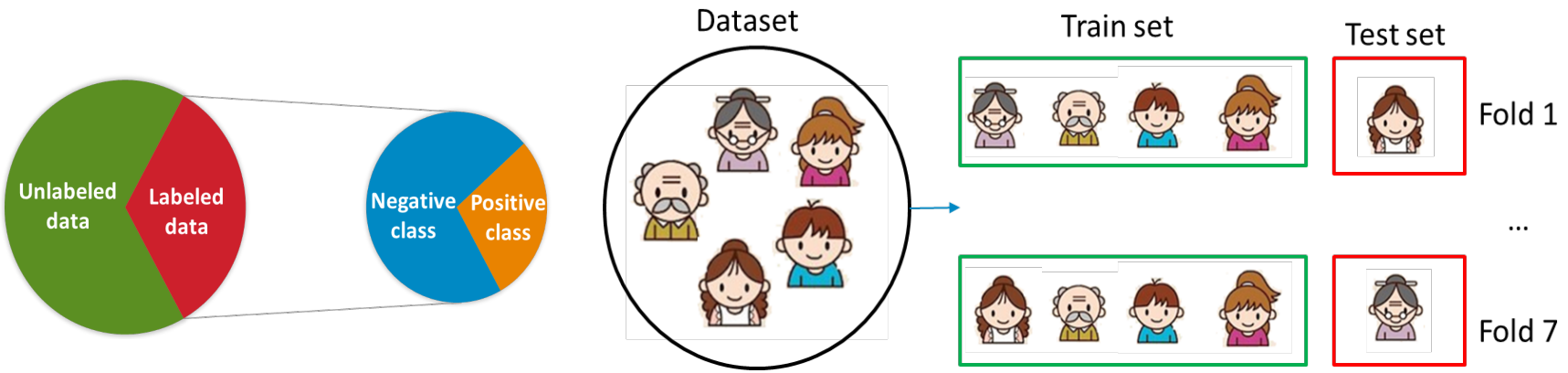
Development of the cough classification systems

Leave one subject out cross validation: Train on group of patients and then test on the unseen patient



Main features:

- It learns from a wide group of people with different type of coughs
- No labeling process required after the patient dataset creation
- Flexible
- Quick to use
- Suitable for large scale application

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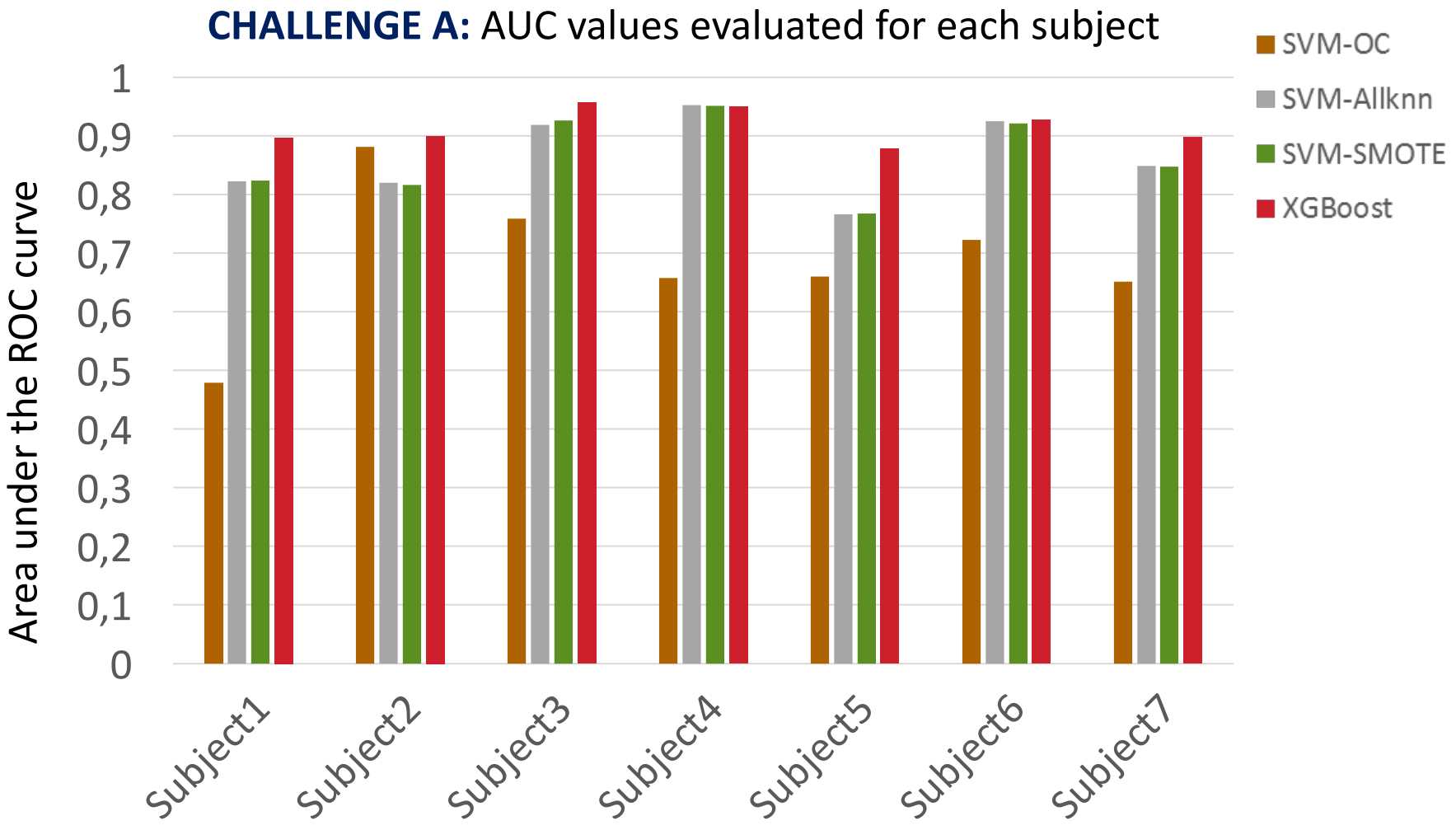
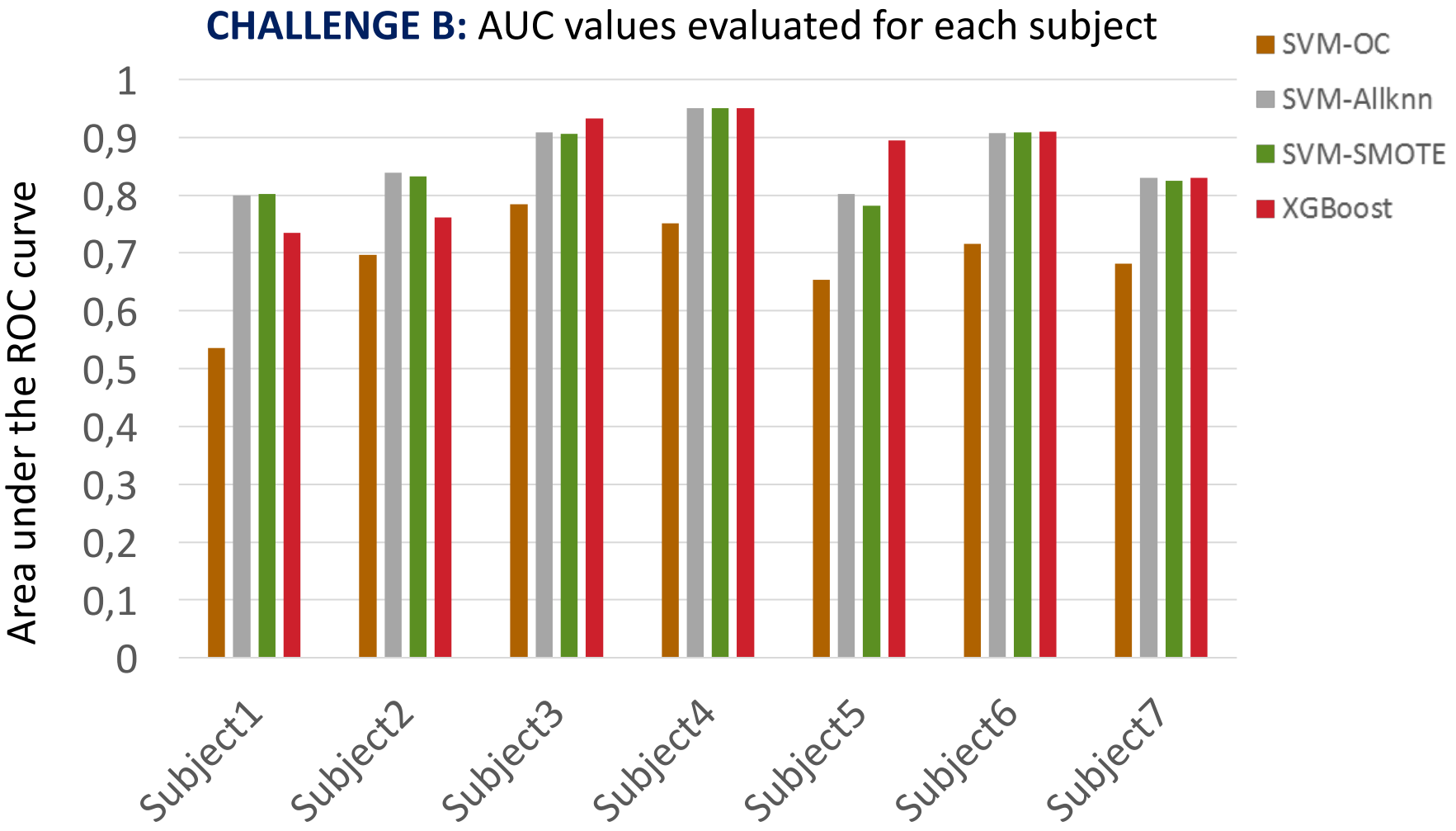
Results of the cough monitoring system challenge A



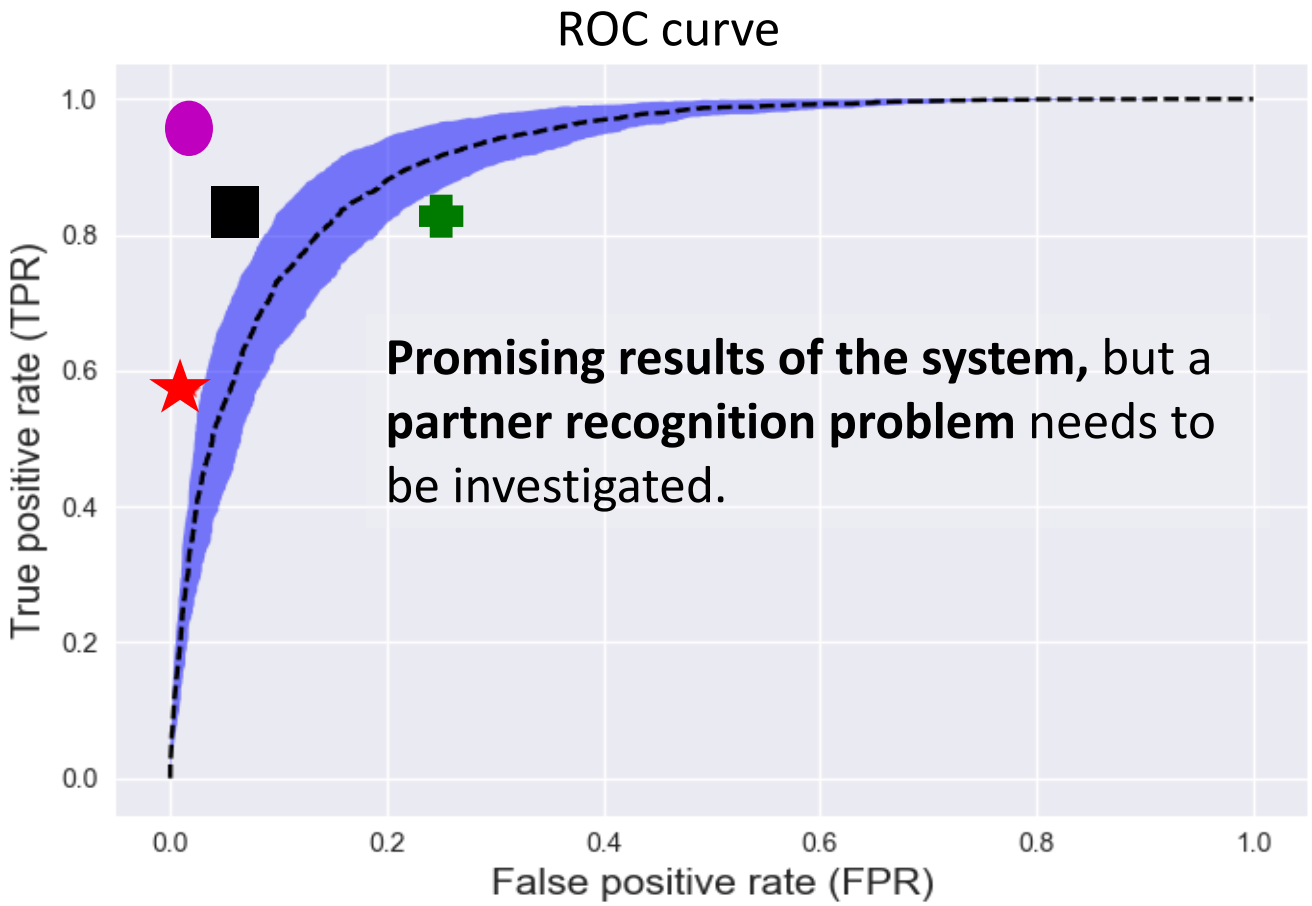
XGBoost provides the best performance (AUC = 0.916 ± 0.027) for detecting environmental cough events for all the patients including the ones with the coughing partner (Subject1, Subject2)

Results of the cough monitoring system challenge B



XGBoost performs better (AUC = 0.858 ± 0.079) or quite the same for all the subjects **except for S1, S2 (with coughing partner) where the SVM-Allknn and SVM-SMOTE perform better.**

Developed system (challenge A) against competitors



- Mean ROC on all patients (**Automated, unobtrusive, long-term assessment**)
- Standard deviation
- Recurrent deep neural network (automated, obtrusive, short-time assessment)
- Convolutional deep neural network (automated, obtrusive, short-time assessment)
- HACC/LCM (semi-automated, obtrusive, short-time assessment)
- VitaloJAK (manual assessment, obtrusive, short-time assessment)

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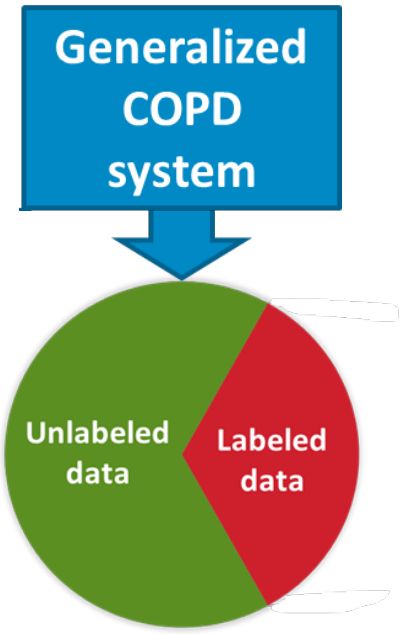
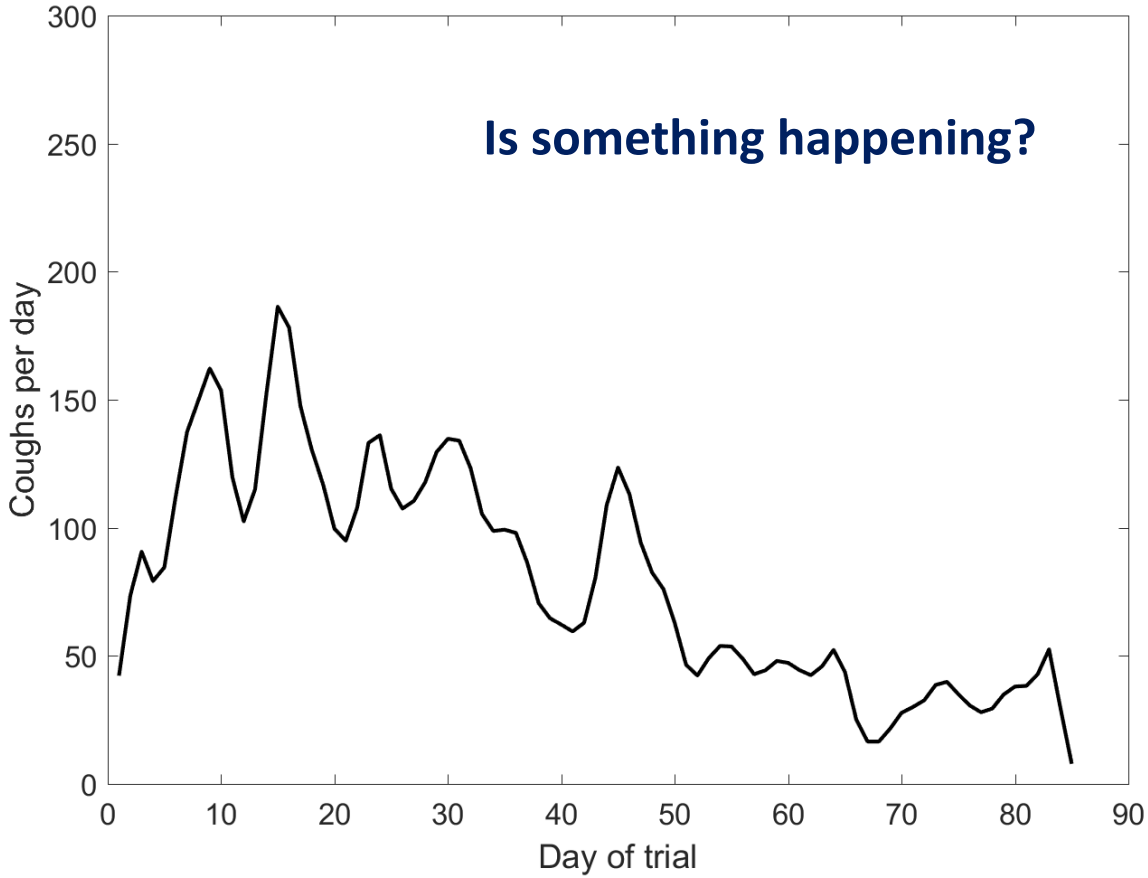
Possible outcome: Cough trend over days



Use the probability in output from the classifiers to generate a binary output (Cough, not cough)

High values of decision thresholds might be selected in order to have a **conservative system** where **cough events detected** have an **high probability** that are **coughs**

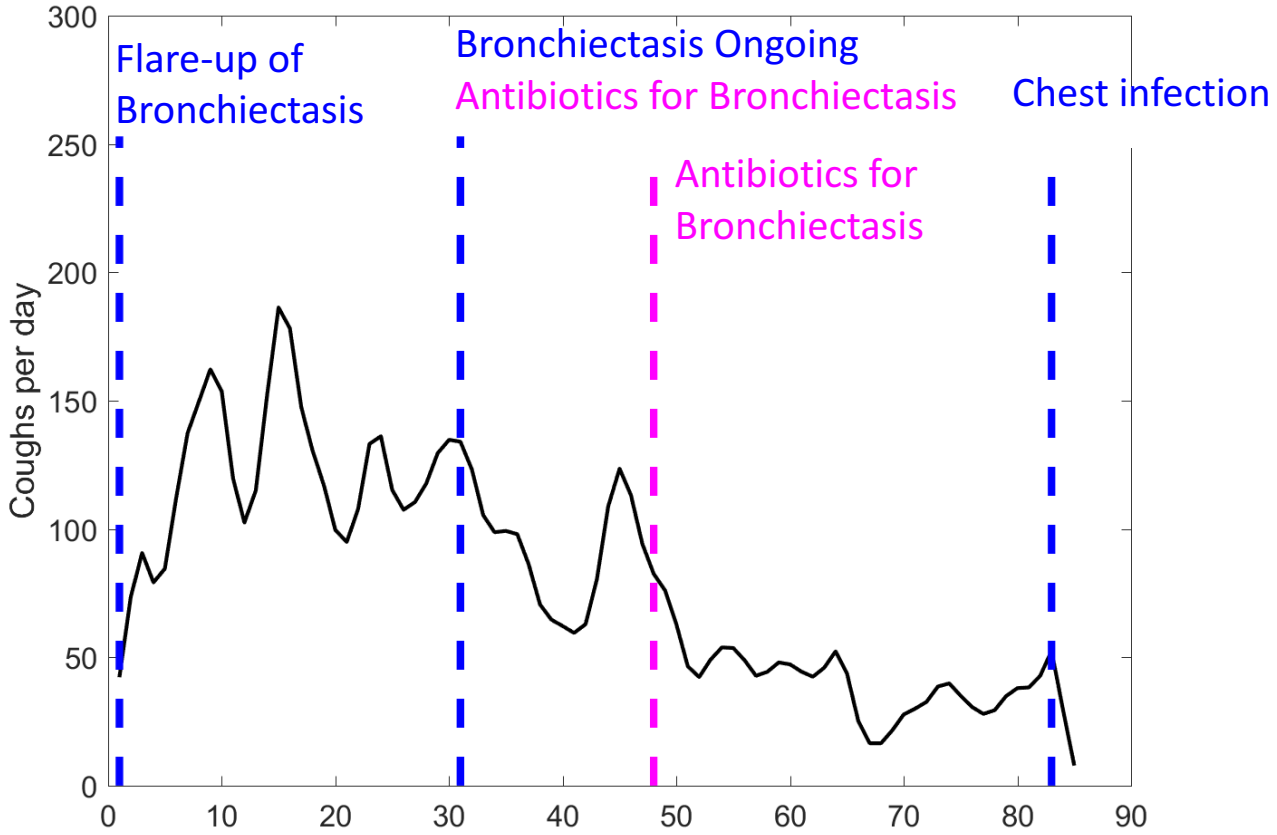
Possible outcomes: Cough trend over days



Interpretation:

- Increasing trend at the beginning of the experimental trial
- Then a decreasing trend

Possible outcomes: Cough trend over days



Interpretation

- Increasing trend at the beginning of the experimental trial → **Bronchiectasis**
- Then a decreasing trend → **Antibiotics**
- Chest infection might be due to different symptoms or cough is changing

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Conclusions

We developed a new cough monitoring system that is unobtrusive, automated and suitable for long term assessment

Results are **promising** and comparable to competitors that, however, are not fully automated and unobtrusive.

The cough classification system is able to detect

- **Challenge A:** coughs coming from any person in the environment with an AUC of **0.916 ± 0.027**

- **Challenge B:** cough events of COPD patients only, with an AUC of **0.858 ± 0.079**

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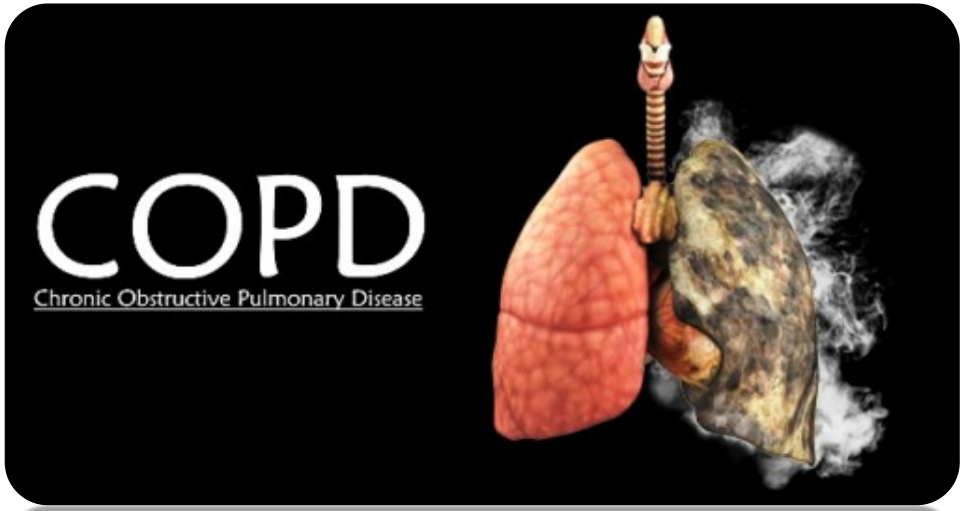
Future Works

Future works:

- Enlarge the number of patients enrolled in the study
- Study the correlation between symptoms and cough trend
- Design a classifier that allows a **partner recognition**

One step ahead in COPD management !



Thank You!

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