An automated and unobtrusive system for cough detection in COPD management

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What is COPD?

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

\(^1\) R. Lozano \textit{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,” \textit{The LANCET}
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
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

There is **no standardized** cough monitoring **method** that is:
- Unobtrusive
- Automated
- Suitable for long-term assessment
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
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
Two detection challenges proposed

**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

**Imbalance between the two classes**

- **Positive label samples:** 13430
- **Negative label samples:** 21324
- **Positive label samples:** 24241
- **Negative label samples:** 41971
Machine learning algorithms used

One class approach

One class support vector machine (OC-SVM)

Binary class approach

SVM with undersampling method
SVM-Allknn

SVM with oversampling method
SVM-SMOTE

Ensemble method: XGBoost

Undersampling

Oversampling
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
Results of the cough monitoring system challenge A

**CHALLENGE A:** AUC values evaluated for each subject

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)
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

Promising results of the system, but a partner recognition problem needs to be investigated.

- 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)
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 a 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
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 $0.916 \pm 0.027$

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