Exploiting the Power of the Crowd for the efficient monitoring of diseases exacerbation

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Thank you ITU and Bournemouth University for the invitation.

Webinar Section → Crowdsourced Systems: A people-led paradigm

- https://www.itu.int/en/ITU-T/webinars/20211102/Pages/default.aspx

Our Team

Who we are:

- IoT Lab, Computer Engineering and Informatics
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- Computer Technology Institute “Diophantus”
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Where we are:

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Digital Healthcare

Healthcare **keeps being one of the most important social and economic challenges worldwide, asking for new and more advanced solutions from science and technology!** → Solution → ***Digital "Smart" Healthcare*** → **Internet of Things**, **Healthcare 4.0 & Healthcare 5.0!**

Application examples:

- personalized glucose monitoring, "smart" respirator for personalized asthma monitoring
- personalized sleep, heart rate monitoring through smartwatches and smart-rings
- IBM Watson and Teva have launched a new IoT project for new methods of treating and predicting chronic diseases.
- Apple reportedly working on technology to detect early warning signs of cognitive decline and depression through smartwatch
- Huawei provides personalized stress levels monitoring from vital signs through smartwatch device

An interesting scenario: Implicit COVID-19 exacerbation prevention → *Oura smart-ring* early detection device → heart rate variability, respiratory rate and temperature—among other metrics—to craft a "Risk Score," → attempt to mitigate the silent spread of COVID-19 by flagging potential onset symptoms.

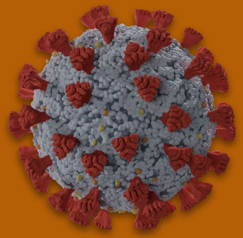
However, the aforementioned solutions are envisaged for *personalized only* disease monitoring.

A Smart IoT Healthcare system workflow.

Smart health monitoring. *Left*: Glucose levels. *Right*: Asthma.

Apple smartwatch.

Oura ring.



Issues & Challenges regarding Healthcare

Common Diseases:

- Chronic diseases → e.g. Allergic Rhinitis, heart disease, diabetes, arthritis
- Epidemic diseases → e.g. COVID-19, Flu

Our case of study → Allergic Rhinitis

Environmental allergic diseases affection:

- among the most common diseases in the world and rank first in Europe
- impact on millions of people life (Quality of Life - QOL)
- consequences: workdays, daily activities, sleep, etc. → individual, company, organizations

Most common allergic disease worldwide: **Allergic Rhinitis** → **pollen grains**

Pollen specifications: airborne over long distances, correlated with various environmental factors (irritants) → humidity, dust → climate change!

For patients, the knowledge of allergens' season onset and counts of detection can yield:

- better control of symptoms + premature treatment start
- when travelling → identification + characterization outside the usual symptoms region
- assessing the exposure to various spatial areas

Issues in Healthcare: high cost of medical diagnosis, expensive services → increase in chronic diseases, like allergic rhinitis!

Challenges! → How can we efficiently achieve:

- spatio-temporal, large-scale monitoring, in real-time?
- early exacerbation prevention?
- prevent the diseases' onset?
- How can we manage hospital operations efficiently corresponding to each disease?
- non-invasive way of monitoring? → patients are getting bored in case of manually participation to the data collection process
- patients' adherence to treatment?

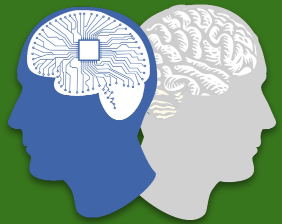
Solution though a People-led paradigm

Solution? → **Yes**! → The exploitation of:

- the power of the crowd through technology and integration of its cognitive knowledge into Healthcare
- IoT non-invasive wearable devices + smartphones

Various technology domains elaborate hybrid information and collaborate with each other providing a much better way for various diseases monitoring than the existing conventional ones:

- Internet of Things (IoT) → usage of smart devices for vital data collection + localization of symptoms
- Crowdsourcing → crowd-intelligence
- Crowdsensing → collaboration of the machine and human intelligence
- Artificial Intelligence → cognitive results



Achievement through a a multidisciplinary study → A hybrid "Smart" eHealth/mHealth Crowdsourcing and Crowdsensing System in the domain of Digital Healthcare for the efficient Allergic Rhinitis monitoring → sentinel of the disease:

- beneficial for communities and organizations through a People-led paradigm
- monitoring is transformed from micro, individual scale to large-scale
- automated collection and analysis of large volumes of patients' data
- early warning in cases of life-threatening circumstances

Allergic Rhinitis monitoring challenges

Instead of the effort of some applications to monitor pollen onsets, these monitoring platforms are developed based only on accurate sensors' measurements.

Restrictions:

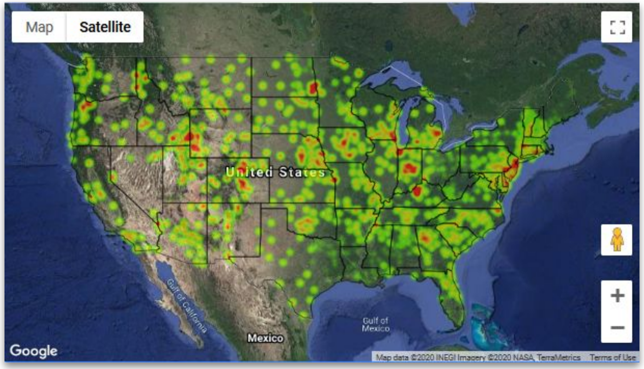
- these sensors are very expensive to be manufactured, placed, and maintained
- the spatial coverage of such systems is quite restricted
- other coefficients correlate with allergic symptoms, e.g. atmospheric conditions, air pollution irritants

Question: How could we achieve better and detailed coverage for the rest of the areas?

Our work started by studying and checking where Pollen's measurements come from in the USA → **there is a huge absence of sensors in the various areas**.

Why the USA? → An easier way to begin our study because of the unilingual context regarding all the regions → English language.

Rotorod Sampler sensor.

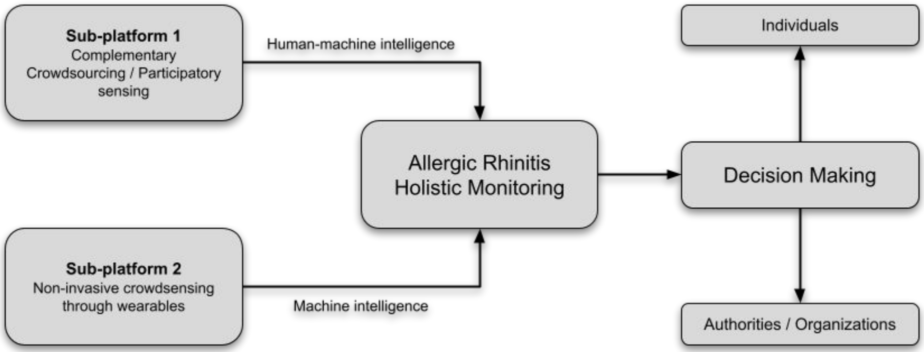


Pollen-Rotorod sensors placed in the USA.

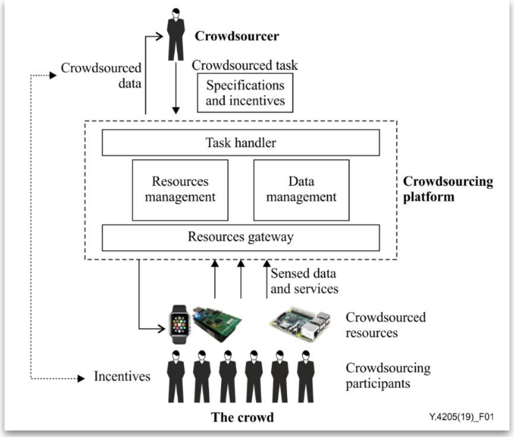
A “Smart” holistic disease surveillance Sensing Platform

Efficient Allergic Rhinitis monitoring → A platform that is developed based on the *ITU-T Y.4205 standard* and comprises 2 main sub-platform components, each one introducing different roles in the sensing scenario:

- Complementary crowdsourcing & users’ participatory Mobile Crowdsensing (MCS) → Hybrid Human-machine knowledge
- Non-invasive, implicit crowdsensing through wearable devices → Machine knowledge → Advanced Artificial Intelligence
- Web Application with an easy to use User Interface → Cognitive results.



The “Smart” Surveillance Sensing Platform.



The ITU-T Y.4205 standard.

Component 1 - Complementary sensing (I)

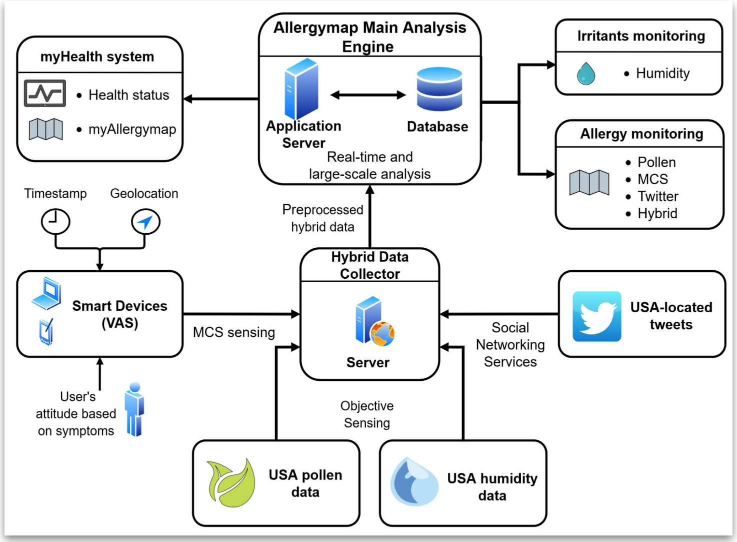
The Component 1 sub-platform architecture

Inputs. Information collection from various heterogeneous sources:

- *Subjective*: spatio-temporal recordings from users' participation → personal assessment regarding their allergic symptoms. → cross-platform (smartphones, tablets, etc.). → **MCS inputs**.
- *Objective*: pollen & humidity concentration levels from sensors.
- *Social Networking Services*: *public only* text posts from Twitter related to allergic rhinitis → collection of tweets that contain allergic-rhinitis-related hashtags and word terms.

Outcomes. Spatio-temporal Maps + Health status line plots:

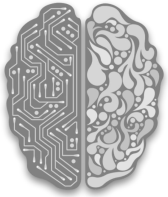
- *Allergic Rhinitis & Humidity monitoring in the USA*: hybrid spatio-temporal representation of the senses , as well as each one separately.
- *Statistical (Categorical and Time Series) analysis* about symptoms' and the allergens that are responsible for the exacerbation in allergy season.
- *Personalized mHealth system*: health course through time and the locations the symptoms occurred.



The Complementary sensing platform.

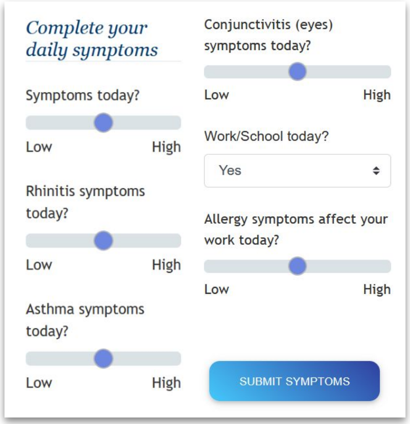
Privacy: data anonymization in analysis procedure, user notification regarding data collection
Security: DB authentication access, credentials encryption, SSL encryption, CSRF token

Component 1 - Complementary sensing (II)



The Main Analysis Engine:

- Statistical analysis & AI → depending the source:
  - Twitter posts: **text-mining** using Natural Language Processing and AI → Goal: recognize all incoming tweets that correspond to allergic rhinitis content:
    - locating public tweets based on the timezone and the state's code or name assigned by the user to her profile (e.g. TX, Texas)
    - Machine Learning based on text extracted features → **92,3% accuracy** in recognizing *only allergic rhinitis-related tweets.*
  - Mathematical and statistical correlation of quantitative Social Networking Services' results with the sensor measurements and the MCS participatory qualitative information.
- Each component complements the other in a hybrid manner, even in case of the absence of one or more of the rest ones. → **Dynamic Analysis based on the sources' amount of data for a specific region.**



Users' personal assessment tool regarding their allergic symptoms.

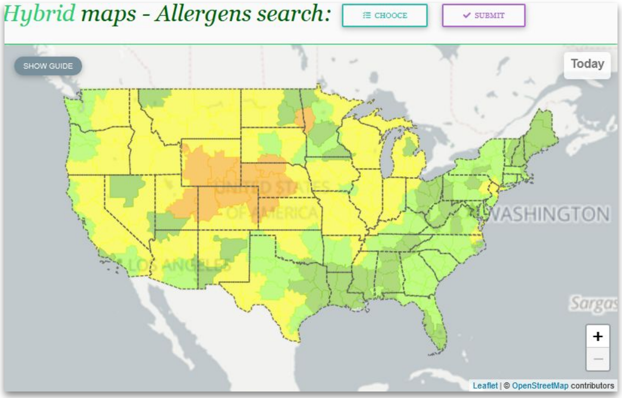
Outcomes - Holistic sensing (I)

Outcomes (I) → Allergic Rhinitis onset levels in various regions:

- Interactive visualization through a User Interface → user experience
- cognitive knowledge
- better decision making

Achievement → a complementary sensing paradigm!! → human perspective, sensing technology, and machine intelligence complement each other to provide a holistic perception of the ongoing disease impact → **Fully coverage for the disease onsets monitoring!**

Privacy concerns: Data anonymization through analysis and visualization procedures.

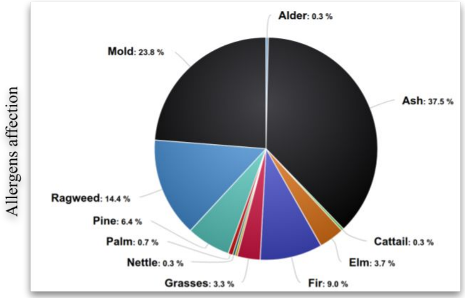


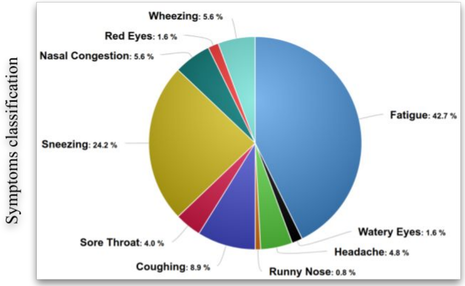
The hybrid spatio-temporal mining for Allergic Rhinitis exacerbation in the USA.

Outcomes - Holistic sensing (II)

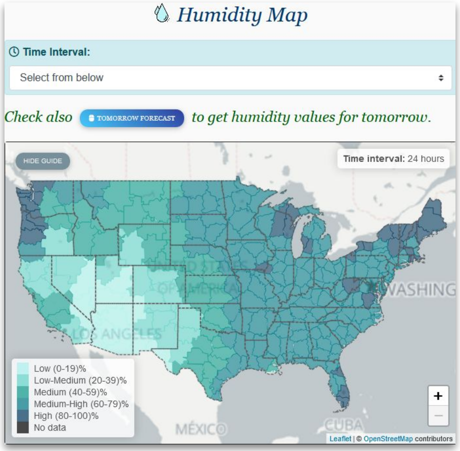
Outcomes (II):

- Useful disease stats extracted from citizens' Twitter posts.
- Time Series analysis for symptoms exacerbation for a selected period of time.
- Humidity (irritant) monitoring through sensors' measurements.





Distribution of the Symptoms that occurred and Allergens that affect the citizens in a specific period of time.



Humidity monitoring based on a selection period of time.

Symptoms exacerbation for a selected period of time.

Motivation - Personalized Health Monitoring

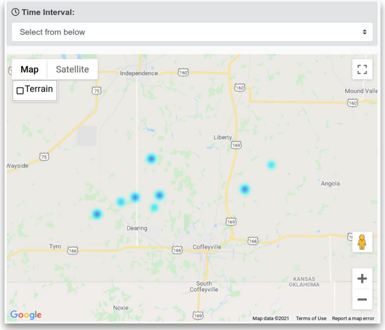
User motivation to participation process: increases the monitoring of the health progress of the citizens → motivation to participate in such initiatives is needed.

⇓

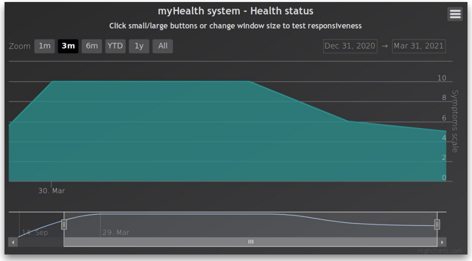
myHealth system

- incentivization mechanism → patient's adherence to treatment improvement
- How? → providing the following *personalized* features based on the symptoms assessment tool submitted recordings:
  - *health status*: how the symptoms affect attitude through time
  - allergic traces heatmap: where and when symptoms occurred → avoidance of such places
  - the users also are encouraged to update their allergy information every two to four weeks
  - medicines and immunotherapy recording → track treatment history

Inference: efficacy of the user treatment → extraction and sharing with the relevant physician → better decision making.



Traces where symptoms occurred.



User's health status based on her historical attitude that occurred from her symptoms.

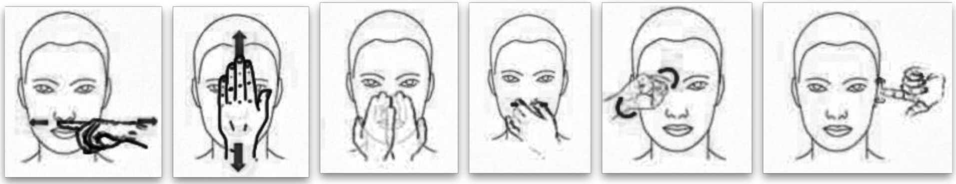
Component 2 - Implicit non-invasive crowdsensing (I)

However, even with the usage of various motivation mechanisms, the user's participation in the crowdsourcing systems has been approved a difficult scenario → **discontinuous participatory sensing**.

How can we get continuous allergic-rhinitis symptoms' exacerbation recordings? → Can we enhance the contribution of the crowd?

Solution? → Yes!! --> A non-invasive way of sensing through smart wearables → exploitation of IoT devices and AI → Human Gesture Recognition:

- Patterns detection in allergic rhinitis symptoms → In patients with allergic rhinitis, contact of the mucosal surfaces of their nose, eyes and middle ear with airborne allergens triggers inflammatory responses presenting as nasal congestion, nasal discharge, sneezing, and itching. As a result, those suffering from allergic rhinitis and/or conjunctivitis, when symptomatic, they perform more or less typical gestures as a response to allergic symptoms.
- Smart wristbands / smartwatches usage.
- **Promoting the sensing procedure at an advanced level.**



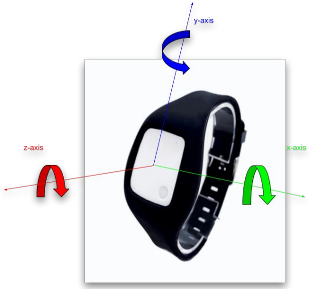
An indicative subset of allergic gestures examples.

Component 2 - Implicit non-invasive crowdsensing (II)

Data collection procedure:

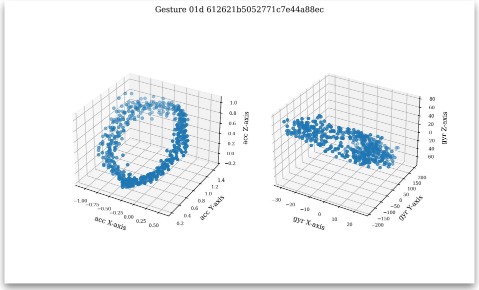
- Doctor stakeholders identified the gestures based on statistical inferences from the patients.
- The clinic data is collected in specialized outpatient clinics in Greece through a modern Web Application that exploits Web Bluetooth API for wristband connectivity directly with the browser.
- A data collection procedure took also place in a laboratory environment → pure gestures with minor noise.
- It is observed that the predefined gestures have different patterns both in accelerometer and gyroscope 3-axes signals (see the Figure on the right).

Note: The data collection process was blocked by the Greek authorities for almost two years because of the COVID-19 exacerbation worldwide → Huge danger for infection through data collection from real patients in the hospital clinics.

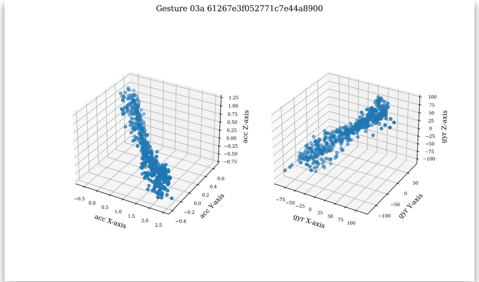


MbientLab MetaMotionR wearable sensor kit.

Bosch BMI160 Inertial Measurement Units (IMUs) including motion sensors embedded in MetaMotionR.



The patient uses the palm to rub the tip of the nose in a circular manner.

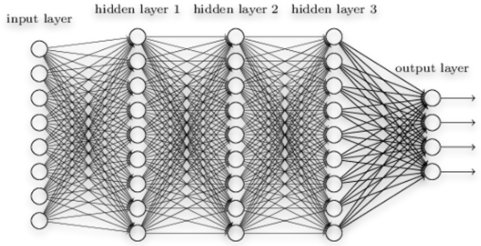


Vibrating maneuver of the tip of the index or the little finger after insertion to the ear canal.

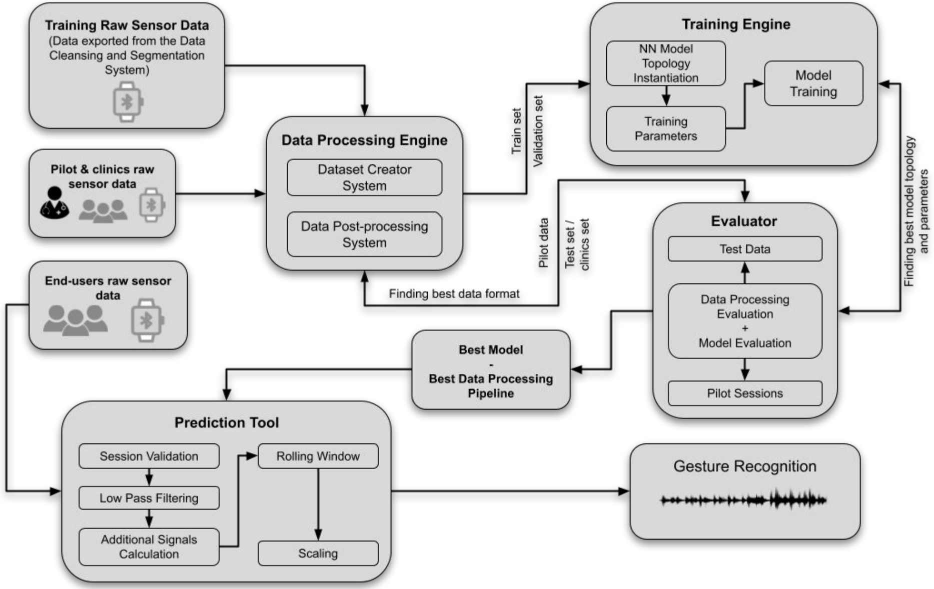
Component 2 - Implicit non-invasive crowdsensing (III)

The Component 2 sub-platform architecture.

- advanced embedded AI
- complex data processing in multiple layers
- automated features extraction
- very deep and different Neural Networks topologies developed, tested, and evaluated
- Neural Networks evaluation of the algorithms both on test and real world data
- evaluation of the algorithms on real-world scenarios



A deep dense Neural Network.



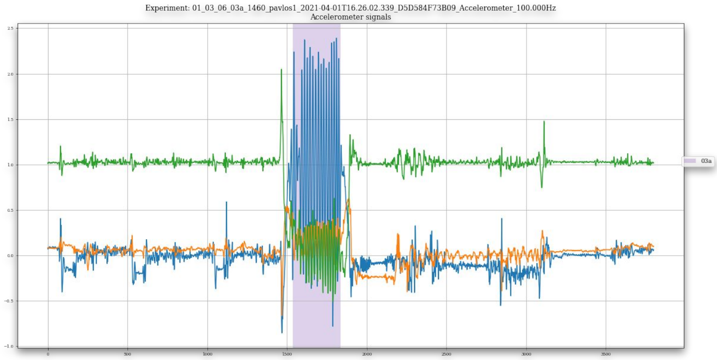
The advanced AI platform for Human Gesture Recognition.

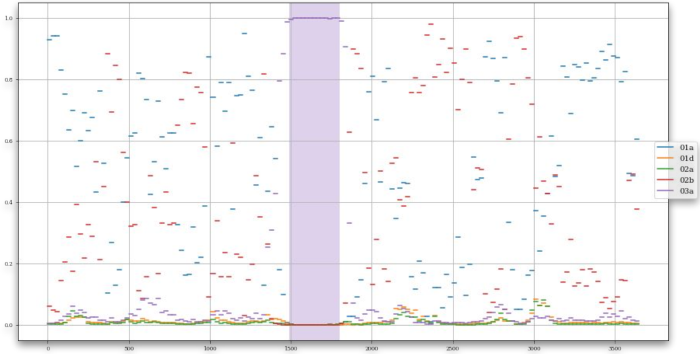
Component 2 - Implicit non-invasive crowdsensing (IV)

Accuracy of the best extracted model (even with few amount of data) → 89,7%

The example below shows a patient that executes a scenario with various activities (writing on a laptop) while in some time doing the allergic gesture we want the platform to predict (marked with purple color in the left Figure) → our platform recognizes with high confidence the predicted wished gesture (Figure on the right → purple color).

Future work: Optimization of the model output through the collection of more data from real-patients and re-fine-tuning both the Neural Network model and the data processing parameters. → better generalization of the model!





Inferences

Contribution to the community:

- using **the power of the crowd** mostly in a **passive** and **implicit** manner → high contribution → **continuous sensing**!
- decisively contribute to the control of the allergic respiratory diseases
- reducing morbidity and improving the quality of patients' life and their performance
- positive economic impact by reducing the loss of working hours and maintaining the productivity of patients with respiratory allergy

Benefits:

- Transfer of medical examinations from the hospital (hospital-centric) to the patient's home (home-centric)
- Proper and timely diagnosis, as well as disease spatial onset prevention will reduce the need for hospitalization

Indicative solutions and future work:

- Remote patients monitoring from the stakeholder doctor, in real time
- Management of hospital operations
- Connectivity of a variety of affordable for the people wearable devices
- Remote medical assistance

The platform can be exploited for other diseases' monitoring too with the appropriate modifications and data recordings.

References

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Publications:

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Thank you!

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