Take-A-Breath: Smart Platform for Self-management and Support of Patients with Chronic Respiratory Diseases

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Abstract. This paper presents the Take-A-Breath project, which focus on the development of an advanced system for supporting personalized approaches to self-management of chronic patients with respiratory diseases to significantly increase the effectiveness of the medical care. Take-A-Breath is a project co-financed by the European Regional Development Fund of the European Union and Greek national funds through the Operational Program Competitiveness, Entrepreneurship and Innovation, under the call RESEARCH – CREATE – INNOVATE. The project has started on July of 2018 (M1) and will have a duration of 36 months. The first section of this report provides an overview of Take-A-Breath, by presenting objectives and innovation aspects as well as by describing the work plan, the implementation phases, the expected results and the impact of the project. The current status of the project is described in section 2, while conclusions and future work are included in the last section.

Keywords: Chronic Obstructive Pulmonary Disease (COPD), Asthma, Health Self-management, Gamification Techniques, Virtual and Augmented Reality.

1 Project Description

1.1 Take-A-Breath Objectives

Chronic respiratory diseases such as asthma and Chronic Obstructive Pulmonary Disease (COPD) are considered to be major health problems of the modern age. In order to understand the magnitude of the problem, it is worth mentioning that COPD is the fourth leading cause of death in the United States and is set to climb to third place in the next four to five years while in Greece, statistics show that 8.5% of the population suffers from COPD. In 2011, there have been recorded 300 million cases of asthma worldwide, including 250,000 deaths.

The aim of Take-A-Breath project, is to design, research and develop an innovative system of personalized monitoring services for respiratory diseases, through the combination of clinical research and new bio-indicators with innovative ICT technologies, such as gamification techniques. Specifically, it enables the guidance of patients to manage their own health, by providing user-friendly tools and applications to increase awareness of the clinical situation and the effectiveness of their health care as well as compliance to treatment. More specifically, the ***objectives*** of the project are:

1. Development of an innovative system for the self-management and compliance in the treatment of patients with chronic respiratory diseases;
2. Design and development of a wireless personal add-on system using non-intrusive (minimally discrete) sensors and technologies that can be adapted to any drug inhaler (pMDIs, DPIs);
3. Use of innovative and augmented reality technologies for effective guidance / assistance of patients (adults and children) in the daily use of drug delivery devices in collaboration with the wireless bio-monitoring system;
4. Implementation of a personalized patient monitoring and guidance platform capable of running on a mobile device (smartphone, tablet) for the effective education of patients;
5. Design and development of an in-depth subsystem of medical inherence and decision support (clinical platform) for effective prediction and interventional treatment of asthma attacks;
6. Evaluation and demonstration of good functioning of the proposed system in real conditions through a pilot application to patients.

Innovation aspects:

- Adoption of innovative software technologies (virtual and augmented reality environment, clinical decision-making system) and hardware (wireless personal bio-monitoring system), aiming at the implementation of a set of advanced self-management services for patients with chronic respiratory diseases, radically changing the way of dealing with the disease.
- "Regular monitoring" is transformed into "personalized monitoring" in real time, the correct use of the pharmaceutical device is controlled in an innovative way, while an early prediction is achieved and the system proposes to the patient a series of instructions for effective intervention to prevent asthma attacks and emergency situations.

The ***Take-A-Breath consortium*** consists of 3 research entities: 1) Information Technologies Institute, Centre for Research and Technology Hellas (CERTH/ ITI–coordinator, CERTH / INEB),2) Department of Electrical and Computer Engineering, University of Patras (UPAT) and 3) Department of Pulmonology, Medical School, Democritus University of Thrace. Moreover, it consists of 2 SMEs: 1) ALLERTEC and 2) VIDAVO, as well as the General Hospital of Ioannina.

1.2 Project Implementation Methodology

The Take-A-Breath work plan is structured in the following 6 work pachages (WPs):
WP1: User Requirements and System Architecture (M1-M24)
WP2: Clinical Study - Testing and Measurements' Protocol (M1-M33)
WP3: Intelligent Add-on for Correct use of the Inhaler drug intake device, via Wireless Sensor Network (M1-M24)
WP4: Intelligent Self-Management Platform and Personalized Guidance (M3-M32)
WP5: Clinical Monitoring and Medical Support System (M1-M36)
WP6: Experimental Assessment and Pilot Demonstration of the system (M18-M36)
The key components of the Take-A-Breath system are: (a) the user's bio-monitoring subsystem, (b) the subsystem for personalized self-management of respiratory diseases, and (c) the medical inherence and decision-support subsystem. The combination of these subsystems with the necessary graphical user interface modules, etc., will result in the implementation of the integrated Take-A-Breath application, which will operate on users' smartphones / tablets, for users of different ages and according to the specifications and usage scenarios defined in detail by WP1. The work plan includes 5 phases which are complemented by the horizontal work of disseminating knowledge and coordination of the project. The **first stage** (Stage of Specifications) includes the translation of end-user needs and partner know-how into a set of functional requirements for the individual Take-A-Breath subsystems. The **second stage** is a detailed planning process where the coordinators of the specific work modules will focus their efforts on the composition of the individual architectures for each of the individual Take-A-Breath subsystems. In the **third stage** of the project (Implementation Phase) the detailed architecture designs of the subsystems will be developed into hardware and software functional elements for the reference platform. The **fourth stage** is the Integration Stage which will integrate and interconnect all the subsystems developed at the previous stages. Interoperability and coordinated communication will be tested with appropriate usage scenarios, while additional adjustments will be made to optimize the operation of Take-A-Breath as an integrated system. The **fifth and final stage** involves the installation and the Take-A-Breath Pilot Test by a set of end-users. The pilot operation will be supported by all partners, implementing streamlined regulatory actions when required.

1.3 Expected Results

The successful outcome of Take-A-Breath is expected to bring both economic and social benefits to users and stakeholders by i) improving the quality of life of patients,

ii) significantly reducing exacerbations, iii) informing clinicians and pharmaceutical companies about symptoms / environmental changes and use of inhaler-related correlations, through the development of tools for improved services and products for monitoring and guiding the use of inhaled drugs, for individual patient. The above results include the following implementations:

- Intelligent Device for the Proper Use of Drug Inhalation via Wireless Sensor Network.
- Intelligent Self-Management Platform and Personalized Guidance
- Clinical Monitoring and Medical Support System.

The Take-A-Breath expected results will be important for the following categories of users and stakeholders:

- *Asthma/COPD patients*: patients will receive suggested strategies able to reduce individual's risk of exacerbations through the online platform and mobile application;
- *Relatives and friends of sufferers*: they will be able to receive timely and valid information on the risks and incidents that may trigger exacerbations;
- *Health professionals*: they will be able to continuously monitor disease progression of each patient and to identify correlations between different ways of using inhaled drugs and exacerbations;
- *Business (pharmaceutical and inhaler manufacturing companies):* Companies will be provided with tools that will enable them to make better use of their potential and to significantly improve their services and products.

2 Current Status &Achievements

Currently, the Take-A-Breath project has completed its first year and specifically the following activities have been finalized:

- *State-of-the-art analysis, selection and benchmarking of best technology practices*: Analysis has been performed on the current technological level, on modern diagnostic practice and management of respiratory diseases, as well as on the best practices that can be adopted within the project.
- *Analysis of user requirements and usage scenarios*: User requirements that reflect needs and preferences have been defined, based on the statistical processing of users' responses to appropriate questionnaires that have been developed by the project team for each user category. Pre-selected scenarios have been prioritized in terms of innovation first and then in terms of added-value to the end-users, while use-cases have been articulated based on users' requirements and towards a formalized description of the services.
- *System Architecture:* Definition of overall system architecture of Take-A-Breath end-to-end platform. A break-down into functional modules and components has been introduced, whereas detailed specifications have been derived for each of them including functional and operational requirements.
- *Methodology and design of Clinical Study's protocol:* Design and plan of the pilot studies, as well as development of the assessment and intervention protocol

- *Definition and design of add-on device using sensors:* Definition and design of an add-on device by completing the set of: (1) sensors (audio sensors, accelerometers, etc.) capable of adapting to any drug inhaler (pMDIs, DPIs), (2) sensors to monitor the patient's environmental parameters (internal and external pollution levels). Each sensing component has been evaluated against user requirements and system architecture with particular emphasis on energy saving and computational power of the integrated bio-network.

3 Conclusions & Future Work

In this work, we have presented the Take-A-Breath project (July 2018- July 2021) co-financed by the European Regional Development Fund of the European Union and Greek national funds. The project focuses to the development of a bio-network monitoring system using non-intrusive sensors, to the collection of data with daily use, to the education of patients using innovative signal processing and computational vision methods, gameplay mechanisms, and using virtual characters, and to the development of user guidance with a decision support system. Project's results are expected to have significant economic and social impact and to improve the efficiency of health care and patients' quality of life.

Future steps in the second year of Take-A-Breath include core activities, such as:

- *Patient modelling and formal representation*: identification and detailed conceptual definition of the entities/concepts of interest for the Take-A-Breath patients' model (e.g. disease, symptoms, diagnosis, risk factors, sensor input, treatment, action plans, interventions, patient, etc.) towards the creation of the models.
- *Development of audio analysis algorithms for the extraction of characteristics*: development and implementation of audio signal analysis techniques for the assessment of the proper use of inhaled drugs.
- *Design and development of a sub-system for medical inference and medical decision making:* Development of a DSS to assist the medical and clinical staff to improve patient care and avoid mistakes arising from the incorrect use of inhaled drugs.
- *Prototype development*: Design and development of the prototype, establishment of a wireless personalized bio-network for monitoring-support of the proper use of patient devices as well as a series of environmental parameters and patient behavior.
- *Development of algorithms and embedded software*: Development of algorithms and embedded software to detect, collect, process and transfer data from the sensors to the mobile device and 'cloud computing'.

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