Acquire, analyze and share auscultation sounds: the ASAP project

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ABSTRACT

Be able to distinguish and characterize abnormal auscultation sounds is important for an accurate medical diagnosis. Even though several researches have been done on the analysis of auscultation sounds, today auscultation remains subjective and difficult to share. In the context of the MERCURE telemedicine platform, we started a project called ASAP. It deals in developing objective tools for the analysis of auscultation sounds and creating an auscultation sounds' database in order to compare and identify the acoustical and visual signatures of the pathologies. Communication and network technologies are fundamental elements to be able to collect, document, share and transmit, in real time or not, auscultation sounds. Finally, the project aims at capitalizing of these new auscultation techniques around the creation of a teaching unit: the Auscultation's School.

Keywords: Auscultation's School, pulmonary sound analysis, telemedicine platform

1. INTRODUCTION

To collect and analyse auscultation sounds, we propose to put in place a new architecture (that will be described more in details in paragraph 2 and figure 2). The collect of the sounds is realized thanks to a wireless digit stethoscope that communicates with a computing unit through a Bluetooth Medical Device Area. The computing unit can send the data through the network, in order to store them, share them (with a colleague for a second opinion or with students for education); the collected data will be used for the fundamental researches that we started in the ASAP context. These researches deal with pulmonary sound analysis and the research of new markers characteristics in some specific pathologies.

Actually, distinction between normal respiratory sounds and abnormal ones (such as crackles, wheezes) is important for an accurate medical diagnosis. Respiratory sounds include invaluable information concerning the physiologies and pathologies of lungs and airways obstruction. Thus, the spectral density and amplitude of sounds can indicate the state of the lungs parenchyma, the dimension of the airways and their pathological modification [1].

Limits of human audition

Studies were performed in order to test the human's ear capability to detect crackles in an auscultation signal [2]. The methods used consist in simulated crackles superimposed on real breath sound. The results indicate that the most important detection errors are due to the intensity of the respiratory signal, the type of crackles and the amplitude of crackles. It can be inferred from these studies that the validation of automatic crackles detection algorithms should not take auscultation as unique reference.

On the contrary, the understanding of mechanisms linked to the creation of breath sounds is, for the moment, imperfect. The recording and analysis of respiratory sounds allow to improve this understanding [3] and an objective relationship between abnormal respiratory sounds with respiratory pathology. Besides, an objective analysis allows to develop classification systems [4] that make it possible to precisely qualify normal and adventitious respiratory sounds. Whilst conventional stethoscope auscultation is subjective and hardly sharable, these systems should provide an objective and early diagnostic help, with a better sensitivity and reproducibility of the results.

Moreover, applications, including diagnosis establishment, monitoring and data exchange through Internet are obviously complementary tools to objective and automatic auscultation sounds analysis. Sensors devices will allow long duration monitoring for patient at home or at hospital. It could also be a useful solution for less-developed countries and remote communities [5]. In addition, this type of system has the great advantage to keep the non-invasive and less expensive characteristics of auscultation.

Finally, Sestini and coll.'s studies [6] indicate that an association between acoustical signal and its image is beneficial to the learning and understanding for students in medical science.

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Definition of common markers
Nowadays, there are several definitions for the typical markers of wheezes and crackles [7]. Thus, a universal semantic has to be created. Several works [8] have attempted to collect definitions of terms relating to respiratory sounds and have arrived at a collection of 162 terms commonly used in the « Computer Respiratory Sound Analysis » (CORSA). Nevertheless, it still doesn't allow physician to have a common definition of terms that are used. For example, a wheeze is still currently associated to a "whistling sound", and a crackle to "a sound of rice in a frying pan".

Definition of semiology
The article of Rossi and coll. [9] gives recommendations concerning the experimental conditions required for recording respiratory sounds. It describes the optimal experimental conditions (principally concerning background noise, including sounds other than respiratory such as vocal sounds) and the specific procedures according to the type of sounds he wanted to record (breath, cough, snores), information for the recording (diagnosis, evaluation of a therapy, monitoring), the age of subject, and the recording method (free field, endobronchial microphone). Lastly, for short recordings, a sitting position is recommended, but a lay position is preferably for long recordings.

2. ASAP : AN INNOVATIVE E-HEALTH PROJECT

2.1 Context

ASAP or "*Analyse de Sons Auscultatoires et Pathologiques*" is a 3-year-long French collaborative project. It is part of a collaborative telemedicine platform called « MERCURE » (*Mobile Et Réseau pour la Clinique, l'Urgence ou la Résidence Externe*). MERCURE (figure 1) deals with projects for remote monitoring and clinical context thanks to modern tools principally coming from the News Technologies of Information and Communication.

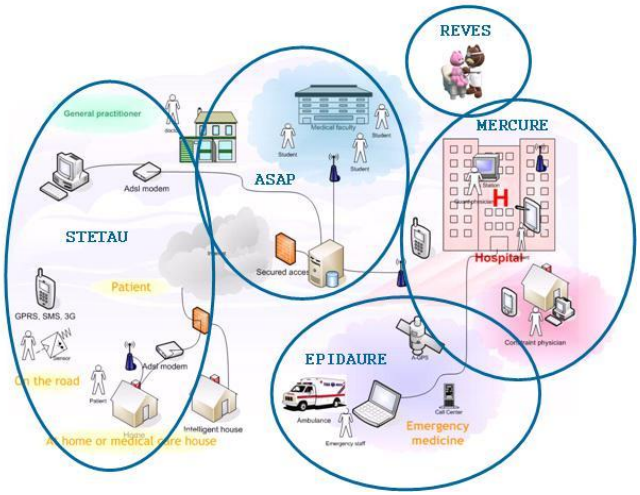

Fig. 1. The MERCURE platform

STETAU is the first project of the MERCURE platform; it aims at providing the patient and medical staff, measurement tools that are non-invasive, mobile, communicant and that allows to transmit vital information by a secured way, objectively qualified by signal processing tools. Thus, physicians will have access to a tool for remote monitoring and exploration of cardiac and pulmonary sounds. Besides, the proposed tools will be made up of an enhanced graphical user interface.
The ASAP project, that we will describe more in details in the next paragraphs, deals with a worldwide database for respiratory sounds, statistical analysis of "pathological" sounds, search of new markers, set up of a medical school for auscultation and a worldwide experts network.
The EPIDAURE project deals with emergency care services. The physician will be equipped with wireless measurement tools that communicate with a processing unit. It will allow him to have access to a first analysis, a diagnosis help, and a transmission for remote second analysis and saving in a patient database. In this project, we will also work on a dedicated call center for optimized handling of cars, specialists, tools and current location that will lean on geo-localisation and navigation.
MERCURE is a project inside the hospital for the deployment of wireless measurement tools, notification servers, voice/data/video transmission, voice over WiFi/GSM with automatic handover, A-GPS and WiFi localization of people, equipment, drugs, foods.
Finally, the last but not least project is REVES. It emphasizes on a robot-friend for children with leukaemia in sterile rooms. The robot-friend is a "new multimedia terminal" equipped with a camera, a microphone, loudspeakers, WiFi transmission, geo-localization. It is connected to a call server plus video server, notification, *etc*. This project is realized in collaboration with teachers for the development of content (educative tools, gaming), and with hospitals practitioners (intensive care unit) for pain stigma detection.

2.2 Our value-added

Some projects or products already propose an evolution of the stethoscope; we can quote in particular the stethoscope Littmann or Jabes. Some firms propose as well as their stethoscope, a CD-Rom with auscultation sounds. Nevertheless, they only allow a basic consultation with some examples, most theoretical, and that are neither interactive nor a diagnosis support. In addition, sounds are quite often synthetic sounds.
In the ASAP project, our ambition is not to propose a stethoscope and to additionally provide sounds, but the exact opposite. Indeed, we will propose a worldwide sound database with visual and acoustical signatures, that allow to consult and analyze sounds, perform standard exchange of data. These sounds will, all the more, be a support for learning auscultation. From

those data, a worldwide auscultation sounds database will be created. It will list an important quantity of data and will allow to create models or criteria to improve detecting of pulmonary and cardiac diseases. Another innovative aspect of our project is to make diagnosis aid.

2.3 Description of the ASAP project

Auscultation is the first medical act that the medical students can realise on patients; it is realised empirically. Our project proposes to introduce an evidence-based medicine dimension at auscultation thanks to the association with signal processing, visualisation and archiving technologies. These new technologies will be considered for the formation of the future physicians and will be accessible through e-learning.
ASAP aims at making evolve the auscultation techniques:

- by the development objective tools for the analysis of auscultation sounds : communicant wireless electronic stethoscope paired with computing device (like a PC or PDA) (figure 2);

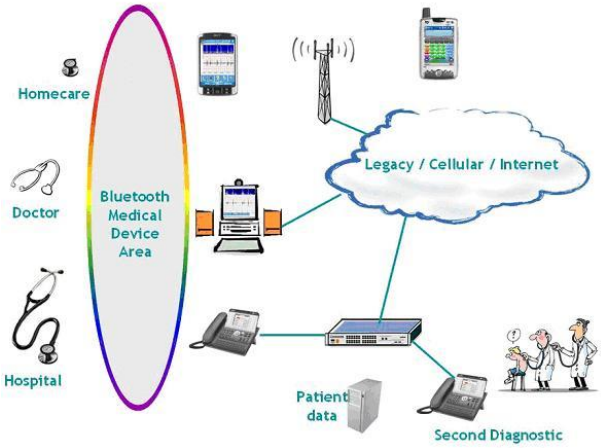

Fig. 2. Remote auscultation
The physician can locally or remotely perform an auscultation, see the auscultation sounds on his PC, PDA or IP Phone; he can share it with students for education, store it locally or in the hospital's database.

- by the creation of an auscultation sounds' database in order to compare and identify the acoustical and visual signatures of the pathologies;
- by the capitalisation of these new auscultation techniques around the creation of a teaching unit : *« Ecole de l'Auscultation »*. This auscultation's school will be destined to the initial and continuous formation of the medical attendants.

There are some major phases in the project (figure 3):

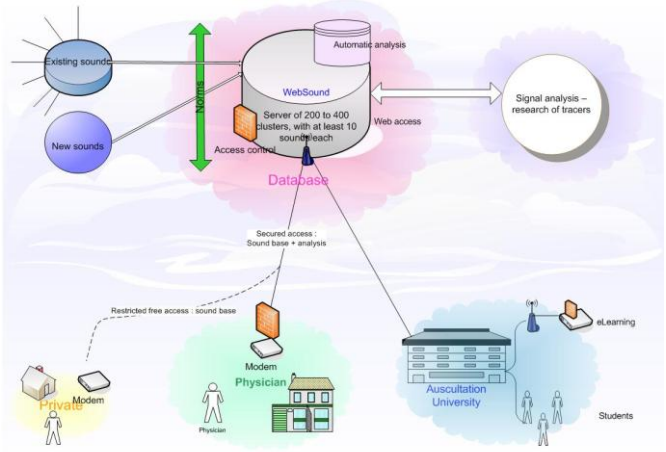

Fig. 3. ASAP project

The first point is the definition of the relevant semiology and thesaurus. It will allow to initialize a platform for collecting, validating, storing respiratory sounds.
The next point is the realisation of a worldwide auscultation sounds database (*WebSound*) .
Then, health professionals and medical students could use this database. The students would dispose of a diversified palette of sounds via new technologies of communication and information. It will allow to make continuous formations related to specific pathologies. This will lead to the creation of the Auscultation's School.
Besides, in order to allow the connection of the information systems of the hospitals, further work is foreseen, to deal with the normalisation of the data formats and semantic.
Afterwards, it will be possible to share auscultation sounds between experts, thanks to a unified format. The expert could discuss about a medical case, and refine the diagnosis.
Finally, our project aims at initialising fundamental research works for the definition of a visual and acoustical signature of a pathology. The first pathologies studied will be asthma, bronchitis, CODP and cardiac pathologies. The aim is to make auscultation more objective and intuit a pathology thanks to the symptoms.
The success of the projects is conditioned by the definition of standard formats of the data and exchange protocols.

Application domains
The applications can be telemedicine with local or remote us. Several medical specialties will be interested in such a tools, among remote monitoring for patients, second opinion, teaching. We can quote:

- Pneumology, for patients affected with bronchiolitis, asthma, COPD, pneumopathy;
- Cardiovascular; in particular Valvulopathy with the diagnostic of heart murmurs, search of

additional sounds and peripheral arterial disease of the lower limbs, carotid stenosis;
- Public health, for the prevention in school, professional environment;
- Gynecology obstetrics for prenatal auscultation of the foetus health, teleconsultation of a specialist;
- Veterinary.

3. FIRST WORKS DEALING WITH THE IDENTIFICATION OF MARKERS

In pulmonary sounds, known markers are crackles and wheezes. The principal algorithm families of detection of these markers are summarised in table 1.

TABLE I
THE PRINCIPAL ALGORITHM FAMILIES OF DETECTION OF THE KNOWN MARKERS

SIGNAL	CHARACTERISTICS AND PROCESSING [10]	ANALYSIS
Normal sounds		
Lungs	Low-pass filtering (between 100 and 1000 Hz)	Periodogram (power spectral density - PSD), auto-regressive models [11]
Trachea	Noise with resonances [100, 3000 Hz]	
Adventitious sounds		
Wheezes	Sinusoid (range ~ 100 and 1000Hz; duration > 80ms)	PSD, STFT(short-time Fourier transform)[11], FFT, linear prediction of coefficients [12], genetic algorithms [13], neural networks [13], wavelet [14]
Ronchus	Series of sinusoid (<300Hz and a duration > 100ms)	
Crackles	Wave deflection (duration typically < 20ms)	Temporal analysis [11], FFT, linear prediction of coefficients [12], fuzzy non stationary filter [12], genetic algorithms [13], neural networks [13], wavelet[15] [16]
Snores		Temporal analysis, PSD [11]
Stridors		PSD, STFT, auto regressive models [11]

4. PERSPECTIVES: THE AUSCULTATION'S SCHOOL

In a nutshell, it can be said that auscultation is an individual act, difficult to share. On the contrary, the Auscultation's School will lean on an objective definition of the sounds useful for teaching and diagnosis aid. Thanks to communications and network technologies, the Auscultation's School will have for purpose to teach to student and professionals the new innovative tools. In the same way, research programs will try to detect new markers, detect pre-markers from some pathologies…

The project begins by the scientific and clinical validation of the service and ergonomic for several pathologies: COPD, asthma, and bronchitis, and cardiopathies. This step allows to collect auscultation sounds that are characterized, documented and qualified. The final goal is to create a worldwide referential interconnected to medical study centres, pharmaceutical research laboratories and auscultation sounds processing systems.

Empirical methods provides already results to show the value added of the analysis and the comparison of the sounds for instance for the correlation between the pulmonary blocking of a patient with cystic fibrosis and the rate of detected crackles, the evolution of the acoustic signature of a cardiac valve, ...

The main strengths of such a referential are:

- improving the incontrovertible medical act that is auscultation, by making it objective, and factual, to share, histories and compare the data;
- lean on the new technologies to push the exploitation of auscultation sounds as a non invasive exam and pertinent diagnosis aid and local or remote monitoring;
- create a new language exploitable by all the profession.

The different constitutive parts of the Auscultation's School will be:

- the good practices of auscultation : how to auscultate, what are the abnormalities researched;
- the classical sounds in the various disciplines: Cardiology, Pneumology, Paediatric, Reanimation. The identification of crackles, wheezes, and their correlation with the follow up of a pathology;
- the new auscultation tools: the digital stethoscope, signal processing tools, visualisation of the sounds and interpretation of the obtained images;
- the ongoing research project;
- bibliographical references.

The access to the teaching could be initial for medical students or ongoing training for experimented general practitioners. Modern learning tools will be privileged. This formation will be accessible by each medical professional, and maybe more.

The first goal of such an initiative is the repositioning of the auscultation as a fundamental non-invasive exam in the medical diagnosis; while pushing to potentialities thanks to the new technologies.

5. CONCLUSION

Today, prototypes of the digital stethoscope have been tested by medical specialists. Algorithm have shown definitive contribution to the improvement of the auscultation act, in the context of the ASAP project. The next step will consist in analysing deeper the sounds with signal analysis techniques to allow the discovery of new characteristic markers.

Real time remote auscultation, commented auscultation sounds transfer, education became possible thanks to the system we described.

Besides, we are working on protocols to transmit, in a standardized way, auscultation data, associated with comments and medical information.
Previous studies demonstrate the need of performing an exhaustive scientific approach, that account of both the definition of a semiology, the consolidation of definition of known characteristics markers, the definition of common or even universal semantics, the development of determinist tools that will allow the detection of these markers. It is precisely the context of an ambitious study of in the so-called ASAP project. This study is handled by a multidisciplinary team including medical from CHRU of Strasbourg, IRCAD for web-based teaching tools, Alcatel-Lucent research teams for the development of the devices, tools, ergonomic, algorithms and communication infrastructure. Among the most identified outcome from the project, it is force in to create auscultation school hosted by the "*Faculté de Médecine*" of Strasbourg (France).

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GRANT

ASAP project (ANR convention n° 2006 TLOG 21 04).

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