The fight against COVID-19 in the age of Connected Medical Sensors and Computational Grids

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Abstract—The dramatic progress in the medical sensor performance and connectivity opens new healthcare perspectives such as home diagnostic of patients, prompt detection of epidemic emergence and in such a case, detailed study of disease properties, statistical monitoring of the evolution from the regional to international levels while providing most relevant field data for validation of epidemiological forecasts.

Index Terms—healthcare, connected medical sensors, computational grids, epidemiological forecasts.

I. INTRODUCTION

The development of the COVID-19 pandemic revealed how the medical data of patients were the basis of the entire chain of the treatment and epidemiological monitoring of the disease. In the absence of comprehensive, sufficiently reliable, up-to-date field data, real-time decision-making, local, regional monitoring of disease progression were often problematic.

If there is one lesson that can already be learned, it is that not only do we need as much field data as possible, but to be usable at all required levels, they must be acquired in a *standard, quasi-automatic* way and be *quickly accessible*.

To meet these requirements, we propose an integrated approach to the acquisition of patient data for monitoring their health, then for their use in comprehensive disease monitoring at the regional level and finally making them available, as experimental data, for epidemiological modeling research. We suggest this multi-step project be achieved as a cooperation of e-medicine specialists, startups expert in connected medical sensors and of scientific institutions like CERN for the aspects of data networking and shared analysis¹.

¹The present article stems from a reply to the call for ideas launched by the CERN against COVID-19 Task Force (<https://againstcovid19.cern/>) established in March 2020 to collect and coordinate ideas and contributions from the CERN community to the societal fight against the COVID-19 pandemic.

II. THE REVOLUTION OF V2.0 CONNECTED MEDICAL SENSORS

The arrival of the latest generation of connected medical sensors [1] opens a new opportunity to acquire comprehensive medical data, at the patient's home, in real time, with the desired precision and temporal granularity.

A typical example is the oximeter device that measures both the oxygen saturation and the cardiac frequency. The O₂ saturation is a critical parameter to identify patients entering a severe phase of the COVID-19 disease. Its use has been highly recommended by the World Health Organization (WHO) [2], [3].

These sensors are evolving very fast. The trend is towards the integration of several medical sensors on each device with the possibility to program the measurements to be performed [4]. The results are analyzed online and can trigger predefined actions (e.g. alarms, new measurements, etc.). They are usually interfaced via Bluetooth to a watch and/or via an USB connection to a PC.

The market of medical sensors is growing very rapidly due to both the COVID-19 pandemic situation and the emerging patient wish of health self-monitoring. The sensors are rather cheap (20-30 \$) and, in large quantities would become affordable by most people.

The latest announcements on the subject from the Computer Electronic Show — Las Vegas 2020 [5] are most amazing. One example: Withings watches [6] not only incorporate several medical sensors such as (T, ECG, Cardiac Frequency, Saturation Oxygen SpO₂, etc.) but can also be programmed for specific tasks such as health alert emission in urgent case such as sleep apnea event.

III. HOME HEALTH MONITORING AND LOCAL FOLLOW UP OF EPIDEMIC EVOLUTION

The most recent high tech sensors now come with a complete monitoring environment [7]. They are standardly interfaced via "data hubs" to a monitoring platform that

Fig. 1. Synopsis of medical sensors-based Remote Patient health monitoring.

Fig. 2. Synopsis of the use of patient health data for regional pandemic follow up and large scale epidemiological studies.

offers wide viewing and analysis (e.g. dashboard display) capabilities. Each doctor is quickly informed, with precision, of his patient's condition (Figure 1). Moreover, the doctors of the on-call team at the hospital can also access the platform for the supervision of multiple patients.

Eventually, the set of sensor measurements (T, SpO2, ECG, etc.) added to the doctor comments allows a remote, precise, fully documented contamination diagnostic, thus avoids unnecessary transfers of patients to hospital, which could cause overflow of admissions with high risk of fortuitous contamination of both the patients and the medical staff. This represents a substantial step beyond the classical or telemedicine kind of consultation especially in epidemical situation.

Worth to underline, for those who could fear a form of gradual dehumanization of the medical consultation, the direct exchange (phone, email) patient-doctor is always the basis of their communication.

Thanks to the connected medical sensors, it becomes pertinent to store in real time each patient's data to contribute to a patient database, which would become the pandemic reference database for the geographic area covered by the hospital.

An important aspect of this health data collection and use is the respect of data privacy rules. The process of storing patient data for later utilization shall not contravene any health law in force anywhere and more specifically shall depend on:

- Voluntary agreement of patient to get his data used, after specification of the kind of data, the purpose of the use (e.g. statistical analysis for forecasts, epidemiological studies).
- Anonymous access to the data, in all cases with a suitable Authentication, Authorization Access scheme.

Because of the growing use of performant connected medical sensors it becomes possible to collect appropriate patient data, in real time, for in-depth statistical studies. These studies could be conducted, in a first stage, in the hospital itself from its own local data. This looks natural to timely respond to questions of the population such as: "what is going on around here?"

Actually, it would be the most suitable system to inform citizens on the statistical and phenomenological characteristics of the pandemic local status, real up-to-date field data being

the best information source.

IV. STUDY OF THE PANDEMIC REGIONAL DEVELOPMENT

The next step beyond the local hospital environment is to extrapolate at the inter-regional level to precisely follow up the evolution of the pandemic situation at the country (neighboring countries) level. At this stage, networking of hospital servers would be recommended to facilitate data exchange and distributed studies, with tasks divided between the different centers. Dealing with patient data exchange the networking aim would be on a broader scope and scale than the existing exchange of statistical information between hospitals.

Experience from other scientific sectors e.g. High Energy Physics could be profitable. Indeed, networked servers integration is a procedure that is customary in LHC experiments at CERN (<https://home.cern> and <https://home.cern/science/computing/network>). One can imagine local support of the institutes of the LHC experiments (<https://home.cern/science/experiments>), in the spirit of collaboration of HEP physics in the fight against COVID-19.

Moreover, CERN and the Institutes of High Energy Physics have scientific data analysis platforms, such as Root [8], well suited to distributed epidemiological research, which could be installed and customized in hospitals and research centers.

Hence, large statistics analysis of countrywide data could be performed (Figure 2) standardly to provide daily up-to-date information on the epidemic characteristics.

Furthermore, the networking of hospital servers would be most useful for any new research investigations induced by the current observations and implying new types of health parameters measurements. The fulfillment of such new surveys would be coordinated through the medical server's network including the needed upload of new measurement parameters on the sensors of the targeted population.

Such a dynamical follow up of the pandemic properties would ease the sociopolitical decision making process for possible confinement. Knowing the impact of confinement on the economic sector, such decision help would be well acknowledged.

V. THE COMPUTATIONAL GRID FOR EPIDEMIOLOGICAL PREDICTIONS

Ultimately, the whole patient data sets, stored at the hospital network level, will constitute a large-statistic pandemic database, covering several regions. They are the most valuable experimental data giving the complete picture of the pandemic properties and thus indispensable to validate the predictions of theoretical models.

The purpose of these models is to work out the characteristics of the medium- to long-term evolution of the pandemic and thus anticipate new types to possibly occur. They are achieved by means of sophisticated Monte Carlo simulation methods. These usually depend on multiple, often-correlated parameters (e.g. health status, age, etc.). The objective is to understand the effect of each of them in individual contamination and in the infection propagation and thus better forecast its effects. This implies to variate each parameter to see its influence up to identify those, which are critical. The whole process requires as many high statistics computations as parameter values. This needs, on a recurring basis, huge computing power.

The same environment of the CERN LHC experiments mentioned above, is routine with this type of analysis and have the necessary computing means in the form of very cost effective computing Grids. They would have a significant supporting role to play in this area as already shown in the recent past [9], [10] in recurrent pandemic situations.

VI. CONCLUSIONS

We have shown that new high tech medical sensors providing exhaustive patient data, connected to a regional network of health servers could be a cost effective solution to respond to three important objectives in pandemic situation: (i) Early diagnostic of the contamination of patients at home for prompt treatment including rapid hospitalization, (ii) Allow at the regional level, all necessary statistical analyses to understand the progression of the epidemic and thus help to take the proper measures and iii) provide basic field data to corroborate epidemiological models predictions and thus anticipate the short to medium term future.

This suggests a typical e-Healthcare Networking initiative of generic kind. Indeed, all what has been described and proposed is independent on the actual pandemic nature. It consists of defining and implementing an overall local-to-international long-term strategy to detect and fight against any kind of pandemic emergence.

It better be carried out as a cooperation between the medical sector institutions, medical sensors startups and the scientific sector such as High Energy Physics. The three objectives of the project could be carried on in parallel to a large extent. This would permit newly interested institutions / partners to join during the course of the project.

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