An adaptive architecture for Healthcare Situation Awareness

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Abstract—An essential condition for IT support for strategic decisions in critical situations is Situation Awareness. It includes the correct real-time perception of what happens in operational scenarios through the analysis of the complexity of heterogeneous information from a multitude of sources. In this work, we present an architecture to provide Situation Awareness in Healthcare to support decision-makers in improving the National Healthcare System and assist emergency management.

Index Terms—Healthcare, Recommender System, Situation Awareness, Big Data, Process Mining

I. INTRODUCTION

The challenge of COVID-19 has shown the importance of building health models capable of adapting to crises. The experience of China and Italy has highlighted the fundamental need to ensure the proper capacity of the ICU beds to cope with the wave of infectious patients with lung breathing difficulties. Flexibility and rapid response to the emergency must become the main characteristics of the health system. An example of the application of these two concepts is the transformation of ordinary hospital units into intensive care units. The rapid evolution of the epidemic has created overloads in access to care due to the lack of equipment [1]. In healthcare, the management of waiting times for access to care is essential. For this goal, it is necessary to understand situations and obtain temporal information about the health process. Identifying and quantifying the bottlenecks related to time within the health system's various processes can make it possible to optimize flows. In Italy, the absence of an overview of the system, decentralization and fragmentation of health services impacted the effectiveness and timeliness of the interventions [2].

II. ENHANCING READINESS IN THE HEALTHCARE SYSTEM

A. Situation Awareness in Healthcare

Patient management in a clinical setting is an ongoing challenge based on uncertainty and unpredictability. Emergency management is always related to the awareness of health personnel based on times, tools and methods of intervention. The choice of a hospital, without appropriate knowledge of the facilities of the structure or the expertise of specialist doctors present, can affect the resolution of the emergency. In the clinical environment, the methods of intervention are always conditioned by three parameters: perception, understanding and projection. Perception is related to the data that comes from the context, understanding is related to the ability to understand the situation and projection is the ability to prevent future events. According to Endsley's model [3], it possible to find the three states of situation awareness and illustrates the basics of the process leading to decision and action. As depicted in Figure 1, situation awareness model describes its three stages: perception operated by the ingestion of data, understanding carried out through data processing and projection as a means of carrying out predictive analysis. The assessment of the management skills of a complex health situation plays a fundamental role: among the indicators considered are the management of tasks, understanding of priorities, the use of available instrumental resources, personnel management, risk awareness. Therefore, the simulation of the critical event becomes a fundamental way to prepare for the correct management and mitigation of the consequences. In the specific case of a pandemic, awareness of the functioning of the health system is a fundamental element for dealing with emergencies and the workloads of operators.

B. Process Mining in Healthcare

At the base of our approach is the mining process: through these techniques, it is possible to understand the performance of the execution of actions and patients' behaviors in the healthcare system to identify flows, understand the processes and highlight the bottlenecks due to reduced quantities of staff or equipment [4]. This allows us to understand where to intervene, changes to be implemented, and where to address investments to improve the health system's inefficiencies. One of the main critical issues to be identified is the performance of access to care based on the availability and allocation of resources. This involves managing waiting lists, which leads to a perception of the healthcare system's quality level.
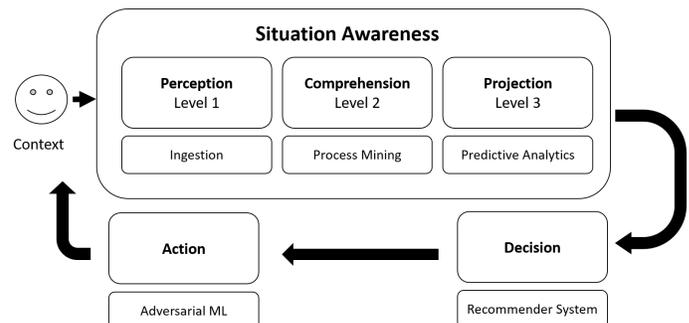

Fig. 1. A technical model of situational awareness.

III. Situation Awareness Architecture

The main aim of this work is the creation of an architecture to support decision makers to improve situation awareness of efficiency of National Health System. The goal is to aggregate all the information from the various software entities in the healthcare facilities where it is necessary to supervise the clinical pathways of the patients and monitor all the healthcare system flows globally and in a standardized way [5]. Another objective is to measure the performance of the health system and to carry out the simulation of flows in order to understand the reaction of the system under stress in the event of global events such as a pandemic in order to highlight weak points and possible critical problems (e.g., beds, machinery, specialized departments, staff, etc.). The result of this work is the architecture depicted in Figure2 of which, in this section, we will describe all the components.
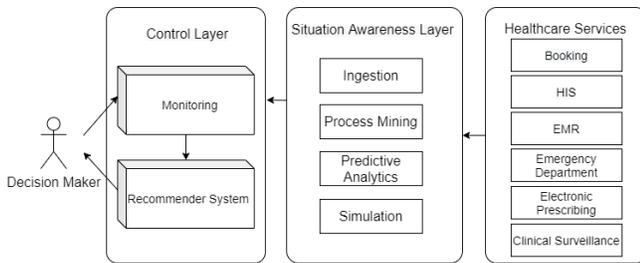

Fig. 2. Situation Awareness Architecture.

The architecture is structured in three main levels:

- *Health Services* are all software modules already used in health facilities. Through this component, we can collect all data relating to patients and flows within the healthcare system. The medical records data can provide us with information about the spread of diseases in the wards and the clinical pictures of patients. Booking systems provide data on waiting lists for clinical tests. Hospital systems provide us with information on emergency room access, hospitalizations, resignations and prescriptions.
- *Situation Awareness Layer* allows us to acquire and ingest all data from Healthcare Services through the Ingest module. This data is processed by the Process Mining module, which will allow you to understand the processes within the system and identify the performance and the relative bottlenecks of the system. Subsequently, the Predictive Analytics module allows you to analyze trends and make forecasts on flows within the system. The last module that of Simulation allows you to create simulations and put the system under stress to identify the probable problems.
- *Control Layer* allows the public decision-maker to have an overview of the health system and to have a view on the critical issues in the operational management flows as show in Figure 3. Recommender System module will provide support on actions to be taken to mitigate future risks and situations resulting from higher loads.
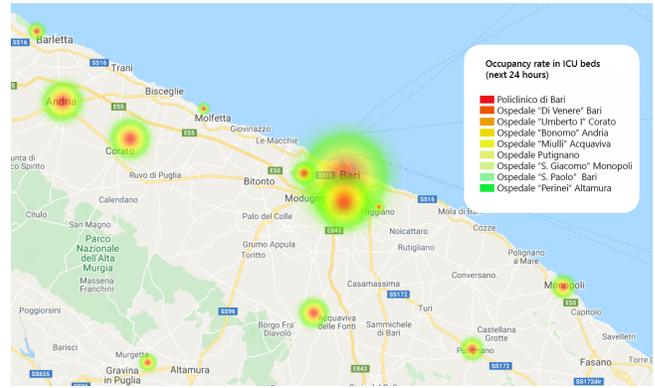

Fig. 3. Example of occupancy rate in ICU beds.

To achieve greater awareness, it is necessary to take stock of the situation rigorously and continuously, through evaluation and control tools capable of detecting successes and critical issues of services. The proposed architecture aims to be a tool capable of helping the public decision-maker in addressing the correct administrative action. The inclusion of health system performance indicators means that during the design phase, support can be obtained on targeted operations such as opening a new hospital or strengthening an existing structure. The simulation environment can be a fundamental tool for knowing critical issues and putting into practice actions to improve the quality of services and patient access to care quickly ensuring fairness in access to care in remote territories, support for the management of chronicity, an access channel to high specialization, better continuity of care through multidisciplinary discussion and first aid for emergency services.

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