

## A Novel Multi-agent Social Multilayer Framework for Improving Health Information Exchange and Management.

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**Abstract.** In recent years, network science has been focusing on the multilayer character of real-world systems, considering the time-varying and multilayer nature of networks, shedding light on their intrinsic interdependence. The Health system can also be described as a complex interdependent network, where the nodes/entities interact through the various layers. We need to include also the social dimension, exploring the social relationships between the different types of entities occurring at multiple layers and extracting the inherent characteristics of the network, which influence the decision-making process. By exploiting all the methodologies of social network analysis and a context-aware approach linked to the dynamics of complex systems, it is also possible to find out emergent hidden behaviors within the population. To describe the health processes, we exploit the multilayer paradigm and the concept of multi-agent system. In our framework, we use the multi-agent systems to model the social entities, represented by nodes or clusters of nodes, therefore we consider complex agents, which represent passive or active data sources with a specific role in the network. Moreover, the introduction of context-aware and cognitive abilities gives agents the ability to transmit the extracted knowledge, decide and apply strategies based on heuristics to reduce the computational complexity. The multilayer structure explicitly includes more channels, where each channel is represented by a layer and a set of entities, which includes agents, communities or clusters, diseases, patients, or data of different nature, at different layers, interacting through some patterns. The novel multilayer framework allows to observe, extract, understand and predict their multi-scale and multi-component dynamics, and we exploit its potential in a smart health context, in particular studying the emergent behaviors by analyzing the interactions and provide a decision support system. The fig. 1 illustrates the multilayer structure in the smart health context. Starting from the bottom, the first layer, called Patient layer, includes the characteristics of the patients and, along with the second layer, called Disease layer, allows building relationships between patients and diseases. In other words, the patient space allows identifying which patients are associated with the various diseases. This layer transforms the associations, considering not only the data, but also the connections between the diseases; therefore, it includes the comorbidity relationships, using the clinical and molecular data to build the disease space, following a multidimensional approach (Capobianco and Liò, 2013). The Social Network layer includes the social dimension in the analysis of comorbidity relationships: the habits and social behaviors, shared with similar friends, and the social contagion process obtained by studying the network connectivity, lead to the clustering of social nodes based on influence (Christakis and Fowler, 2012). Comorbidity and social dimension allow grasping the subtle and deeper connections between nodes, and helping us to extract knowledge. The fourth layer, the Multi-agent layer, consists of complex agents that enclose all the key features of the entities considered in the previous layers, and it allows extracting an organized knowledge, reducing the computational complexity of the process. The final layer, the Health Information Exchange (HIE) and Management Layer, consists of control entities, such as ICT (Information and Communication Technology), physicians, and the same patients that interact with the various layers, through the social network and the various kinds of associations between layers. These entities exploit the tools provided by ICT in order to observe and estimate the various medical, social and economic aspects. The HIE and Management layer solves the interoperability issues among the different healthcare information facilitating the exchange, moving clinical information among disparate healthcare information systems without losing the meaning of the information being exchanged. Furthermore, it is also useful to public health authorities and ICT to assist in analyses of the health of the population and of the single patients. The multilayer framework represents a process of acquisition and organization of the knowledge related to the several aspects of healthcare. It allows us to build a smart health knowledge: starting from data analysis in healthcare context, then all the possible actions and strategies applicable are introduced and evaluated. Then, the multilayer structure enables the inferential and decision-making processes, making them smart and, at the same time, improving and speeding up the steps that lead to the diagnosis of patients and to an overall better health management and information exchange. In this way, the system results extremely flexible and adaptable to various contexts and, moreover, it is also able to optimize the management according to different targets (multi-objective optimization). The ICT procedures and interventions are crucial to understand this complex social system, acting in line with the bio-inspired processes and behaviors emerging from the nature of the multilayer system. The multilayer organization allows to analyze the complex dynamic patterns inside the multilayer, and to increase both performance and awareness.

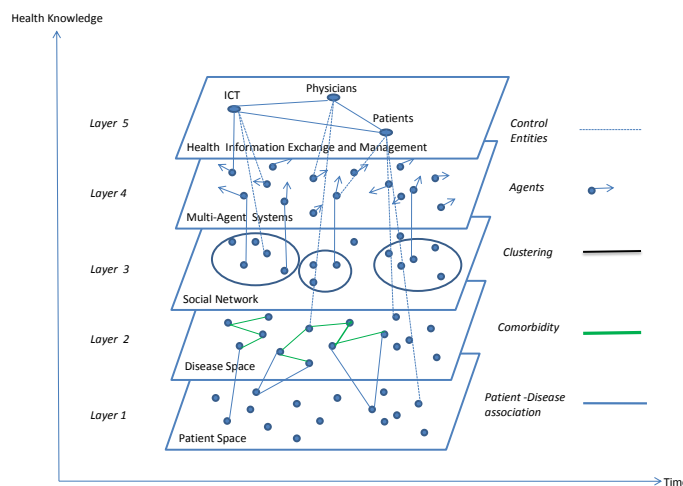


Fig. 1. Social Multilayer Framework for Health Information Exchange and Management.