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PROASSIST4.0: An Optimized Tele-Assistance System for the Future Healthcare

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***Abstract*—An efficient management of chronic patients is a key element in the current and future Healthcare context.**

This paper aims at providing an overview of the PROASSIST 4.0 solution for an healthcare assistance territorial model 4.0. The proposed service relies on the integration between the organizational assets and advanced ICT technologies: a dynamic and adaptive system able to respond to the needs of citizens / patients and to support staff healthcare in the management of an ever- increasing number of patients is proposed. This is achieved by optimizing the scheduling of the territorial assistance based on multiple occurrences and actual patients' health status.

***Index Terms*—Tele-assistance, optimization, healthcare, patient management, adaptive, monitoring.**

I. Introduction

The issue of territorial medicine and its rationalization in terms of proper resources and services allocation within the territory is well known since early '00 and exploded in all its rawness during the pandemic. The Covid-19's spread, more than the upsurge of non-communicable disease's pressure and the rapid epidemiological evolution, requires 1) to relieve pressure on hospital by strengthening the territorial assistance, 2) to optimize the existing healthcare services dynamically adapted to the patient's and the organization new needs and 3) to improve patients' empowerment [1]. Because of this, territorial medicine is part of the Recovery and resilience facility (Rrf), launched by the European Union, and is strongly rooted in the strategies of the National Recovery and Resilience Plan (Pnrr) that Italy has prepared to deal with the serious health, economic crisis triggered by the pandemic [2]. In this contingency, the support of ICT solutions to take care and personalize the health care for elderly patients involve the creation of a secure monitoring system specifically dedicated to an ever- increasing number of chronic patients spread over a large territory. Also the advent of the pandemic and the disomogeneity of human and technological resources ask for user-friendly ICT systems able to support and optimize the organization of personal assistance.

This paper aims at presenting the PROASSIST 4.0 management system for the optimized scheduling of the territorial assistance based on the actual patients' needs.

The paper is organized as follows: Section I gives an overview of the context, the motivation and the main objectives of the proposed solution, highlighting the role of the Family and Community Nurse; in Section II a high level deisgn of the reference system architecture is presented; the system components, the communication infrastructure and the system user interfaces are described in Section III, while Section IV reports details on the optimization procedure. In Section V the socio-economic impact of the proposed solution is discussed and, finally, conclusions are drawn in Section VI.

A. PROASSIST 4.0: Context, Motivation and Main Objectives

PROASSIST 4.0 project was selected and awarded in the framework of a ProMIS (Programma Mattone Internazionale Salute) Competition in 2021. The project involves a multidisciplinary team including technological university departments, healthcare professionals, healthcare socio-economic impact experts and end-users. These are: the Department of Information Engineering and the Department of Industrial Engineering of the University of Florence, the Italian Local Health Unit Toscana Centro, Medea s.r.l and two patients associations (Amici dell'Hospice ONLUS and Associazione Diabetici Pistoiesi ADP).

PROASSIST 4.0 main objective is to design, develop and validate an advanced management system for a real time optimization of the territorial assistance planning based on multiple occurrences and actual patients' health status.

The considered use case is directly related to "Family and Community Nurse" (FCN) model, as better described in the following subsection. The proposed solution is patient centered

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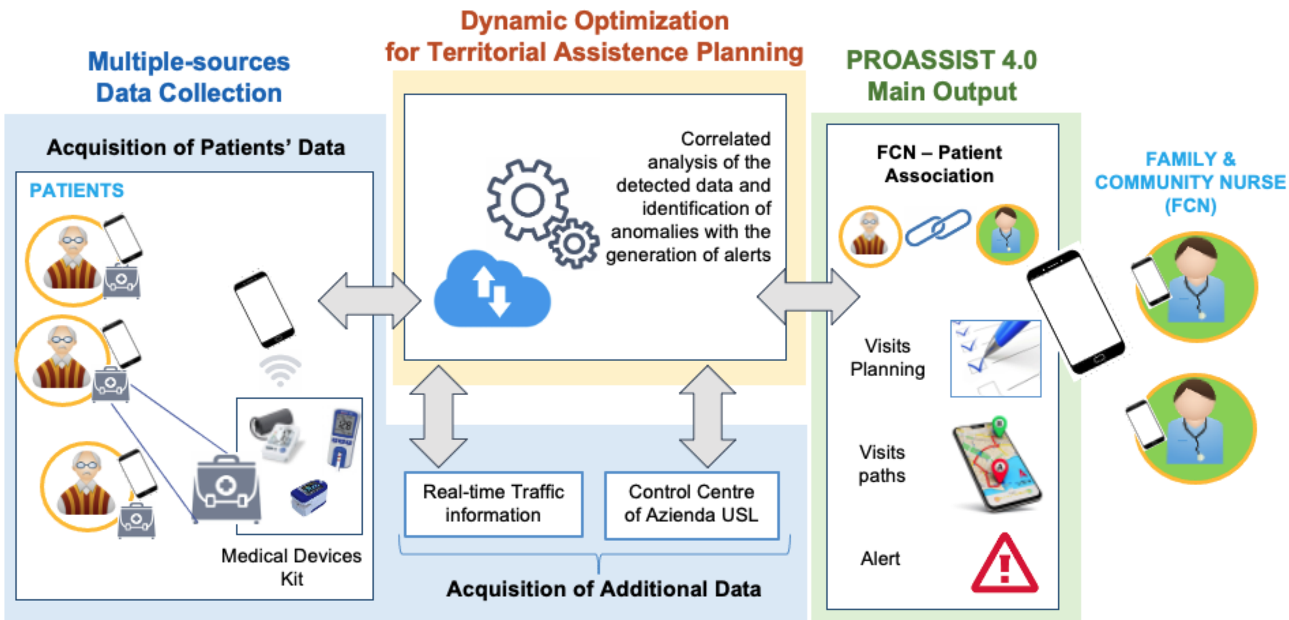

Fig. 1. PROASSIST 4.0 System Architecture High level Design

and involves all health care professionals who manage home care.

It is worth highlighting that PROASSIST 4.0 also aims at promoting the integration of the various ICT systems currently in use in the healthcare, hospital and general practitioners network. The possibility of collecting and sharing patient's entire clinical-care information represents the starting point for a better understanding of health needs ensuring timely, personalized and effective interventions based on specific alerts.

A co-creation approach will be adopted for gathering the needs and validating the expectations of all the actors involved including end-users. This method will enable the implementation of the most adequate technological solution to achieve the following key goals:

- Homogeneity and balance in the provision of healthcare services.
- Flexibility in resource management.
- Integrated vision of health pathways.
- Shared culture of innovation.

This will entail a radical innovation in human health monitoring processes.

B. PROASSIST 4.0 and The Family and Community Nurse

The Family and Community Nurse (FCN) represents a fundamental link between the person / caregiver, the clinical-assistance aspects of their care path and the health professionals involved in it. The PROASSIST 4.0 system will facilitate the FCN's avant-garde model through the combination of new technologies, home care, continuous monitoring of clinical parameters and optimization of both; the tools and resources at end users' disposal. According to this innovative approach, the FNC acquires an even more relevant role; he will not only deal with the direct management of the chronic patient and his/her caregiver, but he will play an even more active role in the empowerment of the person/caregiver through the use of tools able to constantly update the patients' clinical condition and making patient/caregiver deeply involved in their own care path . Because of the role's relevance, the FNC will be involved, together with other health professionals (such as general practitioners), in the starting phase of the project in which the operational tools will be designed, implemented and validated according to a co-creation and co-design approach. With the introduction of these tools, the FNC will be able to implement the model according to three main pillars: 1) proximity (providing for the identification of the chronic patient); 2) proactivity (recognizing latent needs early and guiding them through the network of clinical and social services); 3) equity and multi-professionalism.

II. System Architecture: High Level Design

The efficient management of chronic patients is a key element in the current and future Healthcare context [3]. The proposed service aims at defining an healthcare assistance territorial model 4.0 by integrating the organizational assets with advanced ICT technologies. A dynamic and adaptive service able to respond to the needs of citizens / patients and to support staff healthcare in the management of an ever-increasing number of patients is proposed.

The main objective of PROASSIST 4.0 solution is the optimized planning of patients' home assistance based on the occurrences and actual patients' needs. The service relies on the integration of an optimization model and on a data collection system relating to the health status of patients. Through a remote and realtime monitoring system the patients' biometric parameters are gathered in order to identify any critical issues or unexpected events and consequently automatically change the schedule of the nurses' visits, ensuring timely assistance according to the new priorities.

In detail, as depicted in Fig. I-A the system consists in two main components:

- *Multiple- sources data collection subsystem*. It includes a remote detection of the patient's biometric and physical activity parameters and the gathering of additional data (e.g.: traffic, organizational, etc.) for priorities definition and decision making.
- *Dynamic optimization for territorial assistance planning subsystem*. It represents the core of the system and it is in charge of the advanced processing of the collected data for the optimized scheduling.

The main outputs of the PROASSIST 4.0 system are:

1) FCN- Patient Association
2) Visits planning
3) Visits sequencing
4) Alerts

Details on the output generation are provided in Section IV, where the optimization procedure is described.

III. System Components, Communication Infrastructure and User Interfaces

A. Multiple-sources Data Collection Component

The continuous remote monitoring of chronic patients' health status and the real-time detection of their care needs together with the automatic sharing of the acquired clinical data with all members of the care team is a key element for the efficient management of patients' health.

A remote and real-time monitoring and self-monitoring system will allow extensive data collection relating to the person's state of health in order to identify any unforeseen critical issues and, consequently, automatically modify the schedule of home visits, ensuring timely assistance in function of the priorities that emerged.

The use of wearable wireless sensors will allow both the detection of patient's biometric parameters in autonomous mode (self-monitoring, for example of respiratory rate, heart rate, etc.) and the monitoring of his/her physical activity.

Moreover the acquisition of additional data such as real-time traffic information and organizational data coming from the Clinical Control Center is of fundamental importance in the definition of the priorities of a territorial assistance scheduling.

B. Dynamic Optimization for Territorial Assistance Planning Component

The collected and preliminary processed data will provide an immediate overview of the patient's health status, allowing the identification of any anomalies. This will automatically activate warning or alerts for patient prevention / management actions. These alerts will represent real-time inputs for the scheduling of the nurses' visits and therefore for the dynamic optimization algorithm for territorial assistance planning.

This algorithm will be able to analyse all the collected data coming from multiple and different sources, correlate them and provide a real-time scheduling of the nurses' visits. In fact, a forecast of patient service demand based on historical data will be tuned with real-time data coming from patients' sensors and traffic monitoring systems. This will allow to optimize the sequence to carry out the assigned visits also as a function of additional indicators, which may modified the actual priorities.

C. Communication Infrastructure and System User Interfaces

The communication infrastructure, that allows the data collection and sharing among the involved entities, consists both in short-range and long-range communication links [4]. In detail, the wearable sensors are connected via Bluetooth to a local collector (e.g. a smartphone), able to perform some basic local pre-processing of the gathered data. The aggregated data are then transmitted to a central server hosting the "Dynimic optimization component" for the advanced processing. The data transmission between the local collector and the server and the consequent processed information sharing rely on long range communication links, such as 4G, 5G networks. The interaction between the users and the PROASSIST 4.0 systems will be provided through a customized App and web App. Focusing on the main involved actors (the patient and the FCN) two profiles will be define for the App, which is supposed to be used in a mobility scenario. The patient profile will allow the autonomous gathering of clinical and physical activity parameters, while the FCN profile will allow the realtime visualization of the visits plan, suggested paths and alerts, This will allow the FCN to manage his activities based on the occurred events/priorities and to interact with the patient if needed. On the other hand the operator at the control center is assumed to access to PROASSIST 4.0 system via a Web App both for inserting additional information regarding a specific patient or a new organization priority and for having a real time overview of the FCN scheduled visits. The user interfaces will be defined together with the different end users following a co-design approach, aiming at satisfying their main needs.

IV. Optimization Procedure

The optimisation model receives as input (i) a planning horizon (typically one week), (ii) an actual or forecast service demand from a set of patients, and (iii) a set of qualified operators skilled to perform the service. Specifically, patients are geolocalised in a geographical area and the demand for service is expressed through their care plan, i.e., the number of visits expected in the time horizon for each type of service, their complexity and intensity of care.

The design of efficient and high added-value home care services requires the coordination of a complex set of inter-twined decisions ([5]) and outputs: (i) the operator (or operators) assigned to each patient (assignment decisions), (ii) the scheduling of patient visits in the planning horizon (scheduling decisions), and (iii) the sequencing with which each operator, every day of the planning horizon, visits the patients assigned to him or her (routing decisions). These decisions can be made guaranteeing possible constraints of care continuity or loyalty and respecting temporal constraints such as those imposing that the service is given within time windows provided by the patients or according to a certain regularity [6] (for example, visits always made in the morning or in the afternoon to facilitate the family organisation of the patient). In addition, service design may require the coordination/synchronization among several operators at the patient's promise and/or the management of specific devices shared among patients [7]. The optimization model may consists in a single-objective or multi-objective mixed integer linear programming model. Typical optimization criteria range from travel cost minimization to a balanced distribution of workload among the caregivers to maximization of stakeholders' preferences ([8], [9]). Models from the state-of-the-art literature must therefore be adapted to the specific needs of the use case.

The design of services cannot ignore the management of uncertainty, which can have disruptive effects in this setting. Indeed, model parameters are subject to uncertainty. A source of uncertainty may be related to the high variability of demand: either the number of planned patients may change as a consequence of new entries and exits or the number of planned visits may change as a consequence of improvements/worsening of the patients' clinical conditions. Another source of uncertainty concerns the travel times of operators on the road network, which may vary depending on the day, the time of day, be affected by seasonality or be higher than expected as a result of traffic jams. Typically, uncertainty can be dealt with at two different decision-making levels: tactical and operational. At the tactical level, the perspective adopted is the proactive one in which one tries to obtain solutions that are robust with respect to the variation of boundary conditions. A typical methodology used in this direction is robust optimisation ([10]), an original application of which is shown in [11] for the home care context. At the operational level, the perspective adopted is the reactive one, in which an attempt is made to transform the optimal solution provided by the model into a solution that adapts to changing boundary conditions. A typical methodology used in this direction is re-optimisation.

The effectiveness of the robust optimization models and of the re-optimization algorithms, i.e., their ability to deal with the variability tied to the demand and to the travel and service times, will be evaluated through discrete events simulation [12]. Simulation has often been used as a tool for the design of service delivery systems [13], as it allows two fundamental advantages. First, it allows to fully grasp the complexity of the analyzed systems and to outline their behavior in a stochastic environment, without having to introduce the restrictive assumptions that inevitably characterize analytical models [14]. In our case, demand, service times, travel times, the possible presence of adverse events can be modeled using appropriate probability distributions. This will allow assessing, ex-ante, whether the analytical models developed, once implemented, will lead to satisfactory results. Secondly, simulation allows the compression of time, i.e., it allows observing many weeks of operation of the system in a few minutes. This, in turn, permits to perform a large number of experiments, evaluate multiple parameter configurations, and conduct accurate sensitivity analyses [15]. The ability of simulation models to grasp the complexity of stochastic systems and to easily observe - if necessary through appropriate animations - their behavior, leads to a deep understanding of the service systems under study otherwise not obtainable except with long and expensive pilot tests on the field.

V. Socio-economic impact

The PROASSIST 4.0 expected impacts are mainly related to user's quality of life and system sustainability. First, the project expects to advance the patients' quality of life by promoting and supporting an improvement in terms of patients' health literacy and management of their health status and, at the same time, preventing emergency states that can lead to hospitalization. Secondly, the project foresees to promote the better adherence to health treatments, thanks to a thorough and timely monitoring by the FCN and all the involved actors (formal an informal caregivers). In the design phase preliminary relevant indicators (KPIs) of such impact have been identified and will be refined during an iterative approach through the active involvement of patients and nurses involved in the service. Preliminary KPIs are:

- Users satisfaction (patient, formal and informal caregiver).
- Patient perception of nurse taking in charge.
- New family needs intercepted by the nurse.
- Health literacy of end-users.
- Adherence to treatments by end-users.

Furthermore, the project aims to generate a wider impact on the system sustainability according to the following dimensions:

1) Optimization of resources allocation through a remodelling of the interventions, with consequent improvement of the overall sustainability of the FCN service,
2) Improvement of the equity of access to treatment due to a better allocation of resources,
3) Reduction of avoidable hospitalization events, through the timely management of chronic patients,
4) Reduction of unexpected costs for both the patient and the health system as a whole caused by incorrect treatments and / or low adherence to treatments by patients.

The project therefore has the potential to change the healthcare organization by laying the foundations for a more flexible and personalized system in which resources are adequately allocated according to a "win-win" approach aimed at reducing resources' mismanagement (human and monetary) by strengthening the transfer of the place of care from hospitals to the home-care and paving the way for a home-based care 4.0.

VI. Conclusions

COVID 19 has changed our needs and attitudes towards healthcare services and towards the way they are provided on a territory. According to this, PROASSIST 4.0 gets the opportunity to revolutionize the local healthcare system management because of its taking root on concrete needs and on cutting-edge technology. In particular, it wants to promote the dissemination and systematic use of specialist skills in the healthcare domain thus favoring the equal distribution of assistance and health care services in both, urban and in rural areas without discrimination, and guaranteeing a higher patient as well as of all the identified actors' involvement through the integration of services and information.

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