Towards a Smart Region: the Case Study of a Teledermatology Platform in Sardinian Region (Italy)

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Abstract—Teledermatology offers the possibility of improving access to dermatologic care by using telecommunication technologies for connecting several medical centers and enabling to exchange information about skin conditions over a distance. This paper describes the main points of the implementation of a teledermatology project following the so-called smart region paradigm. A case study is presented to describe how the implementation of a virtual organization model using teledermatology is able to promote and facilitate the diagnosis on skin diseases and improve the quality of care for rural and remote areas. Initial results and assessment by general practitioners and dermatologists show that the proposed software platform can be used as a decision support system for dermatological patients.

Keywords-smart cities; smart region; teledermatology; e-health platform; healthy cities.

I. INTRODUCTION

Living in healthy and smart place-based communities is a widespread aspiration not only among policymakers but also among residents and city users. Different proposal and solutions are being used to compare the future city visions under different focuses on health such as competitive cities, resilient cities [1], green cities [2], creative cities [3]. Catalyzing sustainable urban transformations towards smarter, healthier cities generates development also at regional level [4], by transforming the conventional interaction with single places and creating dynamic networks for all involved people [5]. Habits changed by virtues of a higher well-being that extend to health can make more attractive and competitive the entire context of reference [6]. The World Health Organisation (WHO) underlines the correlation between health and territory, stating that a healthy city is one that is continually creating and improving those physical and social environments and expanding those community resources which enable people to mutually support each other in performing all the functions of life and developing to their maximum potential [7]. Hancock also underlines the characteristics of an healthy city, in which the focus is not the city itself, but the people who live there [8].

In this view and according to Garau et al. [10], the concept of healthy city is inextricably interconnected to the idea of smartness - a synonym for growth, efficiency, inclusiveness, and technology - in which the referred territory not coincides with a single city [10], but considers relationships among the nearby cities, by facing complex multisectoral, multiscalar challenges on a regional scale. However, this concept of healthy city at the regional scale must be supported by IT tools, specialized personnel, and advanced medical-patient communication techniques (in literature it is called eHealth).

According to the definition given by European Commission1, eHealth refers to tools and services using information and communication technologies (ICTs) and data sharing between patients and health service providers, hospitals, health professionals and health information network in order to improve prevention, diagnosis, treatment, monitoring and management to meet needs of citizens, patients, healthcare professionals, healthcare. eHealth includes a wide variety of sub-domains such as Electronic Health Records (EHR), telehealth, telemedicine, mobile health (mHealth) and so on.

The growth of this sector is also highlighted by a recent study on telehealth market2. This document states that telehealth market is projected to reach USD 9.35 Billion by 2021 from USD 2.78 Billion in 2016. In their opinion the growth of this market in the coming years can be attributed

1https://ec.europa.eu/health/ehealth/policy_en
to growth in geriatric population, dearth of healthcare professionals worldwide, improvements in telecommunication infrastructure, technological advancements, increasing utilization of connected devices for the management of chronic diseases, benefits of telehealth and need for affordable treatment options due to rising healthcare costs.

Based on these assumptions, planning for the development of healthy and smart communities represents one of the new challenges for strengthening and revitalizing territories. In particular, the field of dermatology is specially suited to telemedicine because skin disorders are visible to the human eye, and clinical information can be acquired, stored and transmitted for accurate diagnosis and treatment plans. In addition, the practice of teledermatology can alleviate the maldistribution of specialty care, and enable patients not located in geographic proximity of expert resource to receive care by improving access to dermatologic care by using telecommunication technologies.

This paper is structured as follow: Section I provides an introduction and Section I-A gives the reasons why we chose the case study of the Sardinian region in Italy. Section II presents a state of the art. Section III gives an overview of the Virtual Organization model and of the software system functionalities. Section IV describes the methodology and finally conclusions are discussed in Section V.

A. Research Background and Setting

This section provides the background and motivations of this study. We chose as case study of this research the Region of Sardinia (Italy) because it is considered to be significant for several reasons described below. Starting from some considerations introduced in Section I, Sardinia can represent a model of a smart region because it is characterized by a dense network of small, low density urban polarities (in Europe, more than 80% of cities are medium sized - between 100,000 and 500,000 inhabitants - and they contain 40% of the population [11]. In Italy, however, 70% of municipalities have fewer than 5,000 inhabitants, accounting for 17% of the population. In Sardinia the proportions are higher: 83% and 31.5%, respectively [12]).

Figure 1 shows the Sardinian demographic situation in 2011 where only two cities exceed 100,000 inhabitants (Cagliari and Sassari) and 2 others the 50,000 (Quartu Sant' Elena and Olbia). From the remaining 373 municipalities, 3 cities exceed 30,000 inhabitants (Alghero, Nuoro and Oristano). It is important to consider that 47 Communes are in the range of 5 to 15,000, and 314 are under the 5,000, of which 122 are under 1,000 inhabitants.

Sardinian region has also the elderly population in Italy: its inhabitants are 46 years old, on average. According to Ufficio Studi di Confragianato Sardegna, in 2050 the rate of its aging population will increase and the over 65 will pass from today’s 366,681 to 553,070 (affecting 40.5% of the total). On the basis of these demographic forecasts the average age in Sardinia will rise from 46 to 54.1 against the expected Italian media of 50.1.

Also its condition of insularity is a disadvantage for Sardinian Region, in terms of accessibility. For example its condition makes expensive and difficulty to move to the mainland in order to obtain health consults.

On one hand, the transport infrastructure in Sardinia is far less developed than in the rest of Italy and this condition compromises the internal movements. Inadequate infrastructures cause suffering to the population. On the other hand, the Sardinia Region has invested in the spread of broadband in the territory, creating an ICT infrastructure that reduces the digital divide and allows the use of technologies such as videoconferencing, even in internal territories.

These small and low density urban polarities, the elderly population and the insularity condition induce Sardinian region to be characterized for a strong local identity, but also for a low availability of economic resources, transport infrastructure and health services. If the population is aging the health costs will rise. The telemedicine as flexible medical technology could lower costs and improve the prevention system. Contemporaneously, in order to transform Sardinia in a smart region it is necessary to increase preventive health care and reduce the queues in the clinics by enabling individuals to take simple and fast actions to improve their wellbeing.

In addition, in Sardinia skin melanoma is one of the major cancers with lung, breast, prostate, colon-rectum, stomach and cervix uteri. The estimated incidence rates of melanoma present a steep and progressive increase in both sexes [26]. Skin cancer - melanoma (MSC) and non melanoma (NMSC) - are common neoplasm with rising incidence over the last decades. Direct exposure to UVA and UVB radiation is undoubtedly the most important risk factor for...
the development of skin cancer [27]. Incidence of MSC and NMSC has increased over the past 50 years in fair skinned populations in Europe, North America and Australia [29].

International dermatology organizations have posed the question of how to achieve healthy skin for all, with emphasis placed on increasing awareness of the importance of skin and delivery of care [28]. The question about how can we achieve healthy skin for all is challenging and focuses on populations with need for skin care.

A review of methods used to raise awareness in primary care is required [32]. One of the global health strategies is to emphasize the need for skin prevention. Nowadays prevention strategies as monitoring the skin and detecting the early signs of melanoma are an effective method of maintaining healthy skin [33].

To address this question, we have developed a software platform for dermatology prevention, diagnosis and training as tool enabling for achieving healthy skin for all.

Dermatology is a specialty reliant on excellent perceptual skills and pattern recognition. General practitioners (GPs) provide preventive and routine health care to patients and they play a key role in the prevention, diagnosis and monitoring of diseases. They are responsible for the initial assessment of skin lesions (10-15% of primary care cases). Their widespread presence in the territory makes GPs a crucial element to ensure a high level of health care, even in sparsely populated area, from which it is often expensive and difficult to get to a specialist. However, GPs need to see dermatology cases frequently enough to remain competent.

Teledermatology services provide a diagnostically reliable method of increasing access to expertise in resource-poor regions.

In conclusion, both potential for Sardinian development following the smart and healthy region concept and for the telemedicine applied to the teledermatology makes it an interesting case study as well as a target for testing our cloud-based software platform that enables general practitioners to provide teledermatology services to their patients and to achieve healthy skin for all.

II. RELATED WORK

This section discusses the works related to our project. The health-care is a right for all people irrespective of the place where they live or their age. The telehealthcare services should satisfy people needs to obtain always a appropriate treatment. In a smart region context these digital care services can also increase the social connectedness and provide skills, resources and health-care advices to people and doctors. For instance the unbalanced distribution of health-care resources led Chen et al. [13] to analyze the usability differences between urban and rural areas in Taiwan for a web portal of telehealthcare. The survey proved that in an urban area the telehealthcare services should provide more information and smart applications than in rural area in which, given the lack of services, is necessary develop basic and simple services of telehealthcare.

IReHMo [14] is a tool, based on the CoAP communication protocol [15], that aims to efficiently transmit healthcare data within an existing network infrastructure. This project by a IoT-based remote health monitoring system seeks to protect the health of elderly people who live in remote areas and choose to stay at home.

Hussain et al. [16] proposed a people-centric framework that provides real-time medical services and increases social network of the disabled and the elderly people. It takes into account all components responsible for context sensing, processing information, data storage and possible responses.

The use of combined tools such as audio, video or message services was identified by Hossain [17] as the best solution in order to achieve better accuracy to remotely classify the patient’s condition. Their work is driven by an awareness of the need to monitor constantly the patient’s condition, specifically for these patients who are diagnosed previously health-related problems.

Going into the specifics of the dermatological care, Kroemer et al. [18] analyzed the diagnostic accuracy of dermoscopic image tele-evaluation for mobile skin tumor screening. They acquired 322 clinical and 278 dermoscopic images obtained by using a mobile phone camera and showed that the tele-evaluation might be useful for tumor screening.

According to Rosado et al. [19] the active involvement of a community of dermatologists is necessary to develop a mobile-based framework for early diagnosis of skin cancers. The authors presented a tool formed by a mobile application for the patients, a module for the image processing and a user interface for the dermatologists. The system makes a report that can assist the doctors in the check-up risk assessment.

Kanthraj [21] showed the importance of the concept of patient-assisted teledermatology practice. It takes into account both the possibility in which a patient enabled to upload his/her clinical images in order to require a medical consultation and the use by the dermatologist to seek expert opinion for difficult cases. Finally Jaworek et al. [22] proposed a cloud based teledermatology system to facilitate and speed up the consultation process between family physicians and dermatologists. This system is formed by a desktop monitoring application and a smartphone application. It is useful to help to inexperienced dermatologists and general practitioners to correctly identify and diagnose a melanoma.

Our project consists in the realization of a virtual organization for dermatological telemedicine aimed at providing an integrated service.

In this paper, we adopt the smart region paradigm because all pillars (living, people, mobility, governance, environment, and economy) always analyzed under the smart city paradigm [11], affect the potential for health and telehealth sector, expanding the classic smart city context to a regional
level.

III. THE VIRTUAL ORGANIZATION MODEL AND THE DermoNet System

We have studied a solution to provide dermatological services directly by the general practitioner with the purpose of shortening virtually the distances between patients and dermatologist. Our studies highlighted the necessity of a new smart environment for dermatological services and led to the design of a special typology of virtual organization (VO).

According to the definition of VO provided by Tamoshpinaite [24] “a VO is a self-sufficient geographically distributed short time or permanent consolidation of organizations, groups or individuals, which/who without time or space hindrances communicate through ICT while reaching a common goal”.

In the teledermatology context, the common goal of the VO participants is the increasing of the quality of the health services. The two most important categories of participants are identified in the general practitioners and dermatologist. The overall value of the virtual organization increases each time new participants join it. The more GPs will join in the VO, the greater will be the popularization and spread of teledermatological services across the region.

Dermatologists increase the value by means their expertise and their availability to be called for a teleconsulting. The VO breaks down the distance problems and the condition of insularity of a region such as the Sardinia. The establishment of the VO requires an ITC infrastructure. We have focused on the creation of this infrastructure by developing a web portal. The realized portal is a web based system with which the accredited users can operate using the system functionalities.

In detail DermoNet integrated software system is a pre-industrial prototype setting up a collaborative software platform of services oriented to support the management of dermatological patients and the diagnosis process by general practitioners and specialists working together in the VO. DermoNet is a model of dermatologic teleconsultation and works in a wide environment of VO. The project involved the creation of a network of dermatologic centers (or competence centers) which provide the dermatological consultation. They are modeled as hub of the network. The general practitioner is modeled as a peripheral node of the network. Using our platform, GPs are able to refer consultations to a dermatologist located elsewhere using two techniques of teleconsulting. GP forwards the consultation request to the specialist. Patients stay under the care of the general practitioner, both in ordinary outpatient services and when they are hospitalized. DermoNet implements two techniques of teleconsulting. The first - real-time teleconsulting - is based on videoconferencing systems providing real-time communication between GP, patient and dermatologist. The second, that is known as store-and-forward teledermatology (S&F), is based on taking digital images of skin lesions of the patient, uploading them in the portal and a consultation request is assigned to an appropriate specialist. Furthermore, the DermoNet project has been started under the assumption that a cloud based information system whose the resources are dynamically scaled and are used over the Internet as services can improve health care services. DermoNet has been developed to ensure the software interoperability. Indeed, DermoNet works together to a heterogeneous set of systems that compose the VO. Therefore, information contained in DermoNet are standardized and structured, and made available by means of tools designed to store and share data. The software interoperability requirements, along with specific design requirements of dermatology functionality, lay stress on the importance of a well defined knowledge base. DermoNet aims to be a useful tool to create a network for dermatologic teleconsultation and providing dermatologic support to general practitioners also to under served areas in the island of Sardinia. The offered consultation service allows the diagnosis and management of patients with skin diseases by GPs or dermatologists. Lozzi et al. [20] show the additive value of second opinion in the management of patients with skin diseases.

In order to manage the information, such as document retrieval by using keywords or other attributes, the system is based on three different Knowledge Bases (KBs). Each typology can be populated through instances of the related support ontologies. We have called these KBs as follows:

1) KB_{GL} - Knowledge base related to the Guidelines for dermatologists. Guidelines contain clinical behavior recommendations with the aim of helping doctors to choose the most medical appropriate assistance.
2) KB_{I} - Knowledge base related to all Images available within the dermatological atlas. It is the knowledge base related to all Images available within the dermatological atlas.
3) KB_{CE} - Knowledge base related to the expertise of dermatologists that work in the competence centers and that provide teleconsulting services.

The software platform uses the ontology as support for the KBs and allows the deduction process in runtime through a reasoner for the normal system operations. By using APIs a user can query each KB. Thanks to the KBs and related ontologies two important features are obtained, namely the data shareability and the data linking. KBs represented the starting point in order to obtain an effective data management. Furthermore, by means of the KBs the software system can provide a content based search of documents and information that works taking in account the meaning of the search terms. In fact, categories, concepts and metadata are described by ontologies. DermoNet portal is reached via a web client and works on the Internet. The portal is developed in order to be fully responsive and capable of working in mobile devices such as tablets and smart phones.
A. The DermoNet portal

The system provides three typology of functionalities: i) general functionalities; ii) dermatological functionalities; iii) management and configuration functionalities. For sake of brevity here we will discuss some general functionalities and in following section we will present the dermatological functionalities that are application-specific functionalities dedicated to the teledermatology.

General functionalities include the patient medical records section. Users access to the system through a login page designed to work with One Time Password (OTP) system. The main menu is composed of a list of available functionalities. The number of displayed functionalities depends on the users typology (i.e. general practitioner, dermatologist specialist, tutor and secretary). A special account, providing the access to the configuration pages, is enabled for the system administrator. Main menu summarizes the DermoNet functionalities. It contains the following entries.

- Staff components opens the team definition page. Teams can be created by choosing from the list of DermoNet users, filtering by category, competence area and department. It represents the starting point to define the VO.
- Questionnaire model opens the questionnaires creation page. GP can write personalized and interactive questionnaire, which will show different questions sequences on the basis of the patients answers.
- Patients opens the patients management page. This page provides a form with which is possible to add and edit patients information. Only the accredited users as tutor or secretary have full access to the functionalities.
- Medical Record opens the medical record page. This page appears as shown in Figure 2. For each patient the system displays an interactive form where patients name, his general practitioner and his dermatologist specialists are highlighted. The Medical Record page provides the list of treatment plans and the list of therapeutic annotations.
- Appointments opens the appointments book.
- Reports opens the report section with which is possible generate formatted views of the users data.
- Dermatological functionalities opens the dermatological section in which are provided all the system functionalities dedicated to the teledermatology. These represent the core of the DermoNet system.

B. DermoNet core

DermoNet system is able to provide advanced dermatological functionalities in relation to these specific KBs. The most relevant dermatological functionalities are described as follows.

- Images analysis. The DermoNet prototype provides an automatic analysis and annotation system for dermatologic images. The system provides a semantic annotation of classification and diagnosis probability on the basis of the KB\(_I\) described above. Figure 3 shows a screen shot of some pictures of skin disorders.
- Guideline services. These services enable the consultation and continuous updating of the diagnosis and therapy Guideline Knowledge Base. A rich set of filters allows an accurate information finding.
- Atlas service. The dermatologic atlas provides cataloging and sharing services of specialized dermatologic data. This service is based on the KB\(_I\). Users can explore the Atlas by means of a semantic search engine working with the ontology that we developed. It is possible look for information of a specific disease by providing the localization or the diagnosis, and following the terminology recorded in the ontology system. Results will be grouped by diagnosis or by body regions.
- Teleconsulting services. DermoNet provides the environment for the teleconsulting which GP may require to a specialist in the VO. The teleconsulting is facilitated by the KB\(_{CE}\).
It provides data and terminology needed to avoid misunderstandings during the communication between GP and the specialist.

To name a few other services provided by the DermoNet portal are learning services that provide a personalized distance learning course about advanced topics in dermatology.

IV. METHODOLOGY AND MAIN FINDING

In order to understand how the implementation of our virtual organization using teledermatology is able to improve the quality of care and put into effect smart growth strategies for specific regions - as the case of the Sardinia - our prototype was tested. Consequently a qualitative study was conducted and we also evaluated the degree of agreement in diagnosis between teledermatology and face-to-face consultation under some set conditions. Our study aimed to identify the perceptions of general practitioners and dermatologists.

To answer to our research questions the software system has been developed using an iterative process with short-term interactions and frequent feedback between developers and users following an Agile approach [30],[31]. All software development phases implied an interactive process with physicians (both GPs and dermatologists) since they were planned as a collaborative process between the software developers and the physicians who tested the system. During all period of software development a small group of 13 physicians (3 dermatologist and 10 GPs) took part in the software validation, and a total of 30 teledermatology consultations were performed. Briefly, general practitioners and dermatologist specialists who participated in the project was invited to express a personal opinion on the elements of satisfaction or technical-professional dissatisfaction about the DermoNet system related to reporting, diagnosis and classifying them in detecting melanomas and separate them from other lesions. The system gives to the GP a diagnosis without the consultation of the specialist. Finally the same patient was referred to a face-to-face consultation with a dermatologist in order to compare the two diagnosis. We used the same classification of levels of agreement both for the dermatologists and the GPs. We measured the satisfaction level in terms of impact on the health system by following the smart region paradigm because of GPs and dermatologist specialists were in different municipalities in Sardinian region.

The number of interviews may be considered small (10 general practitioners and 3 dermatologist specialist), but we followed the principle of saturation, in which it is possible to collect data until to the saturation of information [35] [36]. The analysis of collected data has revealed a not entirely homogeneous framework. Especially due to the reticence of some GPs to the use of the technologies as well as confirmed by some studies reporting that in general obstacles to the spread of telemedicine are also of technological nature. All general practitioners declared very helpful the ability to share care data between Gps and dermatologist specialists. In the face of this consideration as a consequence we formulated a specific question on this thematic. All interviewees confirmed what their colleagues suggested and hence the functionalities of access and information sharing of the system DermoNet related to reporting, diagnosis and photographs of the pathology are definitely useful to improve their work. Another important key point was related to the ethical and regulatory aspects including any legal-medical implications. These considerations also derive because nowadays there are available guidelines on the matter without a specific regulation in this area. All the interviewees agree that the prototype was perceived as a powerful tool to improve dermatological services for populations living in remote areas.
V. Conclusion and Future Works

DermoNet project was financed by regional low 7/2009 with the aim to develop a virtual organization model through a teledermatology software platform able to support general practitioners for diagnosing skin diseases. We have designed, developed and validated a software platform based on cloud technology in order to create a network for dermatologic teleconsultation that provides dermatologic support to general practitioners also to under served and rural areas in Sardinian region. The virtual organization among patients, GPs, dermatologists and healthcare institutions enables to support them during the evaluation of dermatologic patients. In this way the specialists and the general practitioners can collaborate to obtain the best diagnosis possible for specific skin pathologies. One of the main objectives of the project was to improve patient access to care and provider access to specialist expertise and knowledge sources. The system may provide answers about some serious dermatological diseases such as melanoma through a non-hierarchical and open-system Virtual Organization with which the GP can take advantage of the teleconsulting.

The prototype was validated in the Sardinian Region, an island that may represent a model of a smart region especially thanks to the DermoNet platform under study. Peculiar conditions described in Section I-A make the Sardinian region a very interesting case of study. In fact, the demand of easy-accessing dermatological consulting may help to go beyond the disadvantaged conditions of internal areas of Sardinia.

Finally there are some issues that need to be addressed. In teledermatology is particularly important the issue of medical confidentiality and the privacy is a legal issue of primary relevance. Planned future work and improvements include tighter integration with a disruptive blockchain technology that could be used to achieve a trusty interoperability in health application [34]. The distributed and decentralized nature of the blockchain allows the interoperability of several telemedicine systems. The blockchain-oriented approach enables the sharing of patients data based on rules of the consensus algorithm. The introduction of the blockchain technology brings with it some important aspects that will be addressed. The first point is the privacy. Data recorded in a blockchain are publicly available. It is mandatory to study a data recording system based on a cryptographic system. The system will allow both medical staff and the patient to know the medical record. The blockchain is also powerful as a system to authenticate data. Instead of recording documents in the blockchain, it is possible to record only its hash code through a specific hashing function. The unchangeability of the blockchain may allow the document hash code to verify the authenticity of the documents.

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