

Tele-Ophthalmology Eye-Health system deployment in Kolda, Senegal

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Abstract—The Open Window to Senegal is born as a continuation of the Eye-Health project, carried out in the High Pyrenees region, north-east Catalonia, Spain. Eye-Health dealt with the difficulties entailed to life in isolated and poorly populated villages, where no hospitals or specialized doctors are placed.

Open Window to Senegal's main goal is to make specialized eye health available in the region of Kolda, using a telemedicine system designed specifically to improve ophthalmologic medical care. This consists of a cooperation between the family doctors of every village with specialized ophthalmologists of the main hospitals of the regions nearby.

In the particular case of Senegal, this project is especially important as the country's medical resources are limited, and need to be optimized in order to reach the biggest part of the population, mainly those who are far away from resourceful hospitals. The authors hope this is a first step in a series of assistance projects that will help improve and optimize health care in regions of the world where inhabitants still can't reach a sufficient welfare.

Index Terms— Tele-ophthalmology, telemedicine, healthcare, ICT

I. INTRODUCTION

Senegal and Catalonia have different health needs situations and also different health care service. But, in some special cases, the same health systems solutions can be applied.

The Catalan health system is a publicly-funded system with comprehensive coverage and which all the citizens of Catalonia are able to access. During the 80's and 90's the middle-high urban classes contracted a private health insurance in order to avoid waiting lists. Therefore, the Catalan health system is co-paid between public and private funds.

The Senegal health system is guaranteed in its constitution as a right of every citizen and the duty of the state to provide.

The medical and health systems are inherited from French colonization. Senegal was the place chosen to settle High Commissioner that will coordinate the Governors inside the AOF, *Afrique Occidentale Française*. One third of the population is covered total or partial insurance health coverage, and the other two thirds of the population are financing their health fees through their own or indirect supports, [1].

In Catalonia, the physical inactivity inherited from an urban sedentary lifestyle, in combination with the progressive population ageing, treatment of chronic diseases and the rise on immigration levels has put the health system under stress conditions. The health resources management, in terms of hospital placements and professionals, was designed and works as a response to manifestation of diseases in an acute state. This system behavior implies a long and expensive treatment that makes it unsustainable and favors the introduction of e-health systems as a cost-effective solution.

Located in the north-east of Catalonia, the *ILO Lleida Ophthalmologic Institute* detected unattended ophthalmologic demand among the little towns of the High Pyrenees and created the Eye-Health project supported by the technical expertise of the *i2CAT Foundation*. The GPs who provide general health care in the area were equipped with a telemedicine system and send ophthalmologic relevant information to the ILO headquarters where it is analyzed.

Afterwards and as a consequence of the excellent results achieved by the Eye-Health projects, the ILO staff imagined the benefits that the Eye-Health system would bring to improve the development inside eye health field in a developing country. Telemedicine has the potential to decrease health care costs while increasing access, capacity, and quality of health care in sub-Saharan Africa, [2].

Nowadays they are involved in the deployment of a Tele-ophthalmologic system adapted to the needs and special characteristics of the main hospital of Kolda in Senegal.

II. EYE-HEALTH PROJECT

A. Pyrenees region, characteristics and needs

There are some local villages at great distance to any of the qualified ophthalmologic clinics located inside bigger cities. Any patient in need of medical care, such as ophthalmologic attention, has extra difficulties to get it if they do not live in the mentioned cities or in the surroundings. It has to be mentioned that the High Pyrenees region, is a mountainous part of Lleida, inside the north-east Catalonia. This area is one of the most hard to access places in Catalonia due to its difficult terrain shape and lack of access roads.

The lack of ophthalmology specialists close to small villages, along with the high demographic dispersion in the area, are two important reasons to consider the option of telemedicine, particularly teleophthalmology, in order to provide to this rural environment with top quality medical care like in the rest of the country.

Besides, the e-learning factor is very important as well. While family doctors deal with everyday problems in the eye health matter, they are trained at the same time by the ophthalmologists who assist them, entailing a profitable professional relationship for both doctors. Moreover, the GPs placed in remote villages gain access to a wider social community, counteracting the feeling of loneliness that they have due to their isolated and limited nearby society.

B. Eye-Health Project, How it Works

The technical solution developed inside the Eye-Health project incorporates an ophthalmological report's monitoring, control and management system, which can be accessed through the Internet and which gives the possibility to automatically assign the reports to the ophthalmological specialist for future studies and consultations.

Non-specialized doctors (e.g. family doctors) are able to save and diagnose different eye pathologies from their patients, and can as well enclose all the necessary data in the report, including eye fundus' pictures.

Assuming lack of resources related to telecommunications infrastructure inside rural environments, such as the rural villages of Lleida, an important challenge is to obtain a suitable technological trade-off between the bandwidth optimization and the medical pictures quality. The entire technical solution is detailed inside figure 1. It can be seen that there is an ICS replica server to give redundancy to the system and also security in health images. The system is able to pass through firewalls to arrive to any terminal that the ophthalmologist can entry to access the web.

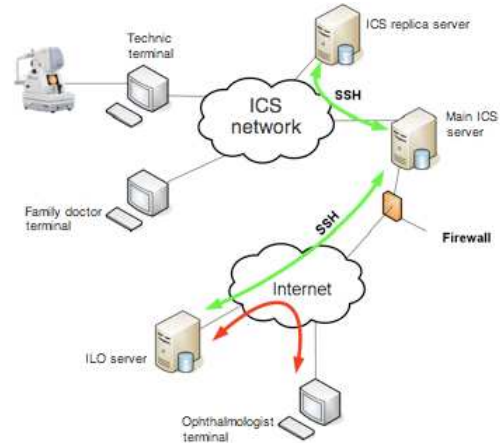


Figure 1. Scheme of the Eye-Health System

C. Shared clinical history in Catalonia (hc3)

In Catalonia, the new Shared Clinical History system (HC3) is currently being used by more medical institutions every year. With this centralized system, the entire medical history of every patient is stored and is accessible by any of the cooperating institutions over the network. This methodology dramatically increases the speed, reliability and safety of the medical data stored. Eye-Health project works with this technology, and it is also adaptable to modifications of it.

D. Project results

The Eye-Health Project has achieved numerous goals in a territory where medical assistance is limited. On one hand, there is no need to regularly have an ophthalmology specialist to handle the first stage of the selection process. On the other, patients save time and money as they do not have to visit a remote hospital every single time they need this type of medical care.

During the whole period that this project was running in the High Pyrenees region, the staff involved consisted of 13 GPs, 3 nurses and 1 ophthalmologist. A total of 489 patients were treated, and 1004 eye fundus' pictures were taken. This test was highly reliable, as can be seen in the following results: Adhesion: 89.50%, Specificity: 84.78%

The project was successful, having an elevated response from the patients. 80% of the cases studied inside the Eye-Health project the diagnoses of both, the family doctor and the ophthalmologist, coincide. In the rest of them, safety prevailed and patients were sent to the specialist, meaning that only the 20% of them are sent to a second evaluation.

The main advantages that this project brought were: reduction of the waiting lists, increase on the patient's comfort, and optimization of the medical specialist's resources, as well as the possibility for isolated population to receive specialized medical care.

III. THE KOLDA REGION, SENEGAL

The Senegal country in the Western Africa region has a total surface of 196,722 km² where live 12,379,000 people, 2,604,000 settled in the capital, Dakar city,[3].

The life expectancy is about 54 years old for men and 57 for women; the 41% of the population is aged between 0-14 and in 2007 the GDP per capita was \$908.4 according to the World Health Organization, [4]. Due to the poverty level and an elevated index of unemployment the Senegal people moved to the city. In 2007 the urban population was about 42% of the total, and it is expected to be growing until 2010 by 3.1% every year which mean that Senegal's agrarian zones, as Kolda, are decreasing their number of inhabitants.

The Kolda region is located in the south of Senegal. Its size is almost 21,011 km² with a population of 847,243 inhabitants where the Peul is the main ethnic group. Despite Kolda is a region with favorable climatic conditions for economic activities and great agribusiness potential with 1,100,000 hectares of arable land, less than 23% is cultivated and had became the poorest region in Senegal.

Concerning to education, small town's illiteracy rate is about 90% and the health situation is critical. The region has low health coverage. There is only one central hospital and four clinics not sufficiently equipped in Kolda city.

In the countryside, clinics (called "case de santé") are almost devoid of most basic medical equipment and inappropriately trained staff that works over their possibilities. Moreover, malaria is widespread in the region and is the first cause of mortality. It contributes to increase the high rate of neonatal and infant mortality.

Senegal's own government, in its Blindness in Senegal report, has stated the need of a methodic and efficient planning for the prevention of this disease, based on a stronger effort of political authorities in order to deal with it as a public health issue.

The Ophthalmologic care service is deficient in Senegal, but especially dramatic in Kolda, where the number of professionals with some ophthalmologic knowledge is extremely low as shown Table 1.

TABLE I
PERSONNEL WITH OPHTHALMOLOGIC KNOWLEDGE

ZONE	OPH (public + private)	TSO public	OPK public
SENEGAL	34+19	79	11
DAKAR	24+18	38	2
KOLDA	0	4	1

OPH - Ophthalmologist
TSO - Nurse education and 2 years specialization in ophthalmology.
OPK - Nurse education, 2 years specialization in ophthalmology and 1 extra year in surgery.

Source: Senegal Health Authority 2008 (Ministere de la Santé)

Blindness in Senegal report also says professionals should be considered as educators, and not only as hospital-exclusive personnel. This is an essential matter, considering the state of the subject in Senegal.

The participation of European governments and non-profit organizations has been basically oriented to solve specific problems, such as operating cataracts. However, future development of these regions involves training and awareness of the population and medical professionals.

Under these economical and social conditions the application of telemedicine systems is going to be a great improvement to support the health care service. In order to achieve this target, it is mandatory to deploy first the required communications infrastructure.

Despite communications' services (Local service, Domestic fixed long telephony, DSL and Wireless Local Loop) are able to be contracted under a full competition market, the new information society tools are very little used. The exception is the cellular telephony which its usage is growing every year.

TABLE 2
INFORMATION SOCIETY TOOLS USE

Tool	Penetration index (100 inhabitants)	Year
Computers	2.22	2005
Fixed Telephone line	1.95	2008
Broadband Internet	0.39	2008
Internet users	8.35	2008
Cellular	44.13	2008

Source: ITU - ICT EYE REPORT, [5]

IV. OPEN WINDOW TO SENEGAL PROJECT

A. The Ferreruela Sanfeliu Foundation

In 2005 the NGO *Ferreruela Sanfeliu Foundation* was created by the ILO staff in order to carry out cooperation international projects in developing countries. The main objective of the foundation is to contribute to the eye health filed improvement through the execution of specific actions as well as transfer good practices as the ones learned by the Eye-Health experience.

The cooperation between the NGO *Ferreruela Sanfeliu Foundation* and the health care service of the Kolda region was born in 2006 in order to establish a permanent relationship between the ILO Ophthalmologists and the personnel of main hospital. The Kolda region was selected due to the fact that its health care service is the most deficient in Senegal and the ophthalmologic supply is inexistent.

The whole project is a 5-year initiative that aims to take care of the unattended ophthalmologic demand and is planned to be

applied as a complete program in concordance with the National Program Against the Blindness lead by the Health Ministry (Ministere de la Santé) and coordinated by the Regional authorities (Conseil Regional and Regio Medicale).

The whole project is divided in 5 subprojects in order to achieve a better management, those are:

1. Cataract surgery
2. Fight against Trachoma and Trichiasis
3. Childen Refraction Defect Detection Program
4. To set up an optic shop cooperative managed
5. Deploy the Telemedicine System based on Eye-Health, *The Open Windows to Senegal Project*

B. EyeHealth to Senegal, is it possible?

The *Eye-Health* experience is not directly deployable to Kolda. This is because it was created to work under the Catalan environment which is completely different and has determining factors with no relationship with the Senegal reality. The report *Health diagnosis comparison between Catalonia and the Republic of Senegal* published in 2007 by the Health authorities of Catalonia, [6], stand out the following index: 1) The total funding percentage invested in health in Catalonia is 31.8 %, in Senegal 10.3 %. 2) The coverage provided by the Catalan health system is 99.4% of the population, in Senegal arrives at 63.57%, in Kolda in about 40%. 3) Life expectancy is 22 years longer in Catalonia than in Senegal. 4) In Catalonia, one physician is in charge of 1.500 inhabitants, in Senegal has 70.893. 5) For 1000 inhabitants, in Catalonia there are 4.7 hospital beds, in Senegal only 0.34.

Taking into account the big distance that separates both realities, we can also find some common points. The Eye-Health system is deployed among little towns of the Pyrenees whose access by road is difficult, especially in the winter when the snow make the physicians and patient's arrival to hospitals more difficult. This high index of inhabitant's dispersion is a fact in Kolda as well, the towns among the region are little populated and its access is complicated too, almost impossible during the rainy season.

Another point, that both realities share, is the lack of ophthalmologists that wants to work on those places. In Senegal, the few people who can pay their studies at the university prefer to practice abroad (mainly preferred to practice in France because of the common language) or at least in Dakar. In Catalonia we find almost the same behavior, the full coverage that the health system provide, require a great number of ophthalmologists and those who finished their own studies are not used to stay and work in remote emplacements far from the urban zones.

C. Open Window to Senegal Project

The *Open Window to Senegal Project* aims to deploy a technological platform able to support the *Ferreruela Sanfeliu*

Foundation cooperation activities based on the experience of the Eye-Health system. For this reason, the *i2CAT Foundation* technical expertise is again required and is involved from the beginning in such deployment.

Nowadays the activities are still in its first stage, the ILO ophthalmologists are regularly visiting the main hospital of Kolda to introduce its medical techniques to the health care personnel and to carry out cataract surgery. Until now, they have done about 350 interventions. To give a permanent back up and support in the complicated post-operation cases, a videoconference system is going to be installed in October 2009 (ILO staff have one already installed in its headquarters) and, at the same time, it will allow the beginning of an e-learning program as a continuity of the training already started.

Such videoconference equipment is going to be installed by the *i2CAT* technical team who will travel to Kolda with the ILO medical staff company in order to survey the requirements and needs of the Ferreruela Sanfeliu Foundation Project and the local staff. This information will be the foundations of the new technological platform and the pillar to construct a properly system.

It is planned to have the technical platform running 6 month after the requirements analysis (April 2010). At such time, the second stage of the project will start with all the required functionalities. In order to fulfill the calendar and achieve a realistic approach, those functionalities will be based in the Eye-Health system which, at same time, will guarantee as much as possible the success of the deployment.

During the second stage of the project, the platform will allow the ILO ophthalmologists to control the patient's eye health remotely. From Lleida they will analyze the eye's fundus and relevant information sent through the application. Simultaneously, the hospital personnel dedicated to eye health will participate into the e-learning program which will train them in system procedures and knowledge need to improve their diagnosis capabilities. During the second stage of deployment, is the great importance for the future success of the project, that the staffs who will use it daily adopt the platform as its own tool.

As a final stage, is expected to achieve the Eye-Health full performance which means to allow physicians to visit the towns surrounding Kolda and establish a direct relationship with the patients. Once this behavior will be achieved, all the benefits of the telemedicine described as a success of the Eye-Health project, will benefit the Kolda region.

D. ICT infrastructure

The Direction des Etudes et de la Réglementation des Postes et des Télécommunications (DERPT) is responsible for the regulation of the telecommunications sector.

Resolutions and actions from DERPT are applied to the *Société nationale des télécommunications du Sénégal* (Sonatel Group). Since November 2006, Orange has become the incumbent provider because Sonatel's network has transferred to them most of the final user's services, mobile and internet access. It has been improved the network to provide services and offers to the inhabitants. But the costs of installing new networks make that prices are above the possibilities of the inhabitants (Orange-Senegal [7] prices 25000 F.CFA TTC for a 1 Mbps / 256 kbps and 53600 F.CFA TTC for a 10 Mbps / 512 kbps).

Therefore, only companies and some neighborhood in Dakar and Sant Louis can be shown as connected areas. In Kolda the cybercafé emplacement is the main internet point for a lot of people. But what is more important is that Kolda's hospital is connected.

The main internet Hospital's access comes from Kolda's Region point, which is connected to Kaolak telecenter, see it in figure 2 as KLK, and from there, it has a redundant connection to the international network, orange lines displayed in figure 2. This leads to a more secure system connection that allows some possible failures on the network.

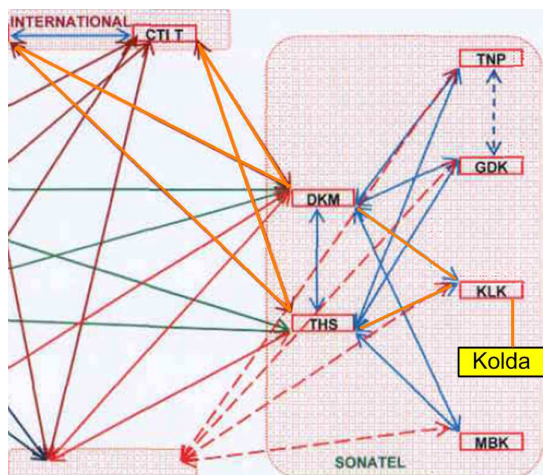


Figure 2. Scheme of Sonatel's Network

What is also important is having connected a generator to compensate for possible power cuts that can occur. Into the next years Senegal will create its NREN, National Research and Education Network, which is in an emerging position according to Boubakar Barry [8]. Nowadays it stills without a name to call it, this is because the plans and proposals to create it have been released and they are going to create it in a few years. It will bring the connection to a greater network and will enhance new developments and share of knowhow with other countries. It also will bring faster connectivity to all the area.

E. Broadband Technical Tests

Various throughput tests of network traffic between NOC-i2CAT (Barcelona, Spain) and the Kolda Hospital (Kolda,

Senegal) have been performed using Iperf testing software. It has been obtained a series of results that ensure the viability of the telemedicine platform proposed.

The exact results of the tests were 300 Kbps in TCP mode and 50000 Kbps in UDP mode. This ensures that H.323 communications are possible with UDP protocol. First Stage of deployment has a 500kbps minimum requirement of UDP connection and tests results shown that it is possible to enable.

V. CONCLUSION

In this paper, we presented a Tele-Ophthalmology system solution for the Kolda region. This system is based in the Eye-Health previous experience settled in Catalonia whose objectives were successfully achieved.

The Kolda population lives dispersed surrounding the Kolda city and this fact has made access to the health care services more difficult. The Eye-Health project has deployed, among the isolated towns of the Pyrenees, an ophthalmologic service provided by the GPs that visits their patients and reduces the mobility of their citizens making easier their access to the health care service.

In the Kolda region there is a lack of ophthalmologists and the few personnel with ophthalmologic knowledge cannot attend the high demand on this field. The Eye-Health project has put the Catalan GPs under an e-learning process that makes them able to carry out preliminary tasks in the ophthalmologic care of the general population. The complex cases are transferred to the specialists, located normally in urban zones, which reduce the required number of professionals.

We have shown that Tele-Ophthalmology allows three main goals: to reach a great number of people at a very low cost, to be able to make up the lack of professionals on the field and the transfer of clinical knowledge. In addition, it also has a significant power on raising awareness on eye health.

We encourage the deployment of telemedicine systems that can improve care in other specialties. It could not be done without the existence of NRENs that should be promoted to allow the creation of research groups and boost technical and scientific development. Moreover, it will ensure a better connectivity, also cheaper, for giving to the Senegalese country a network access to research groups and information that Internet is offering.

Like most developing countries, Senegal is faced with considerable problems in terms of public health and preventive medicine. Its communities, particularly the more remote ones, are increasingly marginalized and barely have access to primary healthcare, let alone to quality specialized healthcare.

The Information Society Tools as Tele-Medicine will provide, to developed and developing countries, a new way to improve their social services. The existence of a basic communications' infrastructure is required to deploy this new tools and system that will provide its great benefits to the general population.

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