Improving Healthcare Using Cognitive Computing Based Software: An Application in Emergency Situation

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Abstract. The goal of this paper is to define the platform specifications dealing with medical information sharing both from research viewpoint and in terms of local health care. The purpose of this research work is based on doctor - patient relationships: VDS - Virtual Medical Doctor System. At this stage the platform is only used for scientific purposes.

In particular, we assume the integrated design of the platform based on different levels (layers), which may be interconnected through the information flows (or links). The first level (the lower) involves the construction of a VDS platform. Based on this system it is possible to foresee a number of extensions such as social network for scientific research design, and risk analysis tool.

Keywords: Doctor-patient relationship, VDS, Virtual Medical Doctor System, Human user interaction, Action decision model.

1 Introduction

The present work is focused on designing and developing a decision support system tool able to analyse data collected from different sources. One of this application is developed in medical field with VDS (Virtual Doctor System) developed in medical field applications. Starting our study from the existing data source and discover other data sources in order to make a more complete and exhaustive analysis. One main point is the interaction with medical Doctors to extract the knowledge base and criteria to be implemented on the system. Since the heterogeneity of collected data a creation of different separated Data Mart including specific data for each expected analysis typology is built. At the end a part of this system will be implemented in an Open Source Software called Pentaho used as a Proof of Concept of this study.

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In order to achieve this goal the following steps are carried out based on these essential steps:

- Requirements analysis and collection;
- Data sources identification;
- System design;
- Proof-of-concept implementation.

2 Research Conceptual Foundations and Methodology

Italy and Japan have two very different cultures, however, they have many similarities in the way they consider elderly people. Japan and Italy share the same strong relationships among family members, both have great respect for old parents and very often elderly are going to pass many of the last years of their life under the direct care of their beloved ones. This situation is resulting in needs of more domicile care for the elderly and a distributed assistance to be performed by Medical Doctors (MD). These MD are often generalist and very few ones have received special training for geriatric treatments. When one of their elder patients requires special assistance (i.e. urology) they send him to a clinic or to a specialist resulting in an extra cost for care and in a waste of time as well as in a source of stress for the patient.

Vast majority of the patients requires more health monitoring and screening especially in particular situation (i.e. summer time, flu pandemic exploits, etc.) where they are more vulnerable. In exceptional situations such as natural disasters (i.e. earthquakes, floods, etc.) elderly people needs to be located, assisted and supported with a special care since they're often limited in mobility and because of their critical health conditions. More the increase of the average age of the population pushes the cost of the healthcare assistance higher and higher causing politics to seriously consider more budgets cuts as only solution to a rapidly increasing of welfare costs with MD and hospital struggling to guarantee an average level of service to the elderly. In a few words, today, elderly people are only seen, by politics, as an increasing source of problems resulting in a bad feeling for younger generation. Japan share with Italy the same awareness of the problem, both they have seen their population to became older and welfare costs are continuously increasing the National Debt (225% of the GP for Japan and 118% for Italy) and both known that this situation may only became worst: more elderly, more needs of assistance, more money for healthcare, less money for investments, less opportunity to grow the economy, less feeling for a better future, less money to have children to young couples resulting in an increase of the average age of the population: a vicious loop.

This loop could be interrupted by increasing the level of assistance to the elderly reducing at the same time the cost for it providing a new technology able to act simultaneously in three directions:

1. Increase the screening and monitoring level of the health conditions of the elderly people, allowing early warning on possible pathologies (i.e. prostatic cancer, Alzheimer, hypertension, diabetes, etc.) .

2. Provide direct assistance to elderly people (diagnosis, psychological support, treatment monitoring.
3. Provide support in case of natural disaster by providing for most vulnerable patients: identification of their health conditions, clinical and psychological support as well a immediate point of contact with a MD that make them feeling not abandoned.

This paper is focused on the development of a possible technology able to provide the above-mentioned actions.

The methodology decision support tool is based on doctor - patient relationships that is very well expressed in the Japanese study of Virtual Medical Doctor System.
In particular, we assume the integrated design of the platform based on different levels (layers), which may be interconnected through the information flows (or links) as presented in the following figure 1.

- The first level (low) involves the construction of a VDS platform that will act as the core of the entire technology.
- VDS will have an avatar base interface (a) able to create a realistic representation of the patient both form the physical and the psychological point of view (b), the avatar based interface will be responsible to create an empathy (d) among the patient and the MD (real or simulated one) necessary to guarantee the perfect modelling of the real patient health condition.

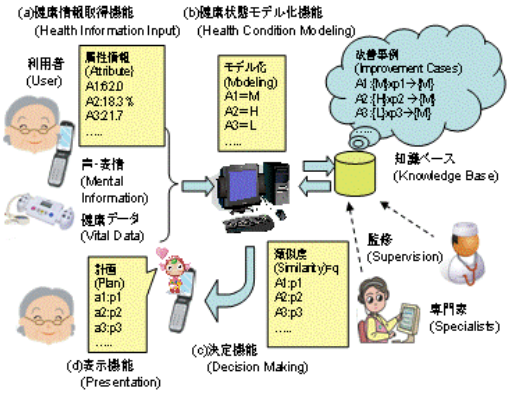

Fig. 1. Logical Scheme of the platform

Japanese VDS is designed to provide two main ontologies: physiological (vital data) and psychological (mental data) representation of the patient, Italian team will ad a third one specifically designed to represent the environmental condition of the patient living situation (i.e. pollution, radiation, temperature, humidity, noise, etc.). This systems will allow the possibility to remotely monitor the conditions of the patient from a single, and even a distributed, point of control. Real Medical Doctors (MDs) will monitor initially the conditions of the patients and, using the mental cloning methodology, will be possible to create a complex decision support system (DSS) able to support MDs to address patients correctly. The main purpose of this project will be

not to substitute MDs but to help them to deal with more patients more effectively providing first level screening and a single point of contact with their patients. A patient will have its well known and trusted avatar as representation of his MD and beyond him several MDs and specialist will monitor him reducing the stress of visiting several MDs when a specialist will be necessary. This system has also a self improvement and a learning loop since the knowledge base will be constantly improved by adding more and more medical records and more and more cases. This huge amount of medical records will be also available for researcher since various patients will be correlated with their physiological and environmental living condition resulting in a complex Virtual Clinic with thousand of patients under monitor. Based on this system is possible to foresee a number of extensions such as social network for scientific research designing, a platform for investigating possible pandemic scenario or simply a coordination point for delivery healthcare remotely in case on natural disaster.

This point is very well addressed considering its technological design: based on Cloud Computing and designed to take advantages from portable devices (i.e. Android OS), this application will have great potential in case of a natural disaster. Within few hours from the event is possible to re-establish 3G networks allowing elder patients to connect back to the VDS. A scared, and potentially injured patient, could connect back to its MD avatar, communicating his vital, mental and environmental parameters and receiving first aid instruction, psychological support (i.e. I am not alone, some one is taking care about me, etc.) and inform relatives about his current conditions. At the same time MDs, supervising the VDS, from a safe place (and potentially distributed) could be addressed on the more critical patients leaving general support to the non critical ones directly to the Knowledge Based Artificial Intelligence.

3 The VDS and Related Technologies

The VDS system is designed to work together with the corresponding human medical doctor in comprehensive coherency using the VDS before to outpatient diagnose and after to classify these diagnosis into classes. So called Simple cases classes could be addressed directly by VDS that would take conclusion and set the diagnosis procedure and appropriate action (e.g., issue drugs to the patient) supervised by the MD using a set of reports. More Complicated cases will require to have the MD to participate in the final decision. In such cases, the system sends the diagnosis reports to the MD and provides an appointment to the patient in the hospital queue. The system reads the queue data at the management centre of the hospital reception assigning the patient to the MD queue, if the Doctor later found that the assignment was appropriate (check mark OK) then the system learned that the decision is appropriate, however, by certain feedback from the doctor the system can learn from the doctor's feedback. The system will provide a window at the doctor office for performance evaluation in order to enforce the learning procedure for the system and, at the same time, such evaluation would provide an effective learning mechanism to increase the reasoning procedure for the diagnosis. Another important issue will be related to the MD Profiling.

Using MD Profiling it will be possible to create different specific representation of the various MD, as in real life. Since knowledge management would be based (i.e., mimic) on a specific Medical Doctor (i.e. Dr. John Doe), therefore, it would be stored in a specific Ontology Management System. So when another MD will doing the outpatient diagnosis (i.e. Dr. Jack Smith) then his profile of decision making related to that Doctor would be used (i.e., recalled). In this way will be possible to accurately mimic and categorize various physicians' actual practices. The VDS System would to simulate patient - doctor interactions using a virtual face (avatar) of an actual MD with pre- assigned virtual version of that medical doctor able to communicate and interact with the patient. The actual facial real-time created images of the MD will be synchronized with a spoken language in the same style of the actual physical doctor is created. The style mimics the actual doctor emotional expression as well his/her diagnosis style. Also the MD speaks in natural accent with emotions based on the patient mental mode, estimated by the patient profile (age, gender, ego data), and his/her situation automatically measured by data resembles (blood pressure, body weight, body temperature, and thermal analyzer), at the same time several environmental variable will be collected in order to create a broader view of the patient living situation. These devices are assembled to the patient desk chair where it would sit on, allowing measurements to be collected and transferred through network connection to the virtual doctor system.

Of course the diagnosis and treatment done by the VDS will be strongly based on the actual diagnosis and guidelines specified by real doctor and validated on based scenarios collected in advance. Such specification, which will be specifically made under Medical supervision, will be implemented in the VDS using specific Syntax Languages that is an open standard for representation of medical knowledge. In such ways the MD diagnosis guidelines are represented as a collection of medical logic modules (MLMs): each MLM will represents a single decision that is grouped into three categories: maintenance, library, and knowledge used by the inference engine to better mimic the MD attitude and diagnosis.

4 System Description

4.1 Analysis and Requirement Collection

Requirement Analysis play a fundamental role developing the system and it will characterize the architecture and data organization. We will conduct a careful system requirement analysis through existent documentation of the VDS and a series of interview at doctors and/or biologists to better understand analysis parameter and expected results. We will also conduct a study in order to gather, to organize, and to analyse parameters from the environmental context that VDS will provide us. The output of this phase will be a document specification used as guideline in order to develop this work. Requirements play an important role so we must understand and use each domain application specific term.

4.2 Data Source Identification

During this phase is essential to know where data are stored and how can be used inside the DW. Different data can be extracted from different source with different technology and different representation model. Each data knowledge of stored data. Fundamental principle of data warehousing is the concept of integrated data that allow us to transform general data into end user useful information. This result will be obtained through reconciliation process that consist of integration, cleaning and transforming all available data in a consistent manner.

4.3 System Design

Design phase will be divided into different steps:

- First phase we design the backend, that consists of ETL (Extract Trans for Load) modules.
- In the second step we conceptually design the DW, data organization and structure data into the DW. Main study of this part will be dimension analysis and attribute.
- In the third step we have to logically design the DW, to choose the Star or Snowflake structure and the dynamicity of each dimension in a proper manner.
- Last step is the system design analysis from OLAP, through Mining and Reporting depending on requirements.

4.4 Proof-of-Concept Implementation

At the end of this research study, we will use all the specifications gathered during requirements collection to make some real cases analysis hypothesis; this is useful in order to provide wide and complete view of system functionalities and to obtain the Proof of Concept.

5 Design of a Decision Model Tool

The first step of research activity will concern the VDS network and validation of its operations through the implementation and testing in medical care areas, at the public/private laboratories. Patients and MDs specific behaviours as well as with some critical situations, related to the definition of patient's diagnosis parameters, will be tested in both countries: Japan and Italy pointing out similarities and differences.

Following the VDS Validation and Verification phase against real-life situations, VDS will be used to train doctors, using the platform as a simulation environment, providing Physiological, Psychological and Environmental data of real and simulated patients to the MDs. The VDS will be validated with reference to real case studies in an experimental campaign specific for each country; it will be tested to assess the impact on various performance measurement such as: reduction of waiting times in the laboratory, variation of user number in queue, variation of service's level and readiness of medical answers for some diseases like flu, bronchitis and other diseases

that do not require specialist visits. In addition it will be tested the possibility of using the system to route through specialist if the investigated parameters are not aligned with those characteristic of normal situations, or can not be restored to normality by simple medical knowledge.

A further development is related to the design of platform extensions in order to enable:

1. Collection and acquirement of new knowledge about new therapies or new diseases.
2. Collection and acquirement of information from the field about symptoms related diseases diagnosed.
3. Collection and acquirement of new knowledge of possible side effects about therapy
4. Remote monitoring about patients' current health condition in case of an emergency or a natural disaster, case classification, first-aid support.
5. Simulation on possible effects of pandemic infections (i.e. SARS, A1-N1, etc.) on most fragile population.

This research work will extend the VDS original Ontology by adding more information regarding the environmental variables. In this way the VDS will be enabled also to increase the number of parameters used by VDS to perform processing and to monitor the phenomena identifying the possible environmental hazards (i.e. pollution, radiation, etc.).

In the first case we might expect to collect in the layers the geospatial information that will enable the VDS to expand its knowledge correlating this information in the form of cause/effect diagrams as well as performing regressive analysis. In the second case, depending on the symptoms experienced by the patient or from the diagnosis made in a specific period in a certain area, it will be possible to aggregate this information and make analysis of correlations (with events that occurred) to study phenomena and, potentially, to forecast the possible evolution. The design of these layers will necessarily assume the use of an appropriate simulation approach enabling the possibilities of a multi-scenarios analysis.

It's clear that these applications will affect the design of platforms for sharing the research ideas, like social networks, which may share information through blog and forums. The platform may share experiences of different national and international scientific communities in the field Medical creating a network with existing platforms. The scientific documentations, such as papers published in various scientific panel, diagnostic studies and data might be contained in the cloud environment, shared and accessible to researchers in order to enhance the quality of the DSS's internal inference engine. Beside the core, made by VDS, this project would like to define a platform where researchers may have access, upon registration, with an ability to modify and to upload the results of the latest innovations in medical science and, at the same time, where other users, such as operators and local medical officials may have easy access to check for updates and various international experiences linking to the results obtained using the VDS as a "Virtual Clinic" in order to help MD to identify best experiences and/or drugs to cure and to prevent certain forms of disease.

6 Case Study

Since the Italian Health Care expenses are always constantly increasing this implies the necessity that such expenses must be controlled. It means that having a model tool able to help in managing for a great amount of these healthcare expenses is very important. In addition, considering the great number of elderly people in Italy as regards the whole Italian population our study focus on build a model at low cost able to manage from home all patients having pathologies where hospitalisation isn't required , but such patients can be managed in "remote" manner from a system-model able to satisfy the user and to solve associated problems.

This users-patients target, as it will be analysed, in normal conditions enters in health care emergency system trying to receive answers, but instead always in the critical patients management path are included, implementing a resources waste of healthcare system.

The following data are showed depending on patients age target, kind of 118 emergency calls system, and so forth are referred to Liguria Region regards 2008 year (only 2010 for Savona province). To implement this analysed model on an area such Liguria region is very significant since the high percentage of elderly people living.

At the present time:

- great reduction of financial transfers from central administration;
- need to found new asset in order to manage the hospitals healthcare expenses;
- excess of "required" healthcare services;
- absence of charge for medical health services eliminating the value perception to the system itself;
- absence of a "filter" system to the patients directly sent to the hospital rather than an absence of minimum culture of self-management of more banal symptoms and pathologies manageable at home;
- media aiming to "dramatize" situations of medical need;
- absence of synchronization of system and diagnostic process;
- duplication of diagnostic tests, time and resources waste in the patient management during its investigation path on its disease state;
- over esteem trend to the diagnostic investigation; avoiding accurate differential diagnosis (since emergency department resources are overwhelmed), but the use of as many as possible clinical test hoping to find the problem in a probabilistic way through the big amount of the carried out clinical test.

Outcomes:

- lot of resources waste in patient handling from home to the hospital;
- overburdened of diagnostic services and patients afferent departments (DEA emergency room), overcrowding phenomenon;
- great increase of medical health expenses not targeted to patient treatment and to the effective improvement of itself.

Patient path from the problem perception to its resolution.

At the present time, every system and organization managing (118 Emergency call, doctors on duty) information flow of medical support applicant knows that in the majority of cases, the problem is perceived heavy from the user (red and yellow codes for the 118) doesn't correspond to the real patient clinical state.

This absence of criticality is highlighted even before the beginning of hospital diagnosis process, but from the arrival on the site (patient home) of basic means of aid (bma) or advanced means of aid (ama).

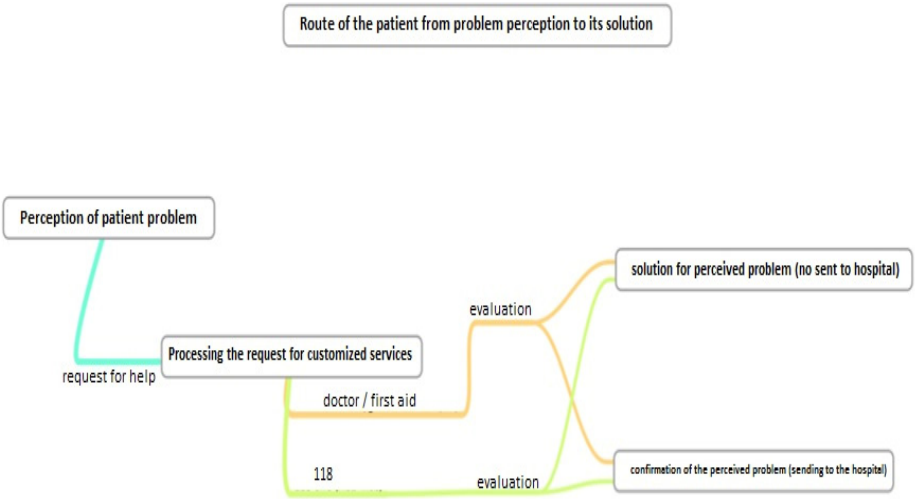

Fig. 2. Route of the patient from the problem to its solution

The particular impact of elderly people for emergency requests highlights that always is an "help" request.

With "help" the customer need to be supported , as for example on advices on assumed drugs dosage, reassured as to the over esteemed symptomatology, it means readdressed to a more correct self assessment of its perceived health state, is intended.

Case study:
It is considered a patient relatively elderly and normally in therapy for pathologies linked to the age, having a clinical stable state living at home alone or with a consort/partner in the same clinical state or even more complex one.

The problem beginning produces the start of user path, that not always has in its time scheduling and procedures a coherency fluency and quickness execution from request and answer.

1. The patient has a problem/perceives a problem; the first difficulty is who's to call? to whom to refer?

Normally the flow diagram for problems linked to the health care field (not important or emerging one (should follow) the following path:

Call to family doctor (from Monday to Friday from 8.00 to 20.00 and for other times and days, call to doctor on duty), that for lots of call could solve on the telephone questions, doubts, and so forth without the need of medical home or patient transfer to the hospital.

Criticalities:

2. Call at the "Family doctor"

- I don't find the family Doctor; I don't know his office study telephone number or other "Health Aggregates Offices", where the family doctor has other offices.
- I speak with the secretary not with the doctor.
- I won't be recalled by the doctor.

3. Call at the "Doctor on duty"

- I don't know how to call the Doctor on duty (I don't' know his telephone number, city number or toll free one).
- His telephone number is always busy and I must wait long time before receiving an answer. I think: "Nobody will respond to me", "Nobody has interest for me", with consequent "anxiety" rising.
- I don't know working days and hours of "Doctor on duty".

Initially the patient had only one doubt, one request of explanation, the desire to have advice; the lack of response and the reinforcement of the need of having it, changes the parameters of the request that are noticed as urgent and imminent: "I have a problem, I must talk with somebody; somebody must listen to me".

4. call to the 118 (only number for national territory emergency) (immediate answer to the user) that usually becomes the user "shelter".

The 118 service as structural and prerogative organization takes care of getting all calls from the medical emergency; another of 118 activities it is included also to give advice but principally it is oriented to codify, in the less possible time the gravity of the problem and send the most suitable help for the patient in the less time possible so that he could be treated and stabilized already in his territory, and then transfer him towards the hospital for the subsequent treatment (diagnostic work up, diagnosis, therapy, recovery and dismissal).

The celerity of the answer, and the possibility of talking with someone, is certainly one of the elements that the user that has no need of "emergency" (bma and ama) believes important. Indeed, the 118 is not the place where to ask only advice; as previously mentioned, the first of its prerogatives is the dispatch of suitable and qualified rescue vehicles, in the minor time possible. As a matter of fact one of the management software used in the operative centrals follow a list of questions particularly aimed to understand the principal pathology and most critical, making a photograph of the most possible scenery it is being described and send rapidly rescue.

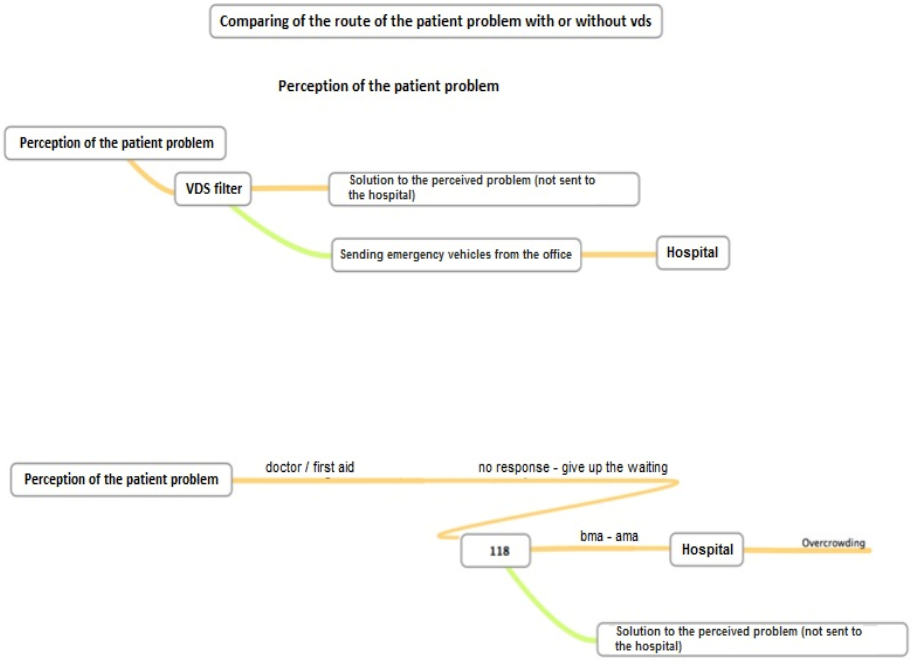

Fig. 3. Comparing of the route of the patient problem with or without VDS

For example, on the usage of central operative software that use the procedure and protocol for dispatch (i.e. protocol proQA):

- This, as one of the first questions they have to ask is: “118 good morning, where do I send the ambulance”, starting the conversation with a lot of questions based on the protocol for the presumed pathology; and not “good morning 118 how do you feel today, I am here to listen to you”. The result for the patient that finally has reached to talk with someone, even after various attempts with other suitable offices that could give an answer/advice (doctor), is that the fear of not being heard will make the client to overestimate the own symptomatology with the hope and need of someone that comes to help him (in listening) taking the risk of “cheating” the 118 system.

Even though the new 118 operative protocols have created questions that do not "induce" the patient to the affirmative answer, i.e. "do you have chest pain?" (if the patient has not understood one question he will answer yes). We have to remember that the patient has called because he needs help and for a question that he has not well understood, answering “yes” implies a better condition regards a negative answer "no", since for the patient in this moment “yes”= help, and “no”=no help.

Open questions (new 118 Operative Protocols) that don’t advise the patient a predictable easy answer (for example where do you have pain?) is preferable.

However, forcing the system is relatively easy since the different Operative Protocols give some quick code procedures and/or the over estimation of the clinical situation.

In case of doubt, it is possible to assign to the patient a greater severity (red or yellow), with the subsequent dispatch of emergency vehicles (bma-ama).

It means that a great percentage of 118 phone calls: dispatch of emergency vehicles of ambulance to the place where the emergency occurred (example patient home) and consequent back to the hospital for other clinical exams, could be managed, without big problems, at the beginning through a system tool, based on a quick answer of a "Patient Service-VDS", dedicated and customized on patient.

In the example of the use of integrated VDS it is possible to consider the following scheme:

An intervention that can be solved with one phone call but basically could instead involve 3-6 persons of health care service and 1-2 emergency rescue vehicles only for first emergency and during hospitalization phase at least 7 persons:

- 2 nurses (1 triage 1 ps);
- 2 doctors (i.e. doctor, medical specialist);
- 1-2 technicians (i.e. lab, radiology);
- 1 operator social health.

Besides the use of various equipment for the diagnosis definition.

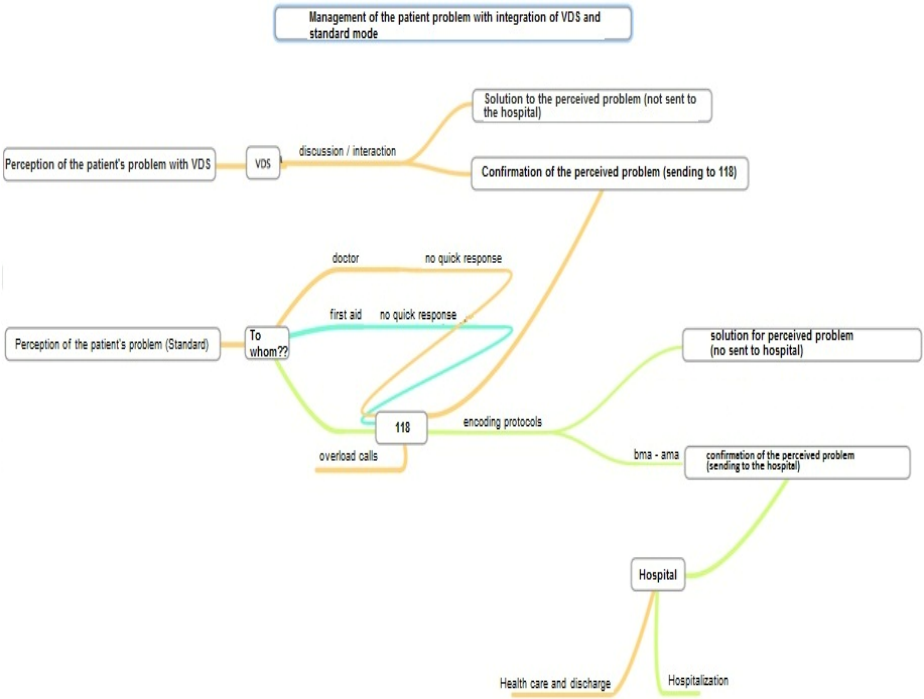

Fig. 4. Management of the patient problem with integration of VDC and standard mode

7 Results Analysis

In this way the results created by the use of VDS as a “Virtual Clinic” will be implemented in the VDS knowledge base resulting in an innovative form of medical interaction between MD and patients. In other word it will be possible to outline an innovative “shared mental model" made of several interacting layers consisting of:

1. A “Virtual Clinic” of local/particular medical experiences obtained from or simulated by mean of the VDS able to reproduce the MD behaviour as well as the doctor - patient interaction;
2. An high-level global network designed to enable sharing, amplification and catalyst for new ideas where result of experience and trials conducted can be shared, updated and directed towards the effective treatment of different diseases;
3. A technological platform where the interactions between the two layers consisting mainly of information exchanges and experiences both at the top level and at the low level will positively affect the experiences of MD and scientist to be prepared to response to unexpected natural or anthropogenic disasters with the help of simulation, case studies and direct experimentation.

8 Conclusion and Future Developments

All these activities will consider other further development to improve the system. First, the system could be published in a Cloud environment to be fully available from every part of the world. The queries could also be submitted through mobile devices such as PDAs or smart phones, ensuring a delocalized accessibility. Through this study you can also encourage the processes of de-hospitalization with significant improvement in patient welfare and reduced costs to the health system. The system could also be used from National Civil Protection to monitor people health in case of particular emergency (Flooding, earthquake). Results of the system as well memorized into the DW could be published in an aggregate manner through social networks for scientific research in order to share knowledge with other colleagues.

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