A COLLABORATIVE SITUATION-AWARE MODEL TO SUPPORT INFORMATION EXCHANGE AMONG MEDICAL TEAMS

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ABSTRACT

The ubiquitous computing and the situation awareness are evolving elements for computer applications in hospitals. Specifically, the application that is able to correlate data from heterogeneous networks to improve the success of healthcare, produces a wide collaboration network. In this context, this article proposes the development of Doctor Collab, a collaborative model that supports the exchange of information between physicians medical teams using the situation awareness. The model aims to use ubiquitous computing resources to improve the inclusion of relevant data in the application, as well as optimize the data output on mobile devices. As scientific contribution, the proposed model employs computational inferences by analyzing different situations in order to improve medical decision-making and support collaboration between medical teams. Evaluations show that the Doctor Collab reached an average of 86.9% acceptance using the *Technical Architecture Modeling* model to check the assent of application to the attending physicians.

KEYWORDS

Situation Awareness, Collaborative Computing, Medical Emergency, Ubiquitous Computing, Activity-Based Computing

1. INTRODUCTION

The creation of solutions that help physicians is critical to the medical effectiveness. The decision-making process has always been one of the main pillars targeted by institutions that seek quality in their work, and in the health area is no different. This criterion becomes crucial to aid medical teams seeking satisfactory solutions to everyday problems, with an appropriate response in a timely manner, especially in situations in which requires Task Management in multi-level (Li, 2014). One of the interesting features in the aid decision-making in multilevel is the possibility of working with heterogeneous groups, due to the challenge of integrating a variety of different networks. It is necessary to ensure the exchange of information without errors between medical teams. Intercommunicate these networks will create a system more efficient in high stress work environments (Li, 2014).

In the case of applying the structure, a cloud-based model computer can be defined as a ubiquitous on-demand access to a set of computing resources (Mell & Tim 2010). This model demonstrate to be a satisfactory alternative to working with collaborative data base. This structure besides being safe and unified, can boost the dissemination of information to several other communities and universal formats (Sultan, 2014). After the cloud stored data is organized, we can work with a large volume of information in high-scale schemes, thereby producing more accurate decisions based on the quality of information to be searched, filtered and presented to the physicians team.

In this article we present the model Doctor Collab targeting at supporting information exchange among medical teams. The main research challenge is the use of collaborative software for emergency medical environments, and we focus on answering the following question: *How would a computer model to support collaboration and exchange information among medical staff in areas of emergencies, using situation awareness?*

In this model, cloud computing (Mell & Grance, 2010) is a structure that gives doctors access to various information related to the patient quickly and transparently in order to group a set of computational knowledge stored remotely, aiming to optimize the medical inferences within the Doctor Collab. The external collaboration is another important point, as in emergency environments where it is of great importance that applications offer support for professional experts who are not physically in attendance place to collaborate in the best possible way, for the well being of patient. This collaboration will take place both in order to encourage mating time and space derailment.

As the main scientific contribution, the proposed model uses computational inferences using contextual levels present in an ontological basis (Chen *et al,* 2003) in order to improve medical decision-making and support collaboration between healthcare teams. The model has a set of modules that allow distributed functionalities to encourage better access to medical records data. In this context, the model employs situation awareness (Endsley & Garland, 2000), by using inferences in ontology. Doctor Collab should manage activities among users who may be physically distant and be able to store important informations for patient care according to established standards.

This article is organized as follows. In section 2 we describe related work. The proposed model is presented in section 3, along with implementation details in section 4. Evaluation aspects are described in section 5. Finally, section 6 presents the conclusions of the work and some directions for future works.

2. RELATED WORK

This section lists some of the most relevant studies and important in search of the state of the art on Situation Awareness and Activity-Based Computing focused on collaboration and use of ubiquity.

Bardram (2005) presents a solid overview of the Activity-Based Computing study and how the concept works with human activities. The framework presents: i) support the management of human tasks using computer; ii) mobility support and distribution activities across heterogeneous environments; iii) support for asynchronous collaboration, allowing in this way that many other people can participate; iv) support synchronous collaboration, thus creating collaborative environments in real time, such as video conferencing.

The study also shows the three-dimensional Activity-Based Computing, they are: i) task and material where the tests will be included; ii) time and space, where they can be controlled status information (started, suspended, ready and finished) as well as support the work multitasking; and iii) users, where it is possible to provide collaboration between system people.

The article by Juan Li et al (2014) sought to address how they can work with a community-based collaborative system for local classified as emergency, like tsunamis, floods and epidemics. In these circumstances it is very important to work with a well-organized system, there is a high level of stress and any information failure organization could result in big problems.

In another study, Bardram (2012) presents an analysis of smart spaces by using Computer Based on activity support collaboration using mobile devices. The work focuses on support for: i) unify interaction between applications using the ReticUI; ii) the management of complex tasks between users and displays, iii) the use or remote location of the services provided; and iv) collaboration among both local users and remote users.

The Fouzi Lezzar study (2013) presents an analysis of the use of collaborative mobile devices in favor of improving the planning focused health tasks. The platform was developed in Android system providing the framework necessary for the implementation of collaborative experiments using mobile devices. For this, Lezzar developed a synchronous grouping of Android mobile devices in order to enable a real-time collaboration where members of these groups may be geographically separated, but still manage to use the system.

The last related work (Abbas *et al*, 2014) used the Utility Theory of multiple attributes to aid in comparison with other different systems that is based on the recommendation and planning for health issues, an important technique for analyzing decisions. The model allows the use of heterogeneous data. For planning information for each data was used to structure cloud DaaS (Data as a Service). The model uses the Centroid Rank Method - ROC (Solymosi & Dombi, 1986) for efficiency testing and ranking of the planning processes.

Table 1. Comparison among related works

Features	Activity-based computing (2015)	Community-based collaborative information (2014)	ReticularSpaces (2012)	Mobile Collaborative Tasks Planning (2013)	A cloud based health insurance plan recommendation system (2014)
Activity-Based Computing	Yes	No	Yes	No	Yes
Multi Level Decision	Yes	Yes	No	Yes	Yes
Emergency Management	No	Yes	No	No	No
Cloud computing	No	No	No	No	Yes
Ontology	No	Yes	No	No	Yes
Collaboration	synchronous / asynchronous	sharing information for community	synchronous / asynchronous	Mobile Collaboration (synchronous)	Yes (potential)
Ubiquitous computing	Yes	No	No	No	No
Context	Activity as context	Model Activity W3C	Adaptive context - Activity Roaming	Medical Context	No

3. DOCTOR COLLAB MODEL

The proposed solution involves the development of a model to assist in the collaborative activities of a medical emergency in order to facilitate the exchange of information among duty physicians. For this idea, some assumptions were established in order to contribute to the development of the model: a) Support collaboration in the application layer: With collaboration, doctors may perform a richest form of patient care through collaborations throughout the evolution of the patient's health status or in real time, b) Computing inferences: Data as contexts and tasks are stored aiming to contribute to the situation awareness proposed in this model, c) Activity Management with a focus on collaboration: Doctor Collab model systematize data traffic, which helps the exchange of information and collaboration.

Figure 1 shows the architecture of Doctor Collab. One of the main features of this structure is its standard-based paradigm Model View Controller - MVC, using concepts of reuse and interaction between each. The architecture's packages were created in order to provide better control of the information trafficked during the exchange of medical shifts. Its components can be detailed in order to optimize the understanding of architecture structure, they are: a) Context Access; b) Activity Management; c) Inference Situation; d) Knowledge Base; e) Activity Database; and f) Collaborative Management.

To protect application data, the Doctor Collab model uses SSL protocol in the security layer. This protocol will be part of an HTTPS connection with data to be transmitted through an encrypted connection. This type of security is necessary for the patient data can be transmitted within the Doctor Collab without the information is seen by other unauthorized persons, thus creating a secure communication channel and an insecure network.

The situation awareness within the Doctor Collab is presented as a solution to improve the perception of the elements found in a medical emergency in order to optimize the medical diagnosis of the future. For this, the model implements three levels of perceptions, based on the concepts of Endsley (1999): i) Level 1 - perception of Emergency Medical elements: period that analyzes the elements of the hospital environment, their status, and dynamic attributes of the elements; ii) Level 2 - Understanding the Current Situation: this understanding is by summary of level 1 items. This level that analyzes the importance of the elements in favor of a specific goal; and iii) Level 3 - Projection of future states: this level is intended to project future actions of the environmental features faster. For this to be possible, it is necessary to have insight and understanding of the elements of a medical environment.

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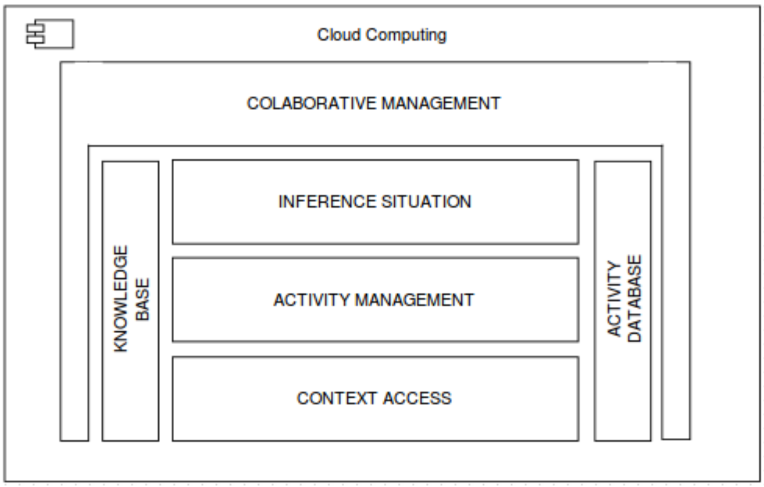

Figure 1. Doctor Collab Architecture

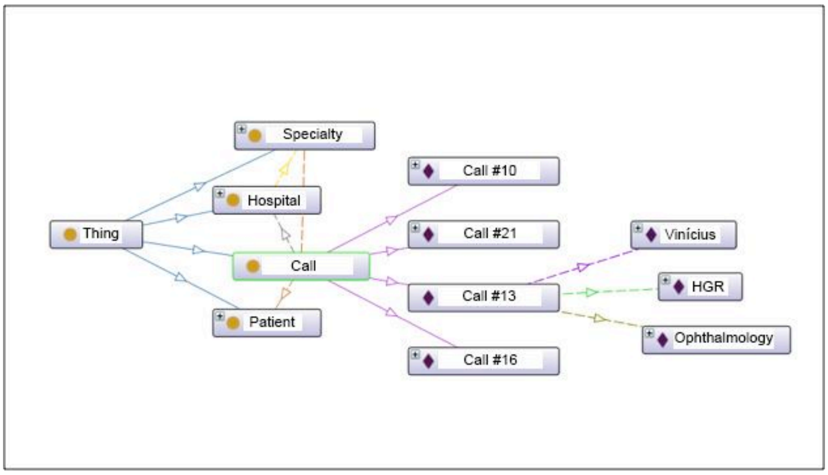

Figure 2. Doctor Collab Ontology

An ontology is used to define situations in this model. With the ontological structure, the model is able to answer the following questions: a) What is the risk classification of the patient's health?; b) What kind of medication available in the hospital would be the most indicated as patient history to be served?; and c) What doctor, even physically far from the hospital, could benefit clinical improvement of a patient?

Ontology Doctor Collab has relations based on object properties (Figure 2). The first relationship is represented by lines, and is between the classes Service (Domain) and patient (range). The property in question is Call -> Meets -> Patient. Still on the relationships that can happen during a call in an emergency medical environment have the Customer class that interacts with the need class through the relationship Customer -> NecessityToSpecialty -> Necessity.

The Reasoner incorporates optimizations through a table of decisions in several areas to highlight: i) Awareness Verification; ii) satisfaction; iii) Classification; and iv) Realization. This topic calculates the different aspects of each individual.

4. IMPLEMENTATION

To evaluate the model, we developed a prototype that meets the collaboration issues within medical settings. In general the Doctor Collab model sought to maintain the minimum structure required to answer the research question. For the production of Doctor Collab model some tools were used. It was used initially the vector drawing tool of Draw.io Web environment. For the design of UML diagrams was used the Astah software design tool in its free version (Community). For the design of the ontological structure was used the Protègè tool, available free from Stanford University. The encoding occurs with Java programming language. The information storage was accomplished by Stardog knowledge base, a Bank of semantic data. This information storage style is given by the need to generate computational inferences and Web Semantics information by Jena Apache Framework.

Some screenshoots of the developed prototype are presented in Figure 3. The interface was designed using the concepts of responsiveness web (Mohorovicic, 2013), so that the screens can adapt to different sizes of devices. Soon after user authentication, the application shows the number of patients within the medical emergency categorized by color. The application gives the possibility of registering attendance beyond the hospital capacity. On the home page is a summary of the number of patients within the medical emergency and categorized by color, red for high risk life, yellow for moderate and green for patients risk of low life. Another important screen to be shown in Figure 3 with regard to the success of service registration and the computational inference. The information is added to the Semantic Stardog database according to the model of RDF triples. In addition, the medical necessity in the requested attendance register is inferred within the Ontological file to check availability of care necessity.

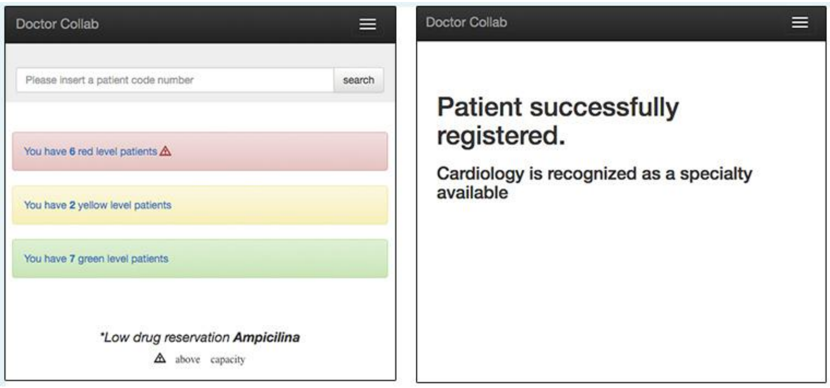

Figure 3. Doctor Collab Interfaces

In Doctor Collab, the detection of situations was modeled in Stardog semantic database, database according to the model of RDF triples. Users can request the attendance register and infer situations within the Ontological file to check availability of care necessity. The records are stored in triple format within Stardog knowledge base and it can be monitored through the Web Information manager Stardog. Computational situations can be understood as an abstraction in high-level settings and information from the application of knowledge bases. This information is also available to improve the level of application intelligence. Figure 4 shows the modeling of a situation. The schema model is defined by the file "DoctorCollabOntology" and the database as "DoctorCollabData". The *executeInference()* method uses the *InfoModel.contains* function of the Jena framework to relate the reasoner with application data, thus informing whether a particular fact is contained in the system. The situation is modeled by inference that is based on sub inheritance classes ontological schema, recognizing instances, like the medical specialties available in the service registration form, inferring that way if the specialty is or is not available in this doctor on duty.

```
public String executeInference(String tipoEspecialidade) {

    org.apache.log4j.BasicConfigurator.configure(new NullAppender());

 Model schema = FileManager.get().loadModel("/Users/infomac/Downloads"
      + "/doctor-collab-ontologies-owl-REVISION-27/TestOntology.owl");
 Model data = FileManager.get().loadModel("/Users/infomac/Downloads"
     + "/doctor-collab-ontologies-owl-REVISION-27/teste-owlDemoData.rdf");
  Reasoner reasoner = ReasonerRegistry.getOWLReasoner();
  reasoner = reasoner.bindSchema(schema);
  InfModel infmodel = ModelFactory.createInfModel(reasoner, data);

  Resource hospital = infmodel.getResource("urn:x-hp:eg/Hospital");
  Resource especialidade = infmodel.getResource("urn:x-hp:eg/"
          + tipoEspecialidade);

  System.out.println("o valor de especialidade é: "+ tipoEspecialidade);

  if (infmodel.contains(especialidade, RDF.type, hospital)) {
     return "Cardiologia é reconhecido como uma especialidade disponível.";
  } else {
     return "Falha no reconhecimento de uma especialidade disponível.";
  }

}
```

Figure 4. Doctor Collab Inference

5. EVALUATION

To evaluate Doctor Collab, we performed a qualitative assessment using the usability verification methodology. For this we used the TAM (Technical Modeling Architecture) proposed by Davis (1989). For the evaluation of this work were incorporated some variables and have the meanings following: **Ease of use** is intended to prove how easily the user can complete the task in the first contact with the Doctor Collab or how fast user performance is improved. **Satisfaction** analyzes the user will proceed to use the application again. **Utility** intended to analyze how the application solves a specific problem in question presented during search.

The Following assumptions for the proposed TAM have been identified:

- H1: The ease of use positively influences the application of the utility;
- H2: The satisfaction positively influences the implementation of the utility.

The first stage of the evaluation was the choice of participants for field experiments. It were selected 20 medical volunteers from 1 to 6 years of emergency medical experience within the Emergency sector at Roraima General Hospital and participants of the Emergency League of Roraima, both in Brazil, chosen for convenience and in a controlled environment. First the doctors were encouraged to use the Doctor Collab application and then fill out the forms of care of hospitalized patients in the emergency department, thus creating a support collaborative environment of activities and medical conditions in that place.

After using the Doctor Collab, we applied a survey containing 8 statements and the evaluators used the Likert scale (Likert, 1932) of five points to agree or disagree. The survey aimed at evaluating Doctor Collab regarding collaboration and situation awareness. This scale provides five choices in a range that starts at point 1 (strongly disagree) to point 5 (strongly agree). After obtained the results, we used statistical techniques for data analysis. The reliability of the form is shown from the use of Cronbach's alpha (Cronbach, 1951) thus allowing to estimate clearly the correlation between responses and respondents. Cronbach's alpha value of this research has reached the approximate value of 0.83 indicating that the questionnaire is reliable to be above 0.7.

Figure 5 shows the positive responses of respondents regarding the use of Collab Doctor in medical emergencies and the high regularity of type responses strongly agree and agree, as well as the higher incidence on the issue 5. Notes also that the issue was one that generated a greater difference in responses, with a high degree of disagreement referring to the statement, this is due to the fact that users disagree with the question stated that users experienced difficulty in using the application.

Many of the comments related to the usefulness of Doctor Collab were positive, thus confirming the information provided in this study. Many stressed the high importance of resources to enhance collaboration between medical teams. According to one user: "Having an application like this in our department would be very good, we lost a lot of time passing the information to the next team." Another reviewer said: "It is great to see that such a platform could be available in public hospitals in Brazil, it would improve greatly the search for information and communication between doctors."

As worst result, it was noted that in the issue number 7, which addresses the user satisfaction, 20% of respondents were indifferent or had no opinion that Doctor Collab application would promote greater interest to the medical management activities within the hospital. This is due to the fact that the natural resistance to professional changes in a bureaucratic process. The question 8 was one of the largest medical acceptance values, 90% positively answered the question that examines whether the assessed application facilitates the work of medical team. It shows the hope of health professionals to join the computer world facilities with health problems of the world. One of the doctors who evaluated positive answered: "We know Information Technology solutions that have been well used in other areas such as law and engineering, and every time that we see health IT solutions, we get motivated, even more solutions for our labor sector as the emergency. Informatics is a reality, we all have to adapt."

Taking into account the results presented in this topic, it was possible to confirm the hypotheses H1 and H2, as shown in Table 2. Thus it can be confirmed that the proposed model is consistent with the identified assumptions.

Table 2. Comparison between the related work

Hypotheses		Analysis
H1	The ease of use positively influences the application of the utility	Confirmed
H2	The satisfaction positively influences the implementation of the utility	Confirmed

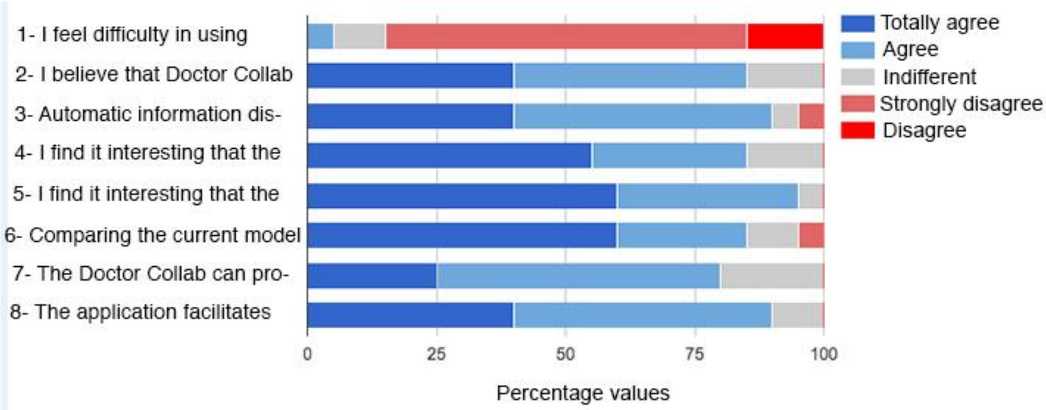

Figure 5. Doctor Collab results

6. CONCLUSION

This article addressed the design of a model to support collaboration and exchange of information through the use of situation awareness on medical inference. Doctor Collab proposes a solution that encourages collaboration between medical teams to improve the exchange of information in the shift change in emergency environments. In this way, the main scientific contribution of this article is a model with an ontology structure and inferences of medical situations.

In order to assess the viability of Doctor Collab model we developed a prototype and evaluated with physicians. For 95% of respondents, the use of an application that uses medical inference is a good solution to improve the passage of information between health professionals. Reinforcing this information, 90% of respondents believe that the Doctor Collab facilitates the work of medical team. Doctor Collab had an average acceptance of 86.9%. Within the evaluation of this study were not analyzed topics such as scalability and efficiency, these issues are suggested for future work.

The current version of the model presents some opportunities for future works. In the field of collaboration, we suggest a deepening on how topics like the coupling of time and space derailment influence the exchange of information between medical teams. With regard to medical inferences, we can provide more rules enabling different situations. We foresee also a need of a performance evaluation and of how the model behaves in an everyday real situation. Finally, further studies related to security to the mechanisms of interaction among medical emergency teams.

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