Knowledge-based Modality Selection for Information Presentation in a Mobile System for Primary Homecare

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Abstract. Public homecare programs have proven to be very effective for Preventive Medicine. In Brazil, the Family Health program, initiated in the late 1990s, has taken medical doctors, nurses and social workers to the homes of lower income population in underserved urban regions. This program has been developed using nearly no IT support for its operations, and we believe that this gives room to opportunities to improve its efficiency. The Borboleta project aims at providing the Brazilian Family Health program with IT support, more specifically making use of mobile computing technologies to improve the quality and reliability of services provided to the population. Many technological challenges must be solved in order to achieve the project goals, among which we highlight *information logistics* - the necessity to bring appropriate information presented at the appropriate format to nurses, medical doctors and social workers performing field work. In order to do that, we are working on a knowledge-based presentation layer that can sense the context of the interactions between field workers and information sources and semi-automatically select the most adequate output modality for information presentation.

1 INTRODUCTION

Telehealth systems are computer based systems aiming at the provision of healthcare using telecommunication technologies. In large urban areas in which a considerable proportion of the population has lower income, telehealth systems can be of particular relevance to bring healthcare to underserved communities.

In Brazil, the Family Health program, initiated in the late 1990s, aims at the provision of *preventive* healthcare to underserved communities. This program has proved to be effective, despite the extremely low level of technological sophistication it has employed so far.

The Borboleta project [2] aims at leveraging the Family Health program with mobile computing technologies. We believe that this can improve the efficiency and the reliability of this program, thus making it even more useful to the society.

Essentially, the Borboleta project provides field workers medical doctors, nurses and social workers who go to the homes of underserved citizens to collect information about them and provide them with assistance and orientation about hygiene and preventive healthcare with portable computing and communication devices (typically, PDAs and smartphones), enabled to exchange data with computer servers located at a Central Hospital.

The data exchange between the mobile devices and the servers must be done in such way as to ensure the privacy of medical records, as well as the reliability of information. Additionally, the information presented in the mobile devices must reach the field workers as effectively as possible, to ensure the effectiveness of the visits to the homes of the population.

In [1] a knowledge-based approach is proposed for the selection of the modality of information presentation, in which a Modality Ontology is introduced. We intend to found our work on the ontology introduced in [1], and build a knowledge-based system for output modality selection for the Borboleta project.

The present article is a work-in-progress report. We are at the moment working on the detailed design of the knowledge-based system for output modality selection. In future reports we shall present implementation and empirical results related to the utilization of this system.

In section 2 we briefly describe the architecture of the Borboleta project, highlighting the information that is conveyed through the mobile devices at the present implemented prototype. In section 3 we briefly review the Modality Ontology introduced in [1], and explain a little further how it can be employed in the Borboleta project. In section 4 we outline our proposed layer for knowledge-based modality selection for information presentation. Finally, in section 5 we present some discussion, preliminary conclusions and planned future work.

2 THE BORBOLETA ARCHITECTURE

The Brazilian Family Health program is managed from central hospitals, and effectively run by professionals who visit the homes of families to provide them with medicine and information to prevent health problems. These professionals are a few medical doctors and a host of nurses and social servers with some basic training on healthcare, to whom we shall refer heretofore as field workers. Due to the focused and instrumental training that field workers have, they are not entitled to make complex decisions related to medical interventions. Given that a limited number of medical doctors are available, the system must be as assistive as possible in order to provide the field workers with the necessary information to carry on their activities.

The field workers have a strict routine to follow. Based on a general work plan, each field worker starts the day with the detailed schedule of visits to be made in that day. The schedule is defined collaboratively, so that the team of field workers can ensure that all families in their region are being visited.

Once a field worker gets his/her schedule for the day, he/she gathers from file cabinets the corresponding (paper based) forms and records for the families that are going to be visited.

On the way to a family home, the field worker studies the medical records corresponding to that family and devises a visit plan. The

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visit consists of enquiries about health conditions of the whole family living in a specific address, comparative analysis with respect to previous records and provision of advice to ensure good health conditions for all.

Typically, because of heavy workload, the field workers do not take many notes during visits. The collected information is added to the records later typically three to seven days later at the central hospital. Information can be lost and become less reliable because of this delay, since the field workers rely heavily on memory to feed information back to the system.

One of the main goals of the Borboleta project is to make the Family Health program more efficient and reliable, by provisioning field workers with mobile communications and processing technology. Our goal is to provide field workers with expert information in real time during field work, as well as to provide them with appropriate means to feed information back to the system immediately after this information is collected.

In order to do so with the required efficiency, information flow must be as unobtrusive as possible in the workflow of field workers. It is of paramount importance that information is provided to field workers at the exact time and at the most appropriate format, and that the system provides the field workers with the best possible means to input information through the mobile devices they carry with them typically, PDAs and smartphones.

To our best knowledge, the Borboleta project is a rather innovative initiative. We have found some initiatives related to the utilization of mobile devices to bring information to medical doctors and to provide them with resources to feed information back to a database, but none of them are addressed to preventive healthcare or to underserved communities. For example, the Constellation project [3] connects medical doctors with a centralized database to interact with patient records within the Womens Hospital at Harvard University, and the MEDIC project [4] connects medical doctors with a centralized database to obtain the results of laboratory exams as soon as they become available.

We already have a prototype system for the Borboleta running and being tested by field workers. This initial prototype was built to solve the fundamental communications problems between the server and the mobile devices, as well as to set up the basic information structures that shall be required to support the full fledged Borboleta system.

In this initial prototype, the information that is provided to field workers is as follows:

- **Patient Personal Data:** personal data referring to the person being visited - name, date of birth, etc.
- **Patient Caregiver Data:** many patients have movement impairment, old age or any disabilities that require that a second person most typically some relative looks after a patient; this item contains to personal data referring to those people who look after other people.
- **Patient Socioeconomic Data:** socioeconomic data that can influence specific treatments provided to the individual professional activities, educational level, nationality, religion, etc.
- **Scheduled Visits:** schedule of future visits to the patient.
- **New Visit Registration:** a form to be filled in by the field worker during the visit.
- **Visit History of the Patient:** access to historical data about previous visits to the patient.
- **Diseases Catalog:** access to the *International Diseases Classification ICD-10* [5].
- **Drugs Catalog:** access to the list of available drugs and medicaments in stock at the central hospital.

3 THE MODALITY ONTOLOGY

The Modality Ontology [1] has been developed to provide support to the selection of the most appropriate modalities to present information in a multimodal information system.

Essentially, the Modality Ontology is a hierarchy of concepts that are relevant to the selection of an output modality (or combination of modalities). These concepts characterize attributes that can be found in different modalities, that can guide the process of rendering specific pieces of information or, alternatively, determine what pieces of information *can* be rendered in a specific device considering the attributes of modalities the device is prepared to handle.

The Modality Ontology classifies the modality attributes in two large groups:

1. Content: the specific sorts of information an output modality is capable of rendering.
2. Profile: operational features of output modalities. The profile is further classified in three sub-groups:
   (a) Information Presentation: characterizes features of modalities that identify how information is presented in each modality. For example, a modality can be characterized as *linguistic* (i.e. text based) or *analogue* (i.e. image based).
   (b) Information Perception: characterizes features of modalities that identify how information is captured by end users depending on each modality. For example, a modality can be characterized as *visual* or *auditory*.
   (c) Modality Structure: characterizes representational features that are specific of each modality. For example, a modality can be *pointer based* (e.g. maps, with which the user is expected to interact by pointing to specific locations) or *annotation based* (e.g. text, with which the user is expected to interact by using words). The modality structure also characterizes dependence relations across modalities (for example, text is usually independent of other modalities, but maps require a combination of images and annotations).

Each specific modality can be characterized using the terminology provided by the Modality Ontology. As detailed in the next section, different contexts require different attributes for a modality, and therefore a context of interaction between a field worker and information sources shall determine the required attributes and, as a consequence, the most appropriate modalities to be employed for specific purposes.

4 KNOWLEDGE-BASED MODALITY SELECTION FOR THE BORBOLETA

Our goal is to enhance the Borboleta system with a knowledge-based layer to select the modality of output data in mobile devices.

The selection shall be based on three sorts of information, which shall be determined when a mobile device sends a query to the server:

1. Device capabilities: depending on the multimedia capabilities of the mobile device in use, the possibilities for effective presentation of information are determined. For example, a smartphone with relatively large display can render text and images relatively well,

but if the display is too small or has low resolution, then images may become inadequate to convey guidance to the field workers (such as, for example, a reference image of what a social worker should identify as a symptom in a patient who may present some dermatological pathology); or a PDA with large memory and fast processor can render small videos relatively well, provided that the resolution is adjusted accordingly.
Device capabilities must be available for a system to decide how to best render output information. We suggest that every mobile device in use at the Borboleta system has an entry at a table, pointing to its corresponding capabilities. This table, together with the device capabilities, shall stay in the system server, so that the device must only communicate its ID together with any query to the server.
There are some alternatives to encode device capabilities that can be found in the literature. In order to abide by widespread standards, we intend to adopt the *CC/PP* ontology to encode device capabilities[2].
2. Type of interaction that is occurring during the field work: we intend to build a small ontology of interaction patterns specifically for the Borboleta project. An interaction pattern characterizes the activities being held by a field worker during the visit to the home of a citizen. Depending on what interaction pattern is being used, different levels of detail and emergency of feedback can be characterized. For example, the emergency of feedback can depend on attribute values such as:

   - Long visit: identifies a visit with no hard constraints on duration. The field worker can stay at the visited home for as long as necessary, interacting with the citizens who live there. In this case, the system response time admits some latency and more detailed information (e.g. higher resolution images and lengthier videos) can be appropriate.
   - Short visit: identifies a visit with hard and definite constraints on duration. The field worker may have, for example, a certain number of visits that must be done in one afternoon. In this case, response time becomes more important, and output format (e.g. image resolution and video length) can be selected in order to optimize performance.
   - Emergency situation: identifies a critical situation in which decisions must be taken as rapidly as possible. In this case, evidently the response time is the most critical feature of the interaction with the server, and data formatting must be selected accordingly.

   Long visits and short visits admit different levels of privacy of information presentation. For example, if the field worker and a patient are holding a private conversation, and if the information presented to the field worker can also be presented to the patient, then we can have less stringent privacy requirements for information presentation, that can enable for example videos with audio commentaries included; if the information cannot be presented to the patient, then audio may be inadequate; finally, if the field worker and the patient are in a room with other people, then more restrictive privacy requirements may be at place.
   The type of interaction must be informed by the field worker together with any query that is addressed to the server.
3. Type of information that is being requested: depending on the specific type of medical information that must be rendered, different output modalities may be more appropriate. For example, a dermatological symptom may be most effectively presented using images; a respiratory tract problem may manifest itself most clearly as a sound; and a neurological pathology may manifest itself as a specific pattern of movements that may be best presented in a short video.
   In order to classify the medical information appropriately, we shall employ the widespread standard *HL7 Reference Information Model*[3].

Information items in the server are already being prepared with a variety of alternative presentations. For example, we can have, for a specific item, a short video, a collection of still images extracted from the video and tagged with textual information, and a text summary of the video content. The envisaged utilization of the system presented here is as a tool to select, among alternative stored presentations for an information item, which presentation shall be sent to the renderer.

We shall maintain in the server two supporting tools to provide information to the mobile devices with the appropriate format:

1. A rule-based system to perform inferences based on device capabilities, type of interaction in field work and type of requested information, that shall advise on the best output modality for the requested information; and
2. An *information renderer* that, given the response to a specific query and a selected output modality, filters out unnecessary details and renders the obtained information using the selected modality, and then sends the rendered information to the mobile device.

The best output modality shall be characterized based on terms that are found at the Modality Ontology [1]. We envisage some possible situations in which more sophisticated reasoning mechanisms may be required:

1. Device, interaction pattern and requested information are underdetermined, i.e. the information communicated to the server is not sufficient to trigger any rule that could be used to infer a modality to be employed to render the requested information. We must include context sensitive default values for all relevant variables in order to cope with this situation, so that we always have at least one suggested modality being sent to the information renderer.
2. Device, interaction pattern and requested information are overdetermined, i.e. the information communicated to the server triggers many rules, which are used to infer several different modalities that could be employed to render the same piece of information. We must include context sensitive preference relations between output modalities to cope with this situation, so that we can always have at most one suggested modality being sent to the information renderer.

This additional layer shall provide the Borboleta system with resources to optimize the presentation of information to field workers taking into account the context of interaction with information resources.

5 DISCUSSION AND FURTHER WORK

The Borboleta project aims at provisioning a primary homecare system with mobile computing technology, thus improving its overall quality by making it more efficient and more reliable.

[2] http://www.w3.org/TR/CCPP-struct-vocab/

[3] http://www.hl7.org/

Among the several technological challenges posed by this project, we have highlighted in this article the necessity to provide field workers with appropriate information at the appropriate format.

To face this challenge, we are designing a layer for the Borboleta software architecture to manage the output modality of information sent to mobile devices used by field workers. In very general terms, this layer is comprised by a classification system that receives information from the mobile devices and associates this information with entries at appropriate ontologies that characterize the features of the information request; a rule-based inference system that infers features of the most appropriate output modality for the requested information based on the features of the request itself; and an information renderer that formats the requested information in such way that it presents the inferred features for the most appropriate output modality.

Evidently, our immediate future challenge shall be to implement this layer as part of the prototypical implementation of the Borboleta system, so that we can carry on with empirical evaluation of this proposed approach to optimize the presentation of information to field workers at the Borboleta project.

The Borboleta project is an open source project, and an initial prototype (which at the moment does not contain the information presentation layer) can already be found at its code repository (http://borboleta.incubadora.fapesp.br).

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