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Use of Flowchart for Automation of Clinical Protocols in mHealth

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Abstract

For healthcare professionals to use mobile applications we need someone who knows software development, provide them. In healthcare institutions, health professionals use clinical protocols to govern care, and sometimes these documents are computerized through mobile applications to assist them. This work aims to present a proposal of an application of flow as a way of describing clinical protocols for automatic generation of mobile applications to assist health professionals. The purpose of this research is to enable health professionals to develop applications from the description of their own clinical protocols. As a result, we developed a web system that automates clinical protocols for an Android platform, and we validated with two clinical protocols used in a Brazilian hospital. Preliminary results of the developed architecture demonstrate the feasibility of this study.

Keywords:
Clinical Protocols; Mobile Applications; Flowchart

Introduction

Software development brings together a number of basic macro-activities, which need specific techniques to execute them. Information technology (IT) professionals are responsible for performing these tasks in the software development process. The coding phase of a software is one of the main steps that requires a professional with technical knowledge of programming languages to consolidate the software as a product.

With the adoption of smartphones and tablets, the mobile applications have become popular to solve and to aid in problems of the personal daily and of diverse areas of the society. Consequently, one of the main sectors affected by the growing use of these information and communication technologies is health [1]. Therefore, physicians and other health professionals become users of mHealth and are not limited to the IT resources of health centers, which are precarious in many underdeveloped and emerging countries, as in several regions of Brazil.

While there are many mHealth applications available in the appStore, free of charge or paid, healthcare professionals rely on commercial or academic initiatives to develop health-specific applications once the construction requires specific skills for practitioners in the field. In addition, each existing application addresses a purpose that often does not serve a broad audience, as it is specific and / or limited to certain health care cases and institutions. In this way, the use of these tools becomes unfeasible for a portion of health professionals, mainly to treat local problems from less open regions.

In the scientific literature are found several works that have been intended to develop mobile applications of Clinical Decision Support System [2], [3] and [5]. From these works, despite the divergent proposals, we can observe a pattern in the logic of development, which is in agreement with some representations of the clinical protocols.

The clinical protocol is a management tool that, in the form of systematized documentation or algorithms, normalizes the standard of health care at one point of attention [4]. The systematic reviews and assessments of the benefits and harms of alternative care options are the base to all content that constitutes the clinical protocols and therapeutic guidelines [5]. These practices aim at improving the quality of care, limiting unjustified variations in practice and reducing health costs, and transmitting health teams in the form of a document.

Given the importance of clinical protocols in the daily life of health professionals due to the contribution to care management based on structured and systematized knowledge, we propose to use them in the analysis phase to build applications. However, it is important to point out that each health institution elaborates its protocols according to factors and incidences of its locality, for example, the treatment of hospital-acquired pneumonia in a particular region of Brazil, will be different from the treatment proposed for this disease in China.

This work presents a proposal for automatic and generic generation of mobile applications, from the data entry structured in flowcharts. Remembering that the flowchart is an instrument used in the preparation of clinical protocols.

Background

The use of flowcharts for automation of clinical protocols is exploited as a form of computer-interpretable to provide decision-making systems. Classified as task-network model, these types of system formally represent clinical protocols, allowing an execution mechanism to process the knowledge represented in order to provide specific recommendations at point of care [6]. The main feature is the easy representation and human interpretation in graphic form. Many of these systems consolidated in the literature have the interpretation of the knowledge realized through own language for this purpose [7] and [8]. For the formulation of these languages are used primitive structures, logical and mathematical operators, flow control through if-then rules and ontologies. The use of each of these tools is dependent on their own syntax and semantics, in which they work with groups of characteristics of the clinical protocols and temporal patterns, to control the patients' clinical situation. Some systems also include the organizational structure of the health system.

In this work, we use the perspective of these systems to carry out a knowledge-driven approach to specific clinical protocols applied to mobile technology. We emphasize that the structure of this work does not allow the temporal treatment of data, because the decision diagnoses are based on the information entered by the user, not being queried in databases, limited the configurations that will be presented in Methods.

Methods

The main feature of the proposal of this work is the form of user interaction with the system through flowcharts. In this way, the methodology used in this interaction, based on the definitions of the flowchart elements given by [6]:

- Oval element - Each algorithm begins with an oval design, representing a population of patients with a defined characteristic, symptoms and complaints. We can call these oval designs as clinical condition.
- Diamond - The diamonds represents the most important clinical decisions. They are decisive for the next steps and we call them of decision points.
- Rectangle – Represents the specific groups of the care process and the description of diagnostic or therapeutic interventions. We call them Service Process.
- Circle – Is the figure of closure, used as "output" every time a process reaches a conclusive stage. From this graphical element, we do not leave arrows.

We describe the proposed logic for these elements in automatic application generation as follows.

Clinical Condition

The clinical condition, represented by an oval symbol, is one of the simplest symbols. To describe it, only one clinical characteristic is necessary. Therefore, for the data entry in the system a text field is used. The clinical condition is obligatorily the first element of the flowchart, because from this the flow begins.

Clinical Decisions

Unlike the clinical condition, the clinical decisions, represented by the diamond, have several classifications in order to apply the most adequate logic to find the answer. Then, to configure the logic of the clinical decision element, the user must establish the most appropriate type of decision, at that point in the flowchart, in which it can be:

1. Numerical comparison.
2. Decision by calculation.
3. Existence of factors.
4. Question.
5. Scoring system.
6. Comparison from reference image.

Each option has a set of steps, which requires the necessary information for each decision logic. Below we describe the configurations of each type of decision.

Numerical comparison

To make a decision by means of a numerical comparison, we define as:

- Fixed values - where the comparison parameters will always be the same.
- Variable Values - where the comparison parameters vary according to the inputs.

It is important to emphasize the terms used in the proposed system and in the present work to determine the characteristics of input values, variables used in the formulation of the decision logic and description of the logic. We determine also:

- Comparison properties - The original terms in the clinical protocols. For the system, the comparison properties are essential information to compose the mobile application, because, through these terms, we identify the input fields of values. Example: Days of hospitalization, Temperature; Heart rate etc;
- definition of variables - such as fictitious terms to represent the comparison of properties in the formula of decision logic;
- Formula - the comparison structure used to carry out the decision logic. We standardize the formulas for each type of clinical decision chosen. Most often, they use the variables associated with logical operators. The user is responsible for describing the formulas according to the type of clinical decision setting chosen.

To compose the formula of clinical decisions based on numerical comparison of fixed or variable values, the logical operators are used.

1. In the description of the numerical formula of fixed values, the character x identifies it as a variable. Thus, for each type of numerical comparison with fixed values, a pattern is identified in the use of the x. For example, for comparisons with a fixed value the x will be at one end associated with a comparison operator and the fixed value, as in (1). For comparison between fixed numbers, x is in the center of the comparison, and the numbers in the borders, as exemplified in (2).
2.

$$x = 10(1)$$
$$0 \leq x \leq 20(2)$$

3. In another free text field, the user will describe in technical terms what represents the x, so that in the mobile application is described as input value, that is, the comparison properties.
4. The decision by numerical comparison with variable values is a situation where the outcome of the clinical decision is dependent on two or more variable values. Therefore, given the definition of two or more variables, we compare them as in the example (3):

$$y \leq x = z(3)$$

5. where y, x, z are variables which represent comparison properties.
6. Because of these clinical decisions, the logic will be binary, ie. two possible flows.

Existence of factors

Another way to make a clinical decision is to check for factors. In this way, the clinical protocols associate absence of factors and/or presence to decide the flow of the process. Including this characteristic in the system, this clinical decision we define through the textual description, in a single field, of these factors associated with logical operators, like "!" (NOT), "&&" (AND) and "||" (OR). We extract the factors from the logic of the exclusion of the operators and we use these words in the mobile application. As a result of this type of clinical decision, logic will also allow only two flow possibilities.

Question

The clinical decision by question does not have any kind of computational logic. This decision depends on the interpretation of facts of the health professional, in which based on a questioning, will indicate if the flow will be positive or negative.

Decision by calculation

Like the numerical comparison of variable values, the decision by calculation will require the configuration of properties, definition of variables and description of the formula. However, we describe the formula as an equation through simple mathematical operators. We can use the result of the calculation described for conference (no flow option or only one) or establish classifications. To stipulate the classifications dynamically by the user through ranges of values, we use the logic of numerical comparisons with fixed value. The number of possibilities of flows will be (4). To define the flow for indeterminate ranges we add 1.

$$flows = ratings + 1 (4)$$

Scoring system

The scoring system is an operation that takes into account a list of criteria, in which each criterion has a value. In order to establish the value of the criterion, we configure this value in fixed or the user must inform. For example, the criterion value is the same as the patient's age. In case the value is fixed, the treatment of the criterion is as the logic of the existence of factors.

By means of the sum of the values, of the selected criteria, we obtain the diagnostic result. To establish the result, in turn, we use the predetermined classifications. The number of possibilities of flows will be as in (4).

Comparison from reference image.

The comparison from the reference image does not require computational effort and is an intrinsic feature to other forms of clinical decision. Through the insertion of images, these can help the viewer user to make decisions.

Customer Service Process

The service process, represented by the rectangle, has the simple objective of providing information. It is usually associated with a clinical decision element. Therefore, it is the ideal element to describe textually the procedures given by the flow.

Simulator

The simulator has a structure, in the development interface, of logic and screens identical to those of the Android application. As the user mounts the flowchart, it is possible to check the expected outputs, according to the element types and their relationships. Therefore, the simulator is a way for the user to carry out case tests before the application is generated.

Results

To evaluate the efficiency and effectiveness of the proposed solution, we performed an experimental evaluation with different clinical protocols of Brazilian hospitals. The evaluation explores divergent protocol perspectives applied in a mobile application. We implemented the logic of the flowchart elements in a web system for generating Android applications. We emulate the applications through Android Virtual Devices, version 2.2. The system default language is Brazilian Portuguese, but there is also a translation of the flowchart settings in English.

Protocol 1 - Treatment of community-acquired pneumonia (CAP)

Protocol 1 describes the treatment suggestions of the CAP through a scoring system, classifying them into 5 treatment possibilities: outpatient, with a lethality of 0.4%; Outpatient clinic, with 0.7% lethality; Hospital brief; Hospital, with lethality of 8.5%; and hospital with lethality 31.5%. In addition, in case of hospital treatments, we verify the need for intensive care unit (ICU). In all other cases, we verify the probability of specific germs and thus the appropriate prescription of drugs by doctors to fight the patient's illness happen. Subsequently, we realize the specific diagnosis of the pathogen. According to the documentation of protocol 1, in this situation, it is possible to transcribe in the proposed system all procedures, and mainly the decision logic. In this example, in the clinical decision element, the punctuation system and decisions by means of questions stand out.

Figure 1 illustrates the scoring system configuration where the user describes:

- The segment of characteristics - text that serves to structure and visually order the characteristics and their scores. A scoring system can have multiple segments, created dynamically by the left button "New Segment".
- Number of characteristics - To create dynamically rows in the table to describe the characteristic and its corresponding punctuation.

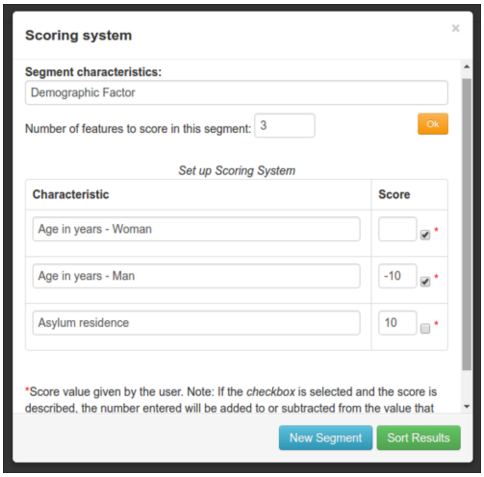

Figure 1 – Example of scoring system setup.

Later the creation of the configuration of the characteristics and their scores. The user must sort the result ranges. The number of result classifications indicated the limit of associations that the decision element might have. Figure 2 illustrates this process.

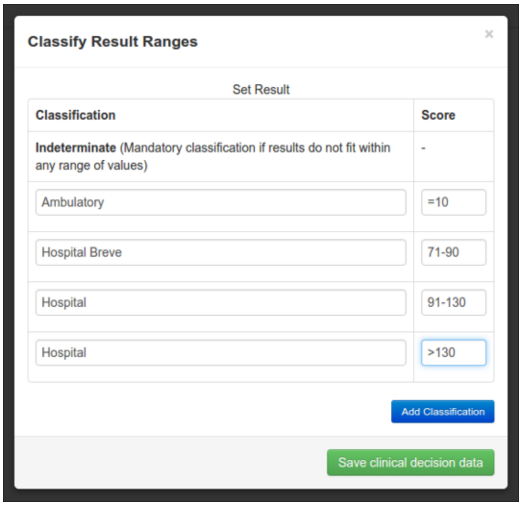

Figure 2 – Example of setting the result ranges for the scoring system.

In the cases of clinical decision by question, the user is only responsible for verbatim informing the type of inquiry. The proposed system of the possibility of inserting an image to assist the physician in the inspection, as shown in Figure 3. However, this type of clinical decision can only be associated with two elements: one corresponding to the positive flow and the other to the negative flow.

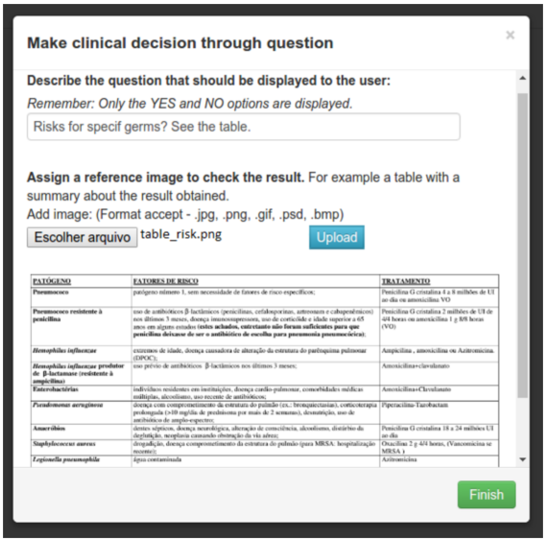

Figure 3 – Example of configuration of the decision by question.

In the example presented, we structure the flowchart as shown in Figure 4. The transcription of all protocol 2 information in flowchart in the system, according to all the necessary configurations, took approximately 35 minutes. We use 1 clinical condition (Pneumonia acquired in the community); 4 elements of clinical decision, being a scoring system and three questions; 11 service processes; and a conclusion.

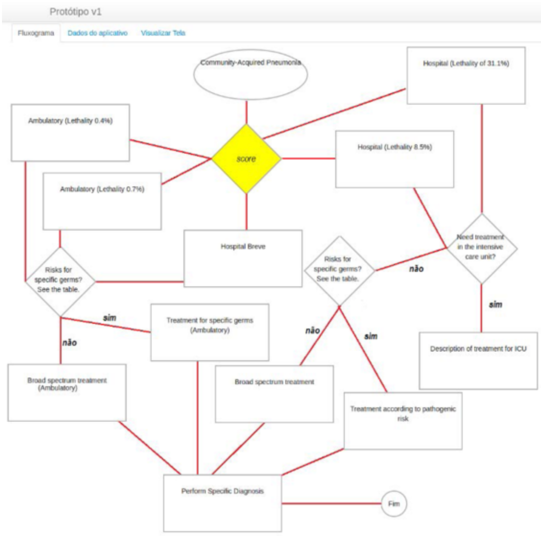

Figure 4 – Protocol 1 flowchart.

The application generated automatically through the flowchart has 16 screens, which reflect each element drawn. The flow of the screens is static except for the decision elements that require user interaction to point the next path. Figure 5 shows examples of each element used in the flowchart. Figure 5 [1] shows the characteristics of the scoring system. In 5 [2] a decision by question.

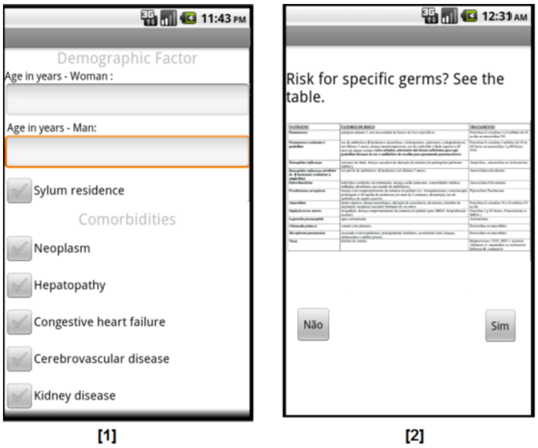

Figure 5 – Examples of graphical interfaces generated for each type of flowchart element.

Protocol 2 - Management of infectious complications in severe acute pancreatitis

Unlike protocol 1 that explores a consolidated scoring system, we present the protocol 2 as a more explanatory document on the management of infectious complications in severe acute pancreatitis. In this way, the service process was widely used to structure the information in the application. Figure 6 illustrates the configuration of this element, in which it requires only: title, description and optionally image to elucidate some of the procedure.

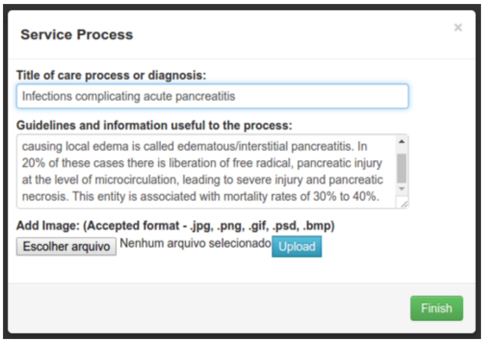

Figure 6 – Example of configuration of the service process

For the diagnosis of pancreatic infection and systemic inflammatory response syndrome, we use the logic of factor checking. Therefore, for the clinical decision configured we chose existence of factors. In this type of decision, the user describes in text the factors to be verified and relates them through logical operators. It is also important to point out how many propositions indicated the positive diagnosis needs. Figure 7 illustrates, as an example of the configuration of this element, the diagnosis of pancreatic infection.

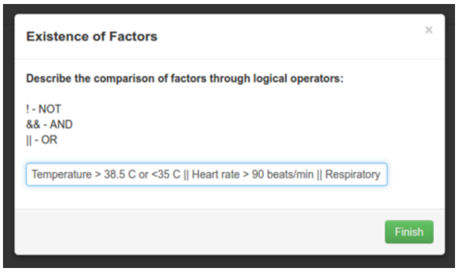

Figure 7 – Example of configuration of the decision through the existence of factors.

Finally, Figure 8 illustrates the graphical interfaces generated in the application from the respective elements exemplified above. In 8 [1] the graphical interface of a service process, and in 8 [2] the decision through the existence of factors are displayed.

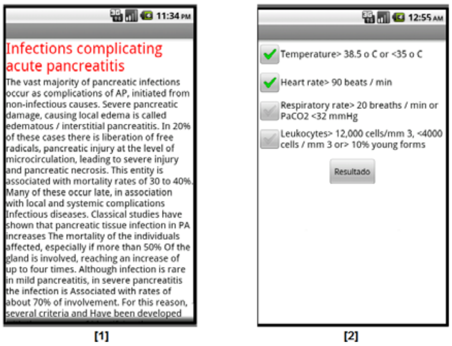

Figure 8 – Examples of protocol 2 graphical interfaces.

Conclusion

One of the ways to structure the protocol information is the algorithm. By means of flowcharts, it is possible to graph the logic of algorithms. In this work, we explored this characteristic of clinical protocols allied to the possible standard of many applications of clinical decision system. Thus, joining these aspects proposed a way to create generic mobile applications for health professionals, without the need for coding.

We obtained the experimental results through real clinical protocols. Due to the limitation of space, it is not possible to demonstrate all proposed features, however, for the examples presented it was possible to transcribe the information as a flowchart in an easy way. Due to the simplicity of the construction of flowcharts, the usability of the system becomes high, that is, there are no ambiguous interpretations for the elements or complicated technical configurations. In addition, the cost of development is quite low. Moreover, from the construction of the project, we realize the creation of an executable android file, without the user having to install any tools.

The generated android applications showed a simple graphical interface, but perfectly usable and correct logic according to the specification in the flowchart, which demonstrates the feasibility of the proposed structure. As future work, we aim to apply improvements in this project.

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