A Rule-based Content Management Framework for Effective Development of Intelligent Mobile Apps in Healthcare

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Abstract: The number of published healthcare articles is increasing dramatically every year, making it difficult for physicians and patients to stay current with the latest information related to healthcare. One possible approach to improving the ability of physicians and patients to stay current with the latest trends in healthcare is through the use of mobile applications. The challenge to this approach is the lack of a content management framework that allows medical experts to continuously integrate new knowledge and content into the design of easy to use software applications for patients and other healthcare personnel. This paper introduces the CANBeWell mobile application, a rule-based content management application for collecting and aggregating important medical data from medical experts, and disseminating this data to patients and other clinicians using a context-aware mobile app in support of preventive healthcare.

1 INTRODUCTION

There is a major push to improve the quality of life for patients with chronic and complex health conditions through preventive healthcare (Deek, 2016). With the proliferation of misinformation on the Internet today, it is becoming increasingly vital that the content needed for preventive healthcare comes from the validated sources and provided to patients in a context that allows them to make informed and accurate medical decisions (Wald et al., 2007).

Intelligent mobile applications (apps) have been developed in a number of areas to inform and help patients and physicians manage chronic diseases such as diabetes (Widmer, et al. 2015), inform and support breast cancer patients (T Ginossar et al, 2017), and provide app-based interventions for the prevention of cardiovascular disease (Eng & Lee, 2013).

Also, wellness apps have been shown to increase self-management in patients and improve outcomes across various socioeconomic spectrums (Handel, 2011). However, evidence-based information is often lacking in healthcare apps (Eng & Lee, 2013). Ideally, medical experts need to be involved in organizing reference medical information used in a mobile app, so it is convenient for patients and providers to use. But the effectiveness and efficiency of these wellness apps are always a big concern for medical experts (Yang & Silverman, 2014). As a result, medical experts attempt to design and conduct various types of surveys to resolve such concerns.

This paper proposes a rule-based content management framework that integrates an easy-to-use, context-aware mobile application with preventative healthcare content. Our framework incorporates an automated workflow for collecting and aggregating important medical data from medical experts, data which can then be disseminated to patients and other clinicians using a context-aware mobile app in support of preventive healthcare. This is an early research work being conducted in partnership with Dr. Cleo Mavriplis of the Bruyere Research Institute, Faculty of Medicine, University of Ottawa, with a focus on preventative healthcare applications (apps).

The rest of this paper is organized as follows. Section 2 provides some background on rule-based content management application frameworks and the usability of mobile applications. Section 3 discusses

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some related work. Section 4 presents our framework and CanBeWell application. Section 5 discusses our findings. Section 6 shows the framework evaluation based on a survey of the application users and Section 7 provides some conclusions and future work for this research.

1.1 Motivation

A survey conducted by Paul Krebs and Dustin T Duncan (Krebs & Duncan, 2015), shows that just over half of the mobile phone users (934/1604, 58.23%) had downloaded a health-related mobile app. North Americans are increasingly relying on mobile technology and the internet for health-related information and resources (Fox & Duggan, 2012). The proliferation of smartphone ownership among US adults, particularly among traditionally underserved populations (e.g., low-income, racial/ethnic minorities), has expanded the potential reach of healthy eating, physical activity, and weight loss programs. From 2011 to 2015, the percentage of US adults owning a smartphone increased from 35% to 68% (Anderson, 2015). In addition, low income and racial/ethnic minority populations are more likely to be smartphone-dependent, thus relying primarily on their phones for health information (Smith, 2015).

In general, the development and adoption of health and wellness smartphone apps have outpaced empirical investigations (Boulos et al., 2011). Making these apps “smarter” through AI can enhance their accuracy, effectiveness, and efficiency – increasing users' trust while allowing input from medical experts, which in turn increases the utility of these applications.

Benferdia and Zakaria identified all the key user groups of m-health apps. These groups are patients (44%), the physicians – health specialists, doctors, and nurses (37%), general users (13%), and finally caregivers (7%). Providing the right health information to the right person at the right time is one of the most important features of every m-health application (Benferdia & Zakaria, 2014).

2 BACKGROUND

2.1 Rule-based Content Management Systems

Rule-based content management systems have been studied for nearly two decades in application areas such as geographical information systems (GIS), metadata catalog systems, and healthcare (Beatty and Lopez-Benitez, 2012). Based on these application areas, content management systems can be classified into two categories - content-type-specific and general-purpose systems (He et al., 2007).

Content-type-specific systems include 1) video adaptation scheme for adaptive video streaming (Chang, Zhong and Kumar, 2001), 2) multimedia content adaptation scheme such as InfoPyramid that provides a multimodal, multiresolution representation hierarchy for multimedia content (Mohan et al., 2019).

The trade-offs imposed by rule-based systems in terms of time to deliver content, memory consumption, and fault tolerance have been analyzed (Beatty and Lopez-Benitez, 2012). This work presents a novel approach that uses a rule-based system to regulate web page generation thereby improving cache performance and query generation with large unorganized data sets. Further, there are approaches that use data mining and statistical techniques to control content-based rules, such as associating significant browsing events with specific contexts (Wang, 2007).

Some general-purpose content adaptation systems have also been developed, such as BARWAN (Brewer et al., 1998), and Power Browser (Buyukkokten et al., 2002). Each of these approaches has some advantages. However, they do not provide for flexible and extensible content adaptation. Their adaptation approach is either fixed or hardcoded in the system. When the adaptation goal is changed, such as when a new client device or a new data type is introduced into the system or a new adaptation technique is developed, the system must be redesigned to accommodate the change.

Finally, He et al. (2007) present an extensible content adaptation system, Xadaptor. This uses a rule-based approach to facilitate extensible, systematic and accommodative content adaptation. It integrates adaptation mechanisms for numerous content sorts and organizes them into the rule base where rules are invoked based on the individual client information. (He et al., 2007)

2.2 Usability of Mobile Apps

Usability is considered important for users to accept the system. A well-known concept in design and healthcare systems development, the concept has its roots in the development of information and communication systems and human-computer interaction (HCI) (Larsson, 2013)

Usability is defined as “the extent to which a product can be used by the specified users to achieve specified goals with effectiveness, efficiency, and satisfaction in a specified context of use" (Jokela, Iivari, Matero & Karukka, 2003). Usability is an important factor in mHealth wellness applications, especially for people who may find it challenging to interact with smartphones, PDAs, etc. Besides a user perspective and an aim toward creating beneficial solutions that are effective, efficient, and satisfactory, the context is considered important and has a significant impact on usability work.

Focusing on usability requires an understanding of the context before, during and after implementation (Larsson, 2013). This means that usability work must be included in all steps of the development process. Studies showed that hundreds of thousands of products are returned each year, not because of its functional behaviour but because of bad user experience (Kalimullah, 2017)

User experience is a consequence of a user's internal state, the characteristics of the designed system, and the context in which the interaction occurs. User experience considers the wider relationship between the product and the user in order to investigate the individual's personal experience of using the product (Kalimullah, 2017). Researchers and practitioners use different techniques and methods to capture the customer's psychological and behavioural aspects toward a product and have those incorporated into the design of future products.

2.3 Standards for Usability Testing

Standards and best practices have long been considered beneficial, as they stop us from designing based solely on personal opinion or experiences. To that end, ISO 9241 was defined. This standard is a multi-part standard from the International Organization for Standardization covering ergonomics of human-computer interaction. The ISO 9241-11 standard defines usability as "the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use" (International Organization for Standardization, 1998). Poor usability is a major obstacle to health information adoption (Yen et al., 2012) and a clear cause of medical errors (Zhang et al., 2003). ISO 9241 identifies three metrics for usability testing:

1) Effectiveness: Measures the accuracy and completeness towards achieving specified user goals
2) Efficiency: Measures the resources expended towards the accuracy and completeness of achieving set user goals
3) Satisfaction: Measures the level of comfort and positive attitudes towards the use of a product.

3 RELATED WORK

Similar to our framework, most content management systems (CMS) used in preventive healthcare integrate with a clinical decision support system. There are two broad categories: 1) event-driven CMS systems - triggering notification based on some clinical contexts and 2) portal or mobile-based CMS – use a portal or an app to allow patients to choose the context for the information they need. Our framework belongs to the second category.

Gunaratnam et al. (2012) propose a conceptual framework for a perinatal clinical decision support system that uses a knowledge-base of rules, a workflow engine, and a notification engine to help physicians to send notifications to families on preventative measures for managing at-risk pregnancies. The knowledge-base is a content management system that comes from validated medial information combined with the patient electronic medical record required to provide the context for the notifications sent to the participants.

Cleland et al. (2017) present the usability evaluation of a mobile app for managing diabetic foot disease that uses a CMS with thermal imageries, customized educational content, and game-based scenarios that help diabetic patients to self-manage their conditions.

Barbara et al. (2017) describe an evidence-based database for educating geriatrics-focused public health professionals. This portal-based CMS provides reliable health information that informs their management of care for elder patients. The portal provides searchable evidence-based content but lacks annotated graphics or a rules engine for context customization.

Kuo & Fuh (2011) proposes a clinical decision support system that uses rules to interpret health examination results. This work supports a custom rule syntax for implementing computer-interpretable logic for interpreting health examinations. These rules rely heavily on ontologies such as diagnosis code, procedure codes, rankings, etc., and a reasoning engine that employs a rule combining algorithm for decision making. The challenge with this system is that it lacks a graphical user interface for managing the rules. That means changes to the rules would require software changes which is a gap for most medical experts.

4 RULE-BASED CONTENT MANAGEMENT APPLICATION

4.1 Framework Overview

Our rule-based content management application leverages declarative rules developed by medical experts with information on the common health challenges that affect various organs of the body for different ages and gender.

As shown in Figure 2, rules are created and managed by medical experts based on research and findings from the literature. These rules are then converted to a machine-readable JSON file and pushed to a mobile app that is made available to users using very interactive, mobile-friendly user interfaces.

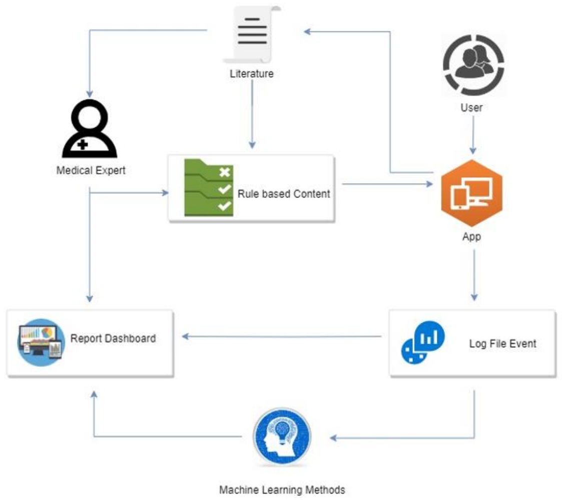
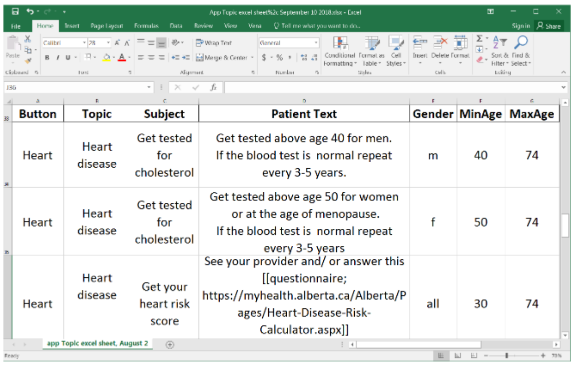


Figure 2: The Generalized Model of Rule-Based Content Management.

As users interact with the application, logs are collected and used to feed both an analytics dashboard and machine learning algorithms that also feed analysis results to the report dashboard. Usage data and analytics results are fed back to experts to help provide more content to patients and service providers.

4.2 Managing Rule-base Content

Rule-based contents are then used to dynamically display the correct content based on the language of the user, gender and age of the patient, and whether they want information appropriate for a patient or a provider. Since most medical experts are familiar with using spreadsheets, we decided to use an Excel spreadsheet to organize and classify information for these experts. Figure 3 shows a snipped of the Excel spreadsheet that was used with our rule-based application. Each of the columns corresponds to the classification of content. Each row is a rule that says what content to display, depending on the value of gender and the age range.



Button	Topic	Subject	Patient Text	Gender	MinAge	MaxAge
Heart	Heart disease	Get tested for cholesterol	Get tested above age 40 for men. If the blood test is normal repeat every 3-5 years.	m	40	74
Heart	Heart disease	Get tested for cholesterol	Get tested above age 50 for women or at the age of menopause. If the blood test is normal repeat every 3-5 years	f	50	74
Heart	Heart disease	Get your heart risk score	See your provider and/ or answer this [[questionnaire; https://myhealth.alberta.ca/Alberta/Pages/Heart-Disease-Risk-Calculator.aspx]]	all	30	74

Figure 3: Content Rules Spreadsheet for Medical Experts.

The content in the first row of the spreadsheet is for a male patient between 40 and 74 years old. The content in the second row is for a female patient between 50 and 74. The content in the third row is for patients of all gender, between 30 and 74 years.

The simple guidelines for the medical expert to follow are summarized in a single simple documentation web page that they can refer to. We have defined two simple annotations that the medical expert can use. One is to include links with an appropriate text anchor for supplementary materials. The other is to embed images in the content displayed.

The content from the Excel spreadsheet from the experts is then translated into different languages as needed to support the targeted users. These files are then converted to machine-readable JSON files. The choice of a JSON file is because of its flexibility with various web and mobile application development platforms. Regression tests are run on the app to ensure that it is functioning properly. And finally, the medical expert manually tests the app to be sure the content specified is displaying correctly.

To support French and English users, there are four content files for the application. One file, topics_en.json, for content on proactive wellness topics and one file, tests_en.json, for content on the screening test. There are French versions of those files as well (topics_fr.json, tests_fr.json).

4.3 CANBeWell Application

The CANBeWell application was developed by engineering students in the Biomedical Engineering Smartphone Training program at the University of Ottawa in collaboration with Dr. Cleo Mavraplis who is the medical expert. It is intended for use by both patients and primary care providers.

CANBeWell organizes information on proactive wellness topics and recommended screening tests by age and gender in an easy to use interface that includes an annotated anatomical image where the user can click on different parts of the body. Users log in as either a provider or a patient and by clicking on different parts of the annotated anatomical body image, text and important links with supporting evidence and supplementary information are displayed based on the context of the use – provider or patient.

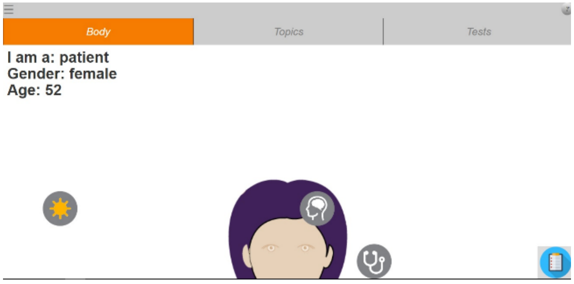


Figure 4: CANBeWell Application Banner.

Figure 4 shows the banner of the application. Information is presented to the users visually through the Body tab or by alphabetically sorted topics if they click on the Topic tab. The top left corner displays the current configuration. The content displayed in Figure 2 is relevant to a female who is aged 52. If the user clicks in that top left corner configuration panel, they can change the configuration so that content is displayed for a different user context and patient. For example, to a physician, or a patient of different ages (18-149) and different gender (female, male or all).

In figures 4 and 5, one can see parts of the body map (In this case for a female). Individual body parts can be clicked on. In Figure 3, the heart has been clicked on and is highlighted but one can see and click on other body parts (lungs, liver, kidneys). There are also additional icons. A needle for vaccinations is shown in Figure 5 A sun icon for sun exposure, a stethoscope icon for physical exams, and a brain icon for memory problems in Figure 4.

In figure 6, the content available is displayed. Clicking on the Heart Icon brings up the Heart Disease topic, and there are three subjects for that topic: Be Active, Get Tested for Cholesterol, Get your Heart Risk Score. The specific content that is displayed depends on the age and gender specified in Figure 2, and whether the information is intended for a patient or a physician.

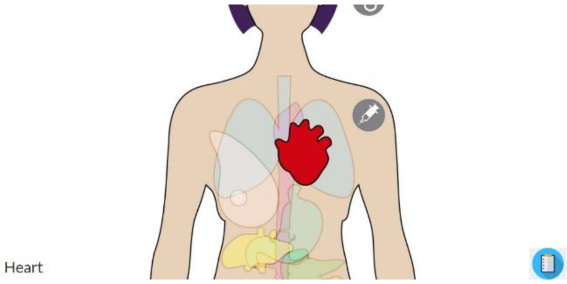


Figure 5: Annotated Body Image with associated icons.

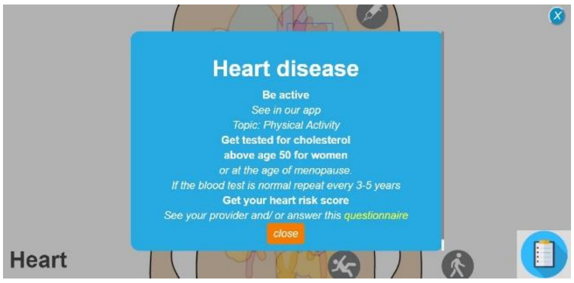


Figure 6: Context-based popup displays information by subject for a given topic.

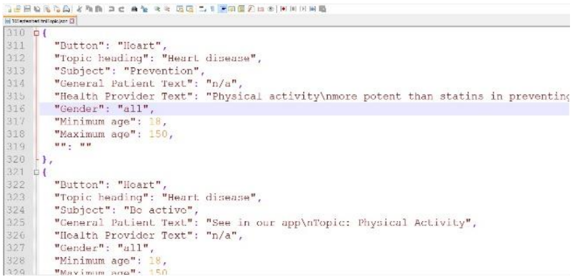


Figure 7: JSON document specifying content-based rules for the application.

Links to evidence or supplementary information are highlighted. When clicked on, they bring up a browser to display the evidence or supplementary information. CANBeWell has built-in multi-lingual support and is currently available in both English and French. The content is classified based on Button clicked, Topic heading, Subject, Patient test, Provider test, Gender and Age range (Minimum, Maximum). The topics or tests from the appropriate JSON file (based on language) are filtered based on patient vs provider, gender and age. When using the Body tab, the list is further filtered to only include those corresponding to the button clicked.

The .json files (figure 7) used in the CANBeWell app are generated from the Excel Spreadsheet. First, macros are used to scan the file and check for any formatting errors, missing values, and incorrect values (gender or age out of range, incorrect button label, etc.).

5 DISCUSSION

CANBeWell app has gone through several iterations of testing, including two third-party assessments by healthcare app usability experts. It is now undergoing a research trial with 30 patients and 10 providers, which will provide quantitative and qualitative feedback on usability being carefully monitored as they use the application.

Enumerated below are some of the strong features of the application.

- Bilingual support (currently supports English and French).
- Optimized for smartphones but runs on any device (laptop, tablet, smart TV, cell phones) with a browser.
- Body image interface.
- Separately and optimally worded text for both patients and providers.
- Easy Filtering and Navigation (body parts, age, gender, health topics, common tests, patient vs provider text)
- Use of embedded images and supporting links in the content.
- Additionally, the current integration of the app has support for content management by the medical expert.

The first iteration of the application was hardcoded as a native android app. The content was communicated to developers in documents, but they were responsible for manually coding the content into the application.

This approach gave great flexibility in being creative in how to display the content, but it was not practical since changes to the content requires code changes and redeployment of the application. Especially, since evaluations by usability experts indicated that consistency and predictability in how content was displayed in the application were better overall in terms of usability for the end-user.

The latest iteration of the app is based on the operational model depicted in figure 8. In this iteration, the rule-based content framework was completed. This new version achieves the desired consistency and flexibility as required by the medical experts. Most importantly, occasional errors in the spreadsheet maintained by the medical expert are easily identified and fixed. Changes were easily made by simply editing the spreadsheet and regenerating the .json files.

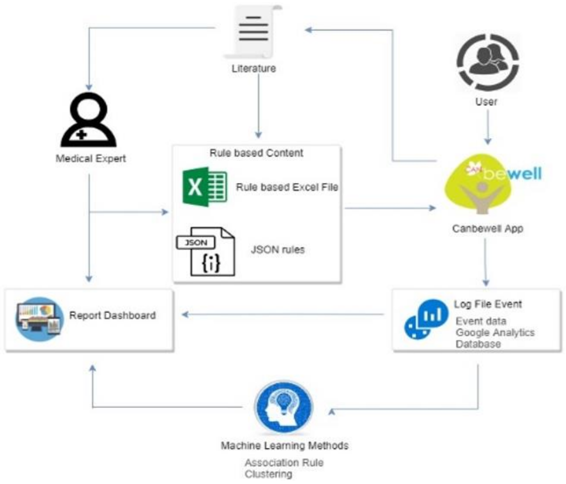


Figure 8: The operational model.

6 EVALUATION

CanBeWell was evaluated in an Urban Academic Family Practice in Ottawa through a usability survey. The survey is adapted from the System Usability Scale (SUS) and administered as an online questionnaire to 22 respondents (16 patients and 6 providers). The respondents were allowed a period of 1 month to use the app before they are allowed to complete the usability survey.

These respondents range from 28 to 64 years old, with average and median ages of 45 and 40 respectively. The mean age for patients and providers was 46.6 (25-70) and 32.5 (27-46) respectively. All the respondents used smartphones – 46% iPhones and 54% android phones. A survey was administered to these users on the usability of the application. Answers were scaled from Strongly Disagree to Strongly Agree (5 Steps).

As shown in Figure 9, the responses show that the biggest strengths of the app centres around ease of use. The respondents are confident that they can use the app, they found it simple to use and follow, and would even recommend it to their families and friends. The biggest negative is that most respondents would not use the app often. They also didn't feel enthused with recommending the app to their healthcare provider.

While we couldn't be very conclusive on these results because of the small number of respondents, it points to some areas of improvement with the depth of content that should be made available to the users. With more content, users are more likely to use the app more frequently and with increased use, it would start coming up at discussions with their healthcare providers.

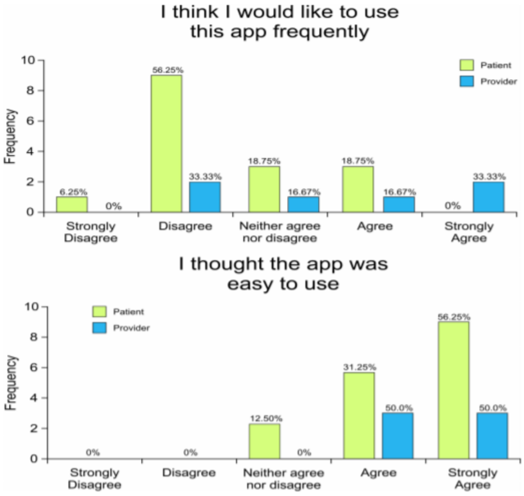


Figure 9: User survey responses analysis.

7 CONCLUSIONS AND FUTURE WORK

It is important to provide researchers and healthcare experts a platform for managing content in a systematic manner using tools they are familiar with. Equally vital is the ability to update the healthcare app without requiring developer intervention.

The CANBeWell app has the potential to greatly improve the ability of patients and physicians to stay current with the latest medical advice on wellness. The app is easy to use in both English and French and provides personalized content based on the age and gender of the user and whether they prefer content designed for patients or for physicians. More importantly, the approach to content management is practical and sustainable allowing the medical expert(s) to manage the content on their own.

In the future, we plan to include a number of improvements. We would like to provide the medical expert with an easy to use HTML interface that allows the medical expert to use the exact same rule-based content management that is used now, but with an interface that can provide immediate rule and content verification, and optimized support during data entry. It would also store the content directly into JSON format so that the effects of the changes can be seen.

We would also like to instrument the application with clickstream logging and IP address logging. This will allow us to collect and analyze statistics to see which content is being accessed, how often, by whom based on geography, age, and gender.

It would also be useful to have a utility that constantly monitored all the links to supporting evidence embedded in the content. A report could be sent to the medical expert(s) any time a link broke (supporting evidence no longer available) or the content referred to by the link changed (update to the supporting evidence).

Finally, it would be advantageous to link this development with a news service that monitored and classified new developments in wellness research and organized them as a service to the medical expert(s) maintaining the application.

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