A Health Records Kiosk, Using An Ontology-Based Information Architecture

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***Abstract*—There is a growing movement to provide patients with direct access to their Electronic Health Record; indeed, in many jurisdictions this is a legal requirement. Such access may be provided simply to allow patients to review the content of their record, or it may allow them to add information in scenarios such as booking appointments, requesting repeat prescriptions, transferring information from a Personal Health Record, or providing information prior to a booked clinical encounter. However, many patients have a low level of "health literacy" which can hinder their ability to understand the information in their record, leading to undue anxiety for themselves and wasted time for healthcare professionals. There are various ways in which this problem can be addressed, including the provision of patient access through familiar, easy-to-use interfaces, such as the kiosk-style interfaces used to place orders in fast food restaurants or to buy tickets for public transport. This paper describes the implementation of a Health Kiosk Application Framework, using an ontology-based information architecture, realized using web technologies: OWL, XML, SVG and XForms. The framework has been used to implement the Oculus Kiosk, a system for the triage of patients attending an Ophthalmology clinic.**

Keywords—Electronic Health Records, Health Literacy, Kiosk, OWL, XML, SVG, XForms, HL7 CDA, ISO 13606.

I. Introduction

From about the time that Electronic Health Records (EHR) first started to be used in routine clinical practice, there have been initiatives to allow patients to access and create information in their own record. At the Mayo Clinic in 1968, an experimental system for an Automated Medical History allowed patients to provide details of their medical history using a light pen and on-screen overlays of printed questionnaires [1]. In more recent times, in many jurisdictions, patients have a legal right to access the information held in their health record, for example through the HIPAA regulations in the US [2], the GDPR regulations in Europe [3] and similar legislation in other countries [4]. There here have been numerous initiatives to provide online or digital access to health records for patients in the US [5], Canada [6], UK [7], Norway [8], Australia [9], Europe [10], and some low to middle income countries [11].

As the use of EHR became more widespread, so the benefits and issues associated with direct patient access have started to emerge [12] and the positive effect on patient involvement in their own healthcare decisions (patient-centered care) has started to be observed [13]. However, despite evidence of both advantages and disadvantages [14] there is still no conclusive evidence that there is an overall benefit to patients, despite their right to access their own record [15, 16]. One issue is the level of health literacy required for patients to fully comprehend clinical information, and the anxiety that can be caused for patients with lower levels of literacy when reviewing their own health record. According to the World Health Organization "Health literacy represents the cognitive and social skills which determine the motivation and ability of individuals to gain access to, understand and use information in ways which promote and maintain good health." [17] and is itself the subject of extensive research and study [18].

One way to address issues associated with access to health records for patients with lower levels of health literacy is to provide a "kiosk" style user interface. Kiosk systems can be characterized as "free standing units containing computer programs that provide users with information services." which are "mostly interactive and usually have a simplified user interface, such as a touch screen or keypad." [19]. These types of system are widely used for ordering in fast food restaurants, buying tickets on public transport or providing general information in public places. For decades, they have also been deployed in a variety of healthcare settings for use by patients [20], including for patient access to their health records [21].

This paper describes a framework for implementing Health Kiosk systems, linked to an EHR which uses an ontology-based information architecture for structured health records based on the ISO 13606 standard [22], with the records themselves created and stored as XML [23] using the HL7 Clinical Document Architecture (CDA) [24].

The objectives in developing the Health Kiosk Application Framework are to provide:

- an interactive, kiosk-style interface for patients to access and update their health record
- a toolkit for implementing Health Kiosk systems, linked to a structured EHR
- a robust, standards-based platform for running the Health Kiosk

The remaining sections describe the method used to implement the Health Kiosk Application Framework and the results of using the framework to develop the Oculus Kiosk, an EHR for triaging patients attending an ophthalmology clinic.

II. Method

A. Client-Server Kiosk

The system architecture of a Health Kiosk, developed using the Health Kiosk Application Framework, is shown in Fig. 1. It is implemented as a web-based, client-server system, using XForms [25] and fed by a full EHR system in the manner described by Chelsom and Dogar [26]. The Kiosk Server runs on the Orbeon XForms Enterprise Java application framework [27], which includes a full XML processing stack and is deployed with an open source XML database, eXist [28]. The Kiosk Client is a single XForm, accessed through the Chrome web browser, running in "Kiosk Mode" on an “all-in-one” touch screen computer.

The XML database on the Kiosk Server contains three types of information:

1. Configuration of the Health Kiosk, including a specification of the care pathway and the set of template HL7 CDA documents that are used to capture the clinical information entered by the user (patient).

then after the patient has been authenticated and a session started

2. The cache of HL7 CDA documents instantiated with data entered by the patient.
3. The full health record for the patient, transferred from the EHR system.

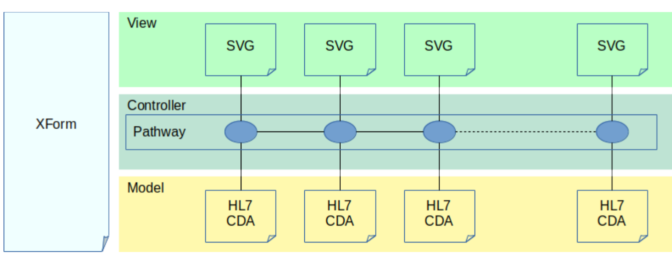

Fig 1: Kiosk pathway implemented as Model, View, Controller in an XForm

Once the session ends, any patient information that has been collected is transferred back to the EHR system and committed to the longitudinal record for the patient. The implementation of the Health Kiosk described in this paper is based on the cityEHR system [29], a model-driven EHR following the ISO 13606 standard which uses HL7 CDA to store the health record and is implemented on the same technology stack as the Health Kiosk Application Framework. Hence the CDA templates, the full patient record and the instantiated HL7 CDA documents can be transferred directly between the Health Kiosk Server and the EHR, although it would be feasible to use any EHR system which is able to import and export patient records as HL7 CDA.

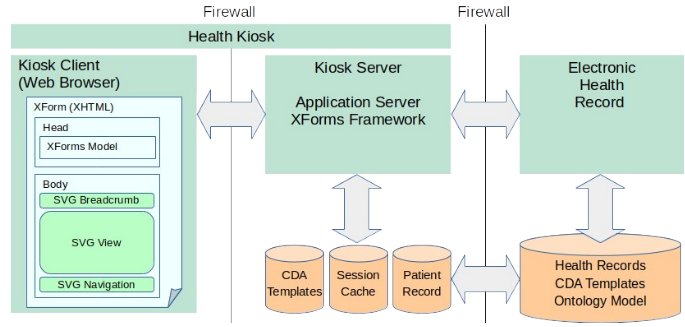

Fig 2: A Health Kiosk deployed using the Health Kiosk Application Framework.

B. XForms Controlled Care Pathway

A Health Kiosk developed using the Health Kiosk Application Framework follows a simple, linear care pathway of tasks, through which the user can navigate forward and backward. Each task is associated with an ISO 13606 Composition (in the form of an HL7 CDA document template) and a Scalable Vector Graphics (SVG) image [30], as depicted in Fig. 2.

The care pathway is specified using a simple XML document which acts as the main configuration for the Controller and is of the form shown in Fig. 3.

C. Interactive SVG User Interface

The SVG View associated with each task is made interactive through the use of a Javascript observer for the user click on any shape that is contained in an SVG <g> element, that has an id attribute. The observer sets the value of a hidden XForms input to the value of the id attribute, which then triggers an XForms action to handle the user click, as shown in Fig 4. That action parses the id as an API call, consisting of a command and a sequence of parameters, separated by underscores (_). In this way it is easy for designers to create any SVG image for use in the Kiosk System and then program its interaction by setting the shape ids. The underscore character was chosen as the separator to ensure that the id attributes are valid NCNAMES (non-colonized names) as required by the SVG standard.

The API calls represented in the SVG ids are summarized in Table 1.

```
<?xml version="1.0" encoding="UTF-8"?>
<carePathway displayName="Oculus Kiosk">
    <task id="oc-1" displayName="Home" model="patientCredentials"
         view="oculusKioskHome.svg"/>
    <task id="oc-2" displayName="Patient Information" model="patientInfo"
         view="oculusKioskInfo.svg"/>
    <task id="oc-3" displayName="Symptoms" model="patientSymptoms"
         view="oculusKioskSymptoms.svg"/>
    <task id="oc-4" displayName="Medication" model="patientMedication"
         view="oculusKioskMedication.svg"/>
    <task id="oc-5" displayName="Therapy" model="patientTherapy"
         view="oculusKioskTherapy.svg"/>
    <task id="oc-6" displayName="Other Information" model="patientOtherInfo"
         view="oculusKioskOtherInfo.svg"/>
    <task id="oc-7" displayName="Advice and Next Steps" model="patientAdvice"
         view="oculusKioskAdvice.svg"/>
</carePathway>
```

Fig 3: XML Representation of the care pathway.

TABLE I. API FOR SVG ID ATTRIBUTES

API Call	Description
authenticate	Authenticates the patient (user) using credentials entered on the kiosk home page.
commit_compositionId	Commits the composition specified in the compositionId and moves the care pathway to the next task.
quit	Ends the kiosk session and returns to the home page. Any compositions that have been committed by the user are imported to the EHR.
previous	Moves the care pathway to the previous task.
next	Moves the care pathway to the next task.
set_entryId_elementId	Sets the Data value of the Element (with elementId) in the Entry (with entryId) in the current Composition. The way in which this is done depends on the data type specified for the Element in the clinical information model. • Boolean - value is toggled true/false • Enumerated Value - set to the next value in the set of possible values • String, Integer or Double - display a keypad for user inputDate - display a calendar for user input
set_entryId_elementId_value	Sets the Data value of the Element (elementId) in the Entry (entryId) in the current Composition to the specified value.

The interactive SVG View is supplemented by an SVG Breadcrumb component displayed above it and an SVG Navigation component displayed below it. The Breadcrumb displays the current task and a history of the care pathway; the Navigation has buttons for moving to the next task in the pathway or back to the previous task.

In addition, further interactive SVG components are contained within <div> elements which are generally hidden but are displayed for modal user interaction (interaction with the SVG View and SVG Navigation then being disabled when such a <div> element is shown).

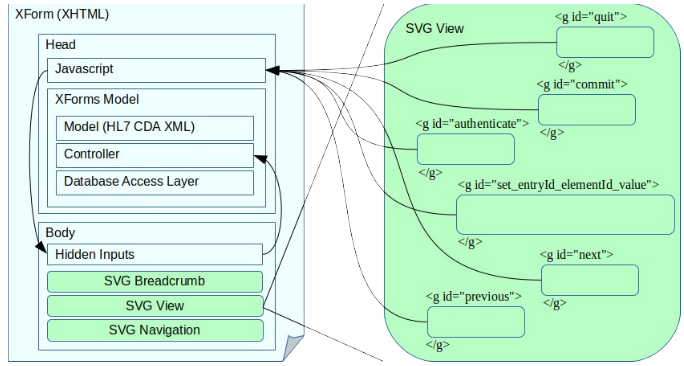

Fig 4: XForm with embedded SVG image containing API calls.

The images used for modal interaction are:

- a keyboard with SVG shapes for each key and a buffer display, updated as each key is pressed
- a calendar date picker
- a confirmation dialogue
- additional images that can be used to select enumerated values for an Element

III. RESULTS

A. *Oculus Kiosk Storyboard*

The Health Kiosk Application Framework has been used to implement the Oculus Kiosk, a system for triage of patients in an Ophthalmology clinic. This implementation required development of the following configuration resources:

1. The care pathway
2. An ISO 13606 information model with the necessary Compositions, Entries and Elements
3. A set of SVG images with embedded API calls

The first step was to create a hand-drawn storyboard which defined the care pathway and a sketch of each associated screen view. The storyboard was then used to create the XML configuration of the pathway, to inform the development of the clinical information model and as the specification of the SVG images.

B. *Ontology-Based Information Model*

A clinical information model was developed for the Oculus Kiosk, using the modeling toolkit of cityEHR [29]. The ISO 13606 compatible model follows the prescribed structure of Composition, Section, Entry, Cluster, Element and Data, where the Data value of an Entry/Element pair can be set through the interactive SVG View in the kiosk.

Using the toolkit, the model was created as a spreadsheet in LibreOffice, transformed to an ontology model represented in the Web Ontology Language (OWL) [31] and then further transformed to create a set of HL7 CDA document templates. Since all three representations of the model are XML, the transformations can be achieved using an XSLT [32] processing pipeline in cityEHR, as shown in Fig 5.

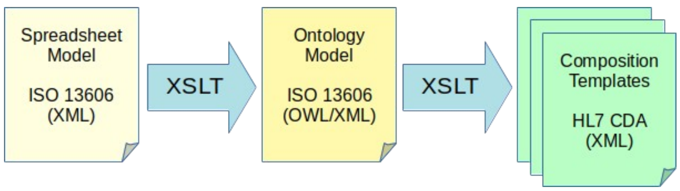

Fig 5: ISO 13606 Ontology model and HL7 CDA templates generated from a spreadsheet.

C. SVG Implementation

Two SVG implementations were made, using the same care pathway and set of HL7 CDA templates. The first used the hand-drawn images from the storyboard, set as base64 encoded image for each screen overlaid with transparent SVG shapes (hotspots) containing the API calls in their id attributes. The style of this user interface is shown in Fig 6.

The second implementation used full SVG images for each screen, redrawn from the storyboard. An example of the resulting screens is shown in Fig 7.

The 'naïve' nature of the hand-drawn interface can seem more appealing than the more 'corporate' feel of the full SVG interface. This may be espcially true for certain categories of patient with lower levels of health literacy, but only a full evaluation with a representative sample of patients will confirm this. One disadvantage of the hand-drawn interface is that any changes made, for example in response to routine testing or to patient (user) feedback, may require the whole image to be redrawn and the invisible SVG hotspots to be repositioned. This can be mitigated by hand drawing on a graphics tablet, so that the the image is created and can be edited digitally, rather than being scanned from a paper drawing.

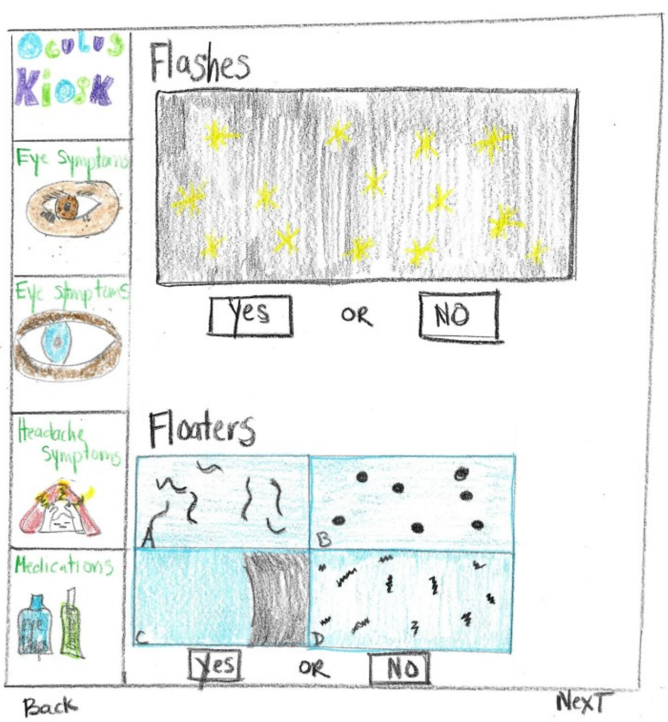

Fig 6: Interactive SVG interface using hand-drawn image.

Another potential weakness of the hand-drawn interface is that it can be more difficult to follow generally accepted user interface design standards or principles.

Based on the initial design sketches that visualized the user flows and necessary UI components for the Oculus Kiosk, a high-fidelity prototype was designed using a collaborative user interface design tool. Improvements made in this design iteration included solidifying a user flow, creating the information architecture of the application, modernizing the UI to comply with web UI standards and practices, and the addition of features that encourage HIPAA compliance. This process was done through user interviews with medical office assistants at ophthalmology clinics and a competitive analysis of how other patient intake forms are structured.

Usability testing was then conducted to optimize aspects such as the user flow, icon design, UI component size, and other accessibility considerations to optimize the user experience. A variety of usability test participants were recruited with adiverse range of visual impairment. Furthermore, vision simulator plugins were used to test how accessible the Oculus Kiosk designs were at first hand.

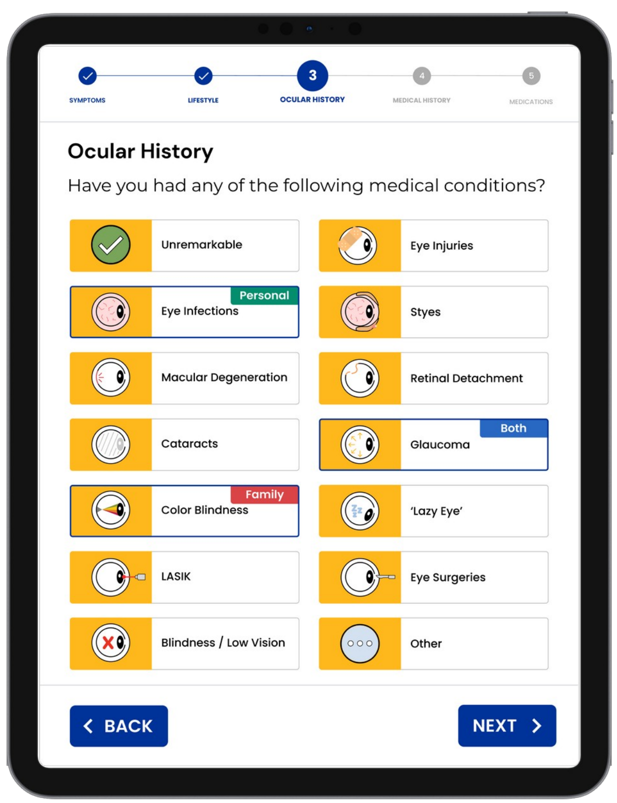

Fig 7: Interactive SVG interface using full SVG image.

IV. Conclusions

Kiosk systems are a valuable asset in the drive to provide patients with access to their own health records, and may help to address some of the issues with low levels of health literacy.

The Health Kiosk Application Framework described in this paper provides an effective way to implement kiosk systems for patients, in which the underlying health record is held as a set of HL7 CDA documents. The framework combines the flexibilty and graphical appeal of the interactive SVG interface, with the touch screen kiosk deployment, and the rigour of a fully structured and clinically coded health record.

Development of the Oculus Kiosk system has validated the design approach, at least to the extent that it demonstrates its technical feasibility. The system, with its two styles of user interface, will provide a solid foundation for further work, starting with an evaluation of the system with patients in a live clinical setting. It is anticipated that this evaluation will result in enhancements to both the Oculus Kiosk itself and to the Health Kiosk Application Framework.

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