A Model Based Approach to Web Application Design for Older Adults Using MVC Design Pattern

Christopher Romanyk, Ryan McCallum, and Pejman Salehi(✉)

School of Applied Computing, Sheridan Institute of Technology and Advanced Learning, Oakville, Canada
{christopher.romanyk, ryan.mccallum, pejman.salehi}@sheridancollege.ca

Abstract. Recent studies show sixty percent of older adults access the internet at least once a week. However, poor website usability and design have been identified as two key factors which negatively impact internet usage among this demographic. Often the specific needs of this user group are not addressed properly by modern web application design, and this can hinder the usability and user experience of these applications and sites for older adults. To solve this issue, we have developed a universal design approach by introducing software-modeling constraints for the MVC design pattern to better address the needs of older adult users on the web.

Keywords: Model-based software development · Aging · HCI · OCL · Model view controller design pattern · Modern web application design

1 Introduction

The Model View Controller design pattern (MVC) is one of the most employed software design patterns currently in use [1]. It is versatile in nature, and benefits from significant horizontal implementation over multiple software systems. The pattern's popularity entails that software users of all ages and backgrounds are frequently exposed to applications based on MVC. This prevalence creates a unique opportunity to develop, design and manage standards that can impact a large web based audience.

In an MVC application the view (V) is what the user directly sees on the screen in front of them. It is the collection of components which represent the user interface elements such as text fields, buttons and images. The model on the other hand, represents the underlying, logical structure of data in a software application and the structure of the information needs to be presented to the user through view (V). In other words, the view is the reflection of the information stored in model elements.

The controller (C) manages the interaction between the model (M) and the View (V). For instance, in an online banking statement application, the controller asks the underlying subsystems to retrieve the necessary information for particular statement and populates the appropriate model (M) elements. Thereafter, the controller sends the model elements to the proper view (V) in order to represent the information to the user. Figure 1 shows the general components of the MVC design pattern.

F.F.-H. Nah and C.-H. Tan (Eds.): HCIBGO 2016, Part II, LNCS 9752, pp. 348–357, 2016.
DOI: 10.1007/978-3-319-39399-5_33

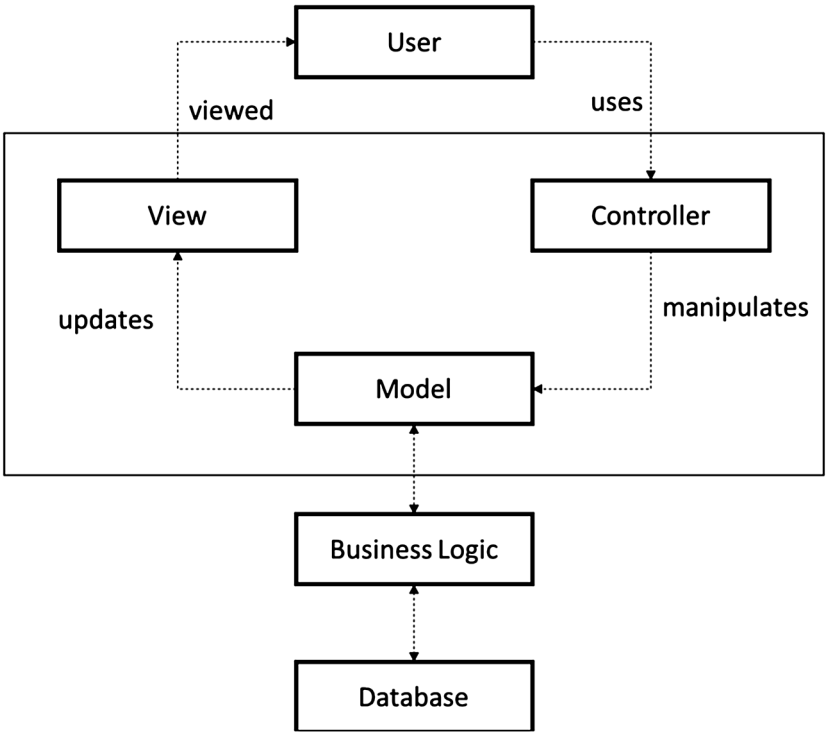

Fig. 1. The elements of MVC design pattern

As people age, various impairments begin to affect older adults more frequently [2]. Many of these impairments relate to HCI, with web usage for older adults being traditionally addressed through interface design. In order to address these difficulties, developers focus most of their efforts on the user interface's design, which is captured by the view (V) in MVC design pattern, and not on the model (M), which encapsulates the information to be represented to the user. To address these problems properly in MVC, the model (M) must also be designed appropriately, as MVC models (M) and views/interfaces (V) are directly related. Usability issues for older adults in MVC occur when a view/interface (V) is visually appropriate for older adults, but the logical processes in the model (M) have not been designed to meet the needs of these users. Logical design and processes in web applications can exercise a significantly positive effect on the usability of software for older adults.

To this end, we have developed a set of model-level constraints for the logical design component of MVC applications to increase usability among older adults. Before designing our constraints, we investigated specific web application and data elements that historically have caused poor usability for older adults, identifying several age-related impairments and areas of functional decline that affect the usability of the documented application elements. We observed that declining functionality in the following areas affects application components relating to the model (M) in MVC:

- Cognitive functionality
- Perceptual functionality
- Motor functionality

We approached the technical design of our constraints utilizing Unified Modeling Language (UML) [3], which is the de facto standard modeling language among software developers, and we developed our constraints using Object Constraint Language (OCL) [4]. OCL is a declarative language for describing rules that apply to UML models and can be implemented and validated through standard modeling tools. In order to evaluate the effectiveness of our approach, we have encapsulated our methodology in a case study, where we present our approach and explore how to best implement the proposed study.

Additionally, we created a UML modelling framework to aid in the design of MVC models(M) utilizing our proposed constraints. This modelling framework can later be expanded upon to enforce any additional constraints that are added.

This paper is organized as follows. Section 2 introduces a set of MVC model(M) constraints that we have developed to increase the usability of software applications by older adults. Section 3 describes the proposed modelling framework that has been designed to help enforce the constraints described in Sect. 2. Section 4 outlines the proposed case study that we have designed to test our proposed constraints, determining the impact they have on software usability for older adults, and the developmental impact on the part of application designers. Finally, Sect. 5 presents our conclusions and how we plan to follow through with our research.

2 Proposed Constraints

Limited Simultaneous Content: We propose a constraint that states the number of properties viewed by users should be limited to no more than five properties per model.

Several studies have explored how older adults process multiple pieces of information and have noted how this behavior differs from their younger counterparts. Results show that older adults incur cognitive decline relating to their attention and the processing of multiples pieces of information. Furthermore, this decline is more prominent when task switching occurs [2]. While there are various opinions as to why older adults may struggle with selective and divided attention, generally older adults are slower at processing information than their younger counterparts [5]. Recognizing that older adults show decreased performance when processing multiple pieces of information and acknowledging how their decreased processing speed relates to difficulties with selective and divided attention, we have decided to address these issues by ensuring that information viewed by users does not require the users to split their attention or process varied amounts of information simultaneously.

Limit the Number of Audiovisual Media Elements to Two: We propose a constraint limiting non text-based properties to two or less. Many older adult web application users are dealing with some form of perceptual difficulty relating to hearing and or visual impairments [6]. Current data suggests that over 40 percent of all older adults are

dealing with some form of hearing impairment or hearing loss [7]. Links between ageing and the prevalent loss of visual acuity are also well documented in older adults [8]. Noting that a large percentage of older adults may have difficulty interacting with web applications that heavily feature audio and or image-based elements, we have designed a constraint that helps increase usability by maintaining that a large percentage of the information provided to users be of a textual nature.

Limited User Input Field Length to Two Hundred and Fifty Characters: We propose a constraint that suggests input fields for users should be limited to less than 250 characters. There is established research that shows a direct tradeoff between speed and accuracy when relating to older adult users and movement. Current literature shows that older adult users tend to have slower reaction and movement times compared to younger users [9]. Keeping in mind the fact the older adults often will attempt to increase their movement accuracy by performing actions more slowly, it is sensible to limit the amount of movement-based activities required by the user. Limiting activities that may require movement, such as typing, ensures that the web application's ease of use will remain high and expedient. As such, we propose that limiting the length of fields relating to user input will help amend these issues and maintain high levels of usability.

Two Types of Password Fields: We propose a constraint that suggests password credential field types be limited to text or image blurb types.

The current de facto standard for web application credentials and password management is a typed password often containing a combinations of mixed case letters, characters, numbers and symbols; often referenced as alphanumeric. Recent studies into the effective password and credential management of older adults have suggested that a viable alternative to the traditional password is the visual password, as older adult users can recognize images with an accuracy rating of nearly 99 percent [10]. Additionally, current research data relating to security suggests that visual passwords are far more secure than traditional alphanumeric passwords. A recent survey suggests that when logically implemented in a manner that is appropriate for older adults without visual perceptual issues, visual passwords are a welcome alternative to alphanumeric passwords, both as a means of ease of use and security. We have designed a constraint that guides and allows for the use of visual passwords in web applications.

Four-Character Length Minimum on User Passwords: We propose that password field length be a minimum of four characters for text password fields.

Significant amounts of literature suggest cognitive issues relating to working memory are prevalent with older adult users [2]. While remembering a password may appear to be a matter of recall or short term memory, password creation can be a function of working memory. Several elements relating to online credential management can include having to generate unique password combinations of varying complexity. When the user is forced to start manipulating alphanumeric characters on mass while creating passwords, the nature of the process changes from simple recall of common words or historical passwords to a working memory process in which unique passwords are created. A recent study examining credentials of application users stated that older adult's users showed a tendency to use shorter passwords than their younger

counterparts [11]. While the study was inconclusive as to why older adult users generally utilized shorter passwords than their younger counterpart, the study hypothesized a potential link between the state of working memory for older adults and preferred password length. Understanding that certain elements of credential management can theoretically engage working memory helps to bolster the notion that length of passwords used by older adults could be related to declines in working memory. As such we have chosen to allow a shorter minimum length password for older adult users in line with the presented research.

3 Modeling Framework

In order to provide software designers with an effective tool to enforce the constraints and the guidelines specified in Sect. 2, we have developed a small modeling framework as an extension to the Unified Modeling Language (UML) through its profiling mechanism. More particularly, we identified different elements necessary to design the Model (M) layer of MVC for older adults and introduced the necessary stereotypes as new modeling elements for this purpose. Finally, we specified the constraints using Object Constraint Language (OCL), the standard language to capture constraints for UML models.

The final profile, called Older Adult Model Design Profile (OAMDP), is implemented using IBM Rational Software Architect (RSA) [12]. Figure 2 presents the implementation the profile class diagram. The OA_Model represents the model element of MVC, which is tailored for older adult users. This element is designed as an extension to the <<metaclass>> Class from UML metamodel. OA_UserInput and OA_Output are the stereotypes designed to represent the attributes of the OA_Model element as an extension to the <<metaclass>> property. OA_UserInput is further expanded into OA_TextInput and OA_NonTextInput to represent text-based and non-text-based input attributes respectively. Text password and non-text password are also specified to better capture different types of passwords.

After specifying the stereotypes in our profile, we defined the constraints using the OCL language which will be presented in the remainder of this Section.

Limited Simultaneous Content.

```
context OA_Model
inv:
self.getAllAttributes()->size() <= 5
```

Limit the Number of Media Elements to Two.

```
context OA_Model
inv:
self.getAllAttributes()
->select(p:Property | p.oclIsTypeOf
(OA_NonTextInput))->size() <=2
```

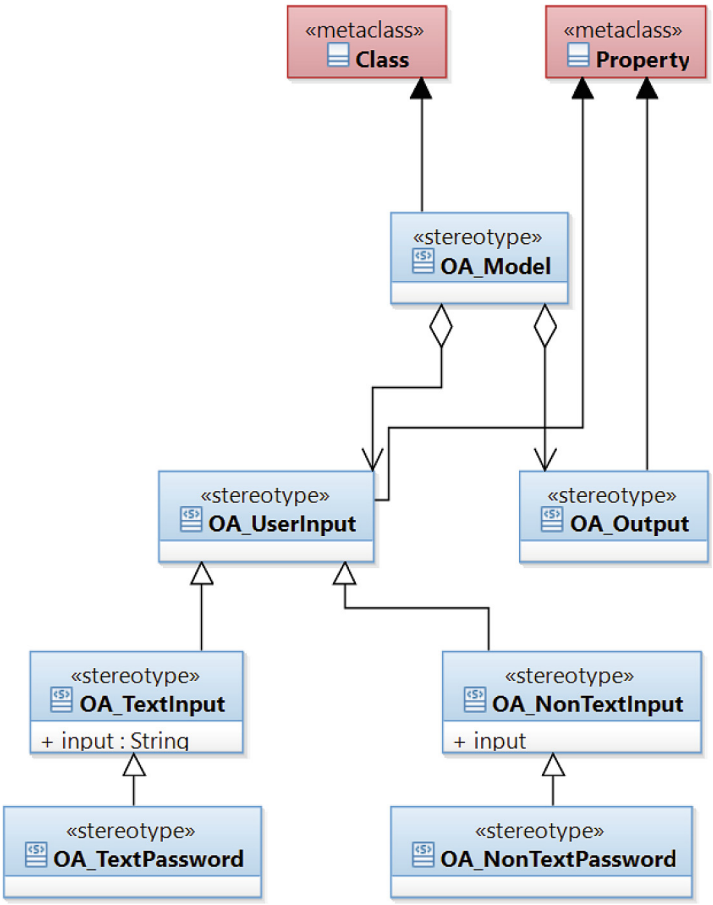

Fig. 2. Older adult model design profile class diagram

Limit User Input Field Length to Two Hundred and Fifty Characters.

```
context OA_TextInput
inv:
self.input.size()<250
```

Two Types of Password Fields.

```
context OA_NonTextPassword
inv:
self.input.oclIsTypeOf('Image')
```

Four-Character Length Minimum on User Passwords.

```
context OA_TextPassword
inv:
self.input.size()<5
```

It is worth noting that the careful design and specification of the stereotypes decreases the complexity of the OCL constraints. For instance, due to the fact that we specified two different stereotypes for text-based passwords and non-text-based passwords, the forth constraint only focuses on the non-text-based passwords. This will improve the quality of the profile and will enhance the performance of the tool during the validation of the models which are designed based on this profile.

4 Proposed Case Study

Purpose of Study: Our proposed case study will attempt to determine how our newly proposed modelling framework will affect the usability of web applications utilizing the MVC design pattern for older adult users. This proposed case study will act as a blueprint for those looking to test our recommended guidelines, giving a general outline of the processes required to determine the viability of these guidelines. The case study will explore how applying our proposed model constraints affect the usability of web applications when compared to applications built to the current best standards, as defined by the w3 accessibility standards [13], as well as those built without any formal standards. In addition, the case study will also explore how the proposed constraints affect the development process for application designers building the application.

Case Study Overview: Using a set of three sample groups, the study tests usability of applications using differing MVC model (M) constraints, as well as how these constraints affect an application designer's development process and ability to meet the needs of older adult users with differing MVC model (M) constraints. Each group will be comprised of multiple older adult users and will have a dedicated application designer, with each application designer being designated a set of MVC model (M) constraints with which to develop their applications. The applications will then be administered to the respective group and the results would be collected.

Application Designer: Three application designers will each be requested to develp a separate application for a specific group. Each application designer will be explicitly informed of their target demographic and will be provided with either our model constraints, current best practices, or no supplementary information.

The first application designer will be given no constraints, and will be requested to develop an application to the best of his/her ability. This application will be referred to as the baseline application and will act as the baseline to which the other applications will be compared.

The second application designer will be given a set of constraints based on the w3 accessibility standards. This application will be referred to as the standard application. The third application designer will be given a hybrid set of constraints. These constraints will be based on the w3 accessibility standards, but will also leverage our proposed constraints. This application will be referred to as the hybrid application.

Application Requirements: To ensure consistent results, it is imperative to give each application designer a set of development requirements that are within the same functional domain. This means that each application must have similar functionality,

and cannot deviate in terms of its in intended use. It is suggested that these requirements include a technological stack.

Groups: The groups will be separated based on the MVC model (M) definitions of their application. Of the three groups, there will be a single control group, and two test groups. The control group would be given the control application and would act as the baseline, while the second and third groups will be given the standard application and the hybrid application, respectively.

Evaluation of Results: The case study sets out to evaluate the impact that our proposed constraints have on the usability of applications for older adults, as well as the developmental process for application designers.

To evaluate the effectiveness of the applications, it is suggested that the common functionalities of the applications be compiled and then delineated based on whether they were affected by the MVC model (M) constraints. A series of tasks would then be extracted from those functionalities that were affected. These tasks would then be given to the user groups as an evaluation for each group's respective application. The results of these tasks would be evaluated using the following criteria: (1) whether the task was successfully completed, (2) how intuitive the user found the process of interacting with the software, (3) whether there were any notable issues with the application that violated current best practices relating to ageing and HCI.

To determine the developmental impact on the application designers, the development time difference $(d_1 = s - b)$ between the baseline application (b) and the standard application (s), and the difference $(d_2 = h - b)$ between the baseline application (b) and hybrid application (h) will be compared. Positive numbers indicate that the baseline was completed more quickly than the compliment, where negative numbers indicate the opposite. The difference in time $(t = d_2 - d_1)$ relative to the baseline will also be evaluated, with a positive result indicating that it took less time to complete the standard application, and a negative result would indicate that the hybrid application took less time to complete. Additional qualitative results will be gathered and analyzed relating to the process's difficulty, as experienced by the application developers.

While looking at creating a set of model constraints to help improve application usability for older adults, we chose to focus on the MVC model (M) due to the direct relation between the model (M) and view (V). In this relationship, the view (V) displays information to the user while the model (M) encapsulates the information that is displayed; the MVC model (M) represents the data's structure and the view (V) displays this structured data.

5 Conclusions and Future Works

Our research led us to find a number of areas in which the MVC model (M) design had a negative impact on application usability by users. Taking these areas into consideration, we designed a number of MVC model (M) constraints. These constraints included limiting simultaneous content such that MVC models (M) would have five or fewer properties, limiting the number of simultaneously-displayed media elements to

two or fewer, limiting the length of input fields to two hundred and fifty characters or fewer, using either text-based or image blurb types as a form of password, and implementing a minimum length of text-passwords to four characters.

While the above constraints are a viable starting point in helping address the needs of older adult users using MVC applications, there were additional outcomes from designing our model constraints. We discovered that well-designed OCL model constraints not only affect the usability of web applications, but also serve as an effective method of communicating HCI best practices to software professionals. While our initial five constraints show that certain issues relating to ageing and HCI can be addressed at the model level, they also show the effectiveness of communicating these issues through OCL model constraints.

Additionally, we will by looking at a methodology of enabling the refactoring of existing models. This would allow user to automatically modify existing models to make them consistent with our constraints and modelling framework.

Finally, our proposed case study serves as a test framework for those who wish to attempt to verify the utility of our constraints. The study provides an outline of steps that can be followed to test the value of our proposed constraints, and how to determine their impact on the application design process.

References

1. Tichy, F.: A catalogue of general-purpose software design patterns. In: Proceedings of the Technology of Object-Oriented Languages and Systems, 1997, TOOLS 23 (1997)
2. Glisky, E.L.: Changes in cognitive function in human aging. In: Riddle, D.R. (ed.) Brain Aging: Models, Methods, and Mechanisms. CRC Press/Taylor & Francis, Boca Raton (2007)
3. Object Management Group, Unified Modeling Language (UML) superstructure, version 2.4.1, formal/2011-08-06. http://www.omg.org/spec/UML/2.4.1/Superstructure2012
4. Object Management Group, Object constraint language, version 2.2. http://omg.org/spec/OCL/2.4/PDF/
5. Kerchner, G.A., Racine, C.A., Hale, S., Wilheim, R., Laluz, V., Miller, B.L., Kramer, J.H.: Cognitive processing speed in older adults: relationship with white matter integrity (2012)
6. Vicki, L.H.: Age and web access: the next generation. In: W4A 2009 Proceedings of the 2009 International Cross-Disciplinary Conference on Web Accessibility (W4A), pp. 7–15 (2009)
7. Cruickshanks, C.J., Wiley, T.L., Tweed, T.S., Klein, B.E.K., Klein, R., Mares-Perfman, J. A., Nondahl, D.M.: Prevalence of hearing loss in older adults in Beaver Dam Wisconsin. Am. J. Epidemiol. **149**(9), 879–886 (1988)
8. West, S.K., Munoz, B., Rubin, G.S., Schein, O.D., Bandeen-Roche, K., Zeger, S., German, S., Fried, L.P.: Function and visual impairment in a population-based study of older adults. The SEE Project. Salisbury Eye Evaluation (1997)
9. Ketchman, C.J., Stelmach, G.E.: Movement control in the older adult. In: Pew, R.W., Van Hemel, S.B. (eds.) National Research Council Steering Committee for the Workshop on Technology for Adaptive Ageing (2004)

10. Nelson, D., Vu, K.L.: Effectiveness of image-based mnemonic techniques for enhancing the memorability and security of user-generated password. Comput. Hum. Behav. **26**, 705–715 (2010)
11. Pilar, D.R., Jaeger, A., Gomes, C.A., Stein, L.M.: Passwords usage and human memory limitations: a survey across age and educational backgrounds (2012)
12. Rational Software Architect, IBM Rational Software (2016). www-03.ibm.com/software/products/en/ratisoftarchfami
13. W3 Accessibility. https://www.w3.org/standards/webdesign/accessibility