AN OVERVIEW OF THE HISTORY IF GRAPHICAL USER INTERFACES AND
CONSIDERATIONS FOR IMPLEMENTATION IN THE CONSTRUCTION INDUSTRY TO
IMPROVE USER EXPERIENCE

By
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Introduction

Building a custom home is a complicated process. Between home owners, builders, architects, landscapers, engineers, interior designers, and dozens of subcontractors there are multiple parties involved in the process. In planning for and facilitating the sharing of information during the process multiple schedules, change orders, mistakes, and delays must be considered. While the use of technology is on the rise in the construction industry there is opportunity for growth in the custom home building niche.

Thesis

This paper involves the research into the considerations for design when developing an application for the custom home building process. This was accomplished through research of the history of graphical user interfaces, UX best practices, UI basic principles, along with the current construction industry to understand how new technologies may be developed to bridge the communication gap between home owners and custom home builders. The final results include a list of suggested principles for consideration.

Methodology

Descriptive research was conducted to gather information pertaining to the history of UX, current UX/UI standards, the home building process, and the construction industry. Various scholarly, professional, and individual sources were used to obtain information relevant to effective interface design and the custom homebuilding process. Sources consist of published works on user interface design, branding in the construction industry and the custom homebuilding process. Additionally, lectures and articles regarding best user experience and interface design practices were reviewed along with documented accounts of users in academic journals. Proper application of these concepts asserted through descriptive research produce principles for designing within the custom home building niche.

LITERATURE REVIEW

History of the Graphical User Interface by Frank McCown provided a detailed history of the evolution of interface technologies and designs from batch processing system in the 1950s to the introduction of touchscreen UI systems in 2012. Dr. Frank McCown is an associate professor in the Computer science department of Harding University and previously worked at Lockheed Martin as a software engineer.

Mobile First by Luke Wroblewski discussed how to create user interfaces that are adaptable and effective across various platforms. His focus on responsiveness and scalability are backed by a review of various technological platforms most tin use today. Wroblewski is a Product Director at Google and has authored three books concerning user friendly interfaces.

About Face by Alan Cooper, Robert Reimann, David Cronin, and Christoper Noessel details the processes by which digital systems effectively communicate with users and how the interactivity between humans and computers creates opportunity for helpful interfaces. Alan Cooper is considered the "Father of Visual Basic" and is a software design industry leader. Reimann is the founder of the Interaction Design Association and has served on the AIGA Experience Design advisory board. Cronin is the Director of Interaction design at Cooper and previously held the same title at GE. Noessel is a well respected UX designer who has developed systems and strategies for multiple products, services and consumer domains.

Digital Art: a Brief History of the Graphical User Interface in Contemporary Art Practice 1994-2004 by Ian Gwilt provides insight into the symbolic interpretation of information and the importance of utilizing visual metaphors. His survey of interface design history clarifies the development and purpose of various interface design elements and tools. Gwilt is a professor of design at University of South Australia and teaches courses regarding design research, information design and data design.

History-Based Device Graphical User-Interfaces by Omojokun & Prasun Dewan explore the fundamentals of interface design, clarifying the necessary commands and easy on boarding of users. Omojokun is a Senior Lecturer at Georgia Tech's College of Computing and is trained in computer science. Prasun Dewan is a professor of Computer Science at University of North Carolina Chapel Hill, his research focuses on user-interface toolkits and operating system design.

A Short History of Computer User Interface Design by Usabilla clarified the history of user commands and their importance in UI. Usabilla is SaaS company that has developed research and user driven digital systems for The Economist, Lufthansa, and Philips.

The Essential Guide to User Interface Design by Wilbert Galtz provided a clear definition of UI and explores how to understand users and defines principles for designing effective systems integrate into users' lives seamlessly. Galtz has authored several books concerning user interface design principles and effective graphical user interfaces.

Human Centered Design by Scott Klemmer provided an in-depth look at the user testing process and the best practices for utilizing UX principles in the initial phases of system designs. Klemmer is a professor of Cognitive Science and Computer Science and Engineering at UC San Diego and founded MOOC a program that specializes in interaction design education.

The Design of Everyday Things by Don Norman clarifies UI and UX best practices including the importance of visibility, feedback, memory aids, understanding action cycles, and the power of user memory. Norman is the Director of the Design Lab at

UCSD, he is recognized as the author of 16 foundational UX books and their impact on design, usability engineering, and cognitive science.

The *Human Interface Guidelines* published by Apple are the leading industry standards for UI design on iOS platforms. The principles laid out are necessary to follow for the design and development of applications compatible with Apple.

Comparative Study of Information Technology Use By Architects, Engineers and Contractors by Pramen P Shrestha et al. surveyed construction professionals to determine how technology is utilized in the industry. The study explores the training, implementation, and usage practices of real professionals.

Event Perception in Mobil Interaction: Toward Better Navigation History Design On Mobile Devices by Yanging Cui et al. is a professional study concerning UI and psychological principles in relation to user navigation in applications. Cui, Oulasvirta, and Ma are prominent researchers at the Helsinki Institute for Information Technology.

Software Advice's overview of construction softwares provided a comprehensive list of current softwares within various niches of the construction industry. Software Advice provides software recommendations and guides that have been featured in the New York Times, Wall Street Journal, Fortune, and Tech Crunch.

Augmented Reality in Construction: 6 Applications in 2019 by Lior Zitzman presented an overview of the upcoming technologies within the current construction industry. Zitzman is the Director of Digital Audience Development with fifteen years of experience in digital media.

History-Based Device Graphical User-Interfaces by Olufisaya Omojokun & Prasun Dewan explore the fundamentals of interface design, clarifying the necessary commands and easy on boarding of users. Omojokun is a Senior Lecturer at Georgia Tech's College of Computing and is trained in computer science. Prasun Dewan is a professor of Computer Science at University of North Carolina Chapel Hill, his research focuses on user-interface toolkits and operating system design.

Capterra's review of Jet Stream provided a collection of product reviews that analyze the performance of the JetStream application. Capterra is a resource that has been featured by Business Week, Forbes, and the Wall Street Journal.

What You Need to Know Before Building a Custom Home by Steve Wylder and Hans Wylder provided insight into the primary pinpoints experienced by homeowners in the build process and explores the digital interfaces utilized by many homebuilding companies. The Wylder brothers are Associate Brokers at Wylder Brothers Real Estate Company and have sold more than $400 million in residential properties.

OBSERVATIONS

fieldwire.com is the landing page for a leading construction industry application. The app is one of the most used construction coordination app and provides useful insight into the collaboration and efficient performance standards of construction management systems.

plangrid.com is the most used application to facilitate project management between home owners and GCs on the market today. A review of the website clarified important and necessary functions for clear communication as well as clearly identifying target users.

procore.com is the landing page for an all inclusive construction team data sharing application. The website provided valuable understanding of the basic functions utilized for project management that is visual in tune with current CAD capabilities and Apple UI standards.

Research Results

A BRIEF HISTORY OF GRAPHICAL USER INTERFACES

Before exploring the history of graphical user interfaces it is important to make the distinction between user interfaces and human computer interaction. According to Anker Jorgensen and Brad Myers, two specialists in the field of human computer interaction, user interfaces are "tangible artifacts" (2416). These artifacts can be seen in use everyday, where as human computer interaction is an academic field of study. Research was conducted into the history of graphical user interfaces that lead to the user interfaces of today.

The first roots of the modern graphical user interface lie in the 1950s with batch processing systems (McCown 2). In the 60s command-line interfaces more heavily emphasized the role of users forcing them to memorize specific functions (3). Command lines required users to input memorized commands with specific and precise syntax (Klemmer). This style of computing did not easily provide feedback or confirmation to users. Today, command line computing is seen in programming and is effective because the abstraction offers programmers the power to create without the hindrances of existing frameworks. While command line computing is effective for some, there was a clear need for a more generally understood form of computing. Thus the graphic user interface (GUI) was conceived.

GUIs are systems in which users directly manipulate an interface (Klemmer). GUIs harness the power of direct manipulation and in so doing provide for a better user experience for most users than command line computing. Klemmer identified several primary advantages of GUIs: continuous representation of information, immediate feedback, and the utilization of metaphors. Through visible cues and perceivable results the input and output of GUIs are easily understood. These systems provide users with feedback, visibility, consistency, and better dispel fears of destruction in the minds of users than command line computing. This shift towards GUIs began in the 1960s when Doug Engelbart showcased a prototype system featuring point and click

technology (3). The system he demonstrated through video is the first visually similar system to current interface technologies.

A new era began when Xerox, the technology giant of the 1970s released WIMP practices (windows, icons, menus, and pointers) (McCown 6). While the results of Xerox's innovations can be seen in modern interfaces it was not until Steve Jobs revealed the Apple Macintosh in 1984 that GUIs became accessible to the masses. The late 1980s were filled with various lawsuits between Microsoft, Xerox, and Apple and relatively minor technological innovations (12). It was not until the early 90s that the GUI began to rapidly change with the introduction of multimedia options, fonts, standard dialogue boxes, drop down lists, and other standard HTML forms. 2001 brought about a GUI redesign from Apple featuring a dock and minimization features. Then Jesse James Garrett coined the Ajaz Method in 2005 and the transition from desktop applications to web based applications began. Then in 2007 the first iPhone launched officially beginning the age of touch screen interfaces (Usabilla 1).

The launch of the iPhone and the rise of smartphones challenged the foundations of UI, removing all unnecessary elements (Usabilla 1). Additionally, the smartphone market began the "App Revolution." In 2003 iconography emerged as a symbolic system of communication (Gwilt 4). While iconography assisted users by providing visual metaphors by which to understand digital systems. This is not surprising considering that during the Industrial Revolution, technologies began to be explained with the language of existing technologies (Cooper 35). This phenomenon is perhaps explained by user's inability to see how new technologies could be utilized.

While users became increasingly familiar new technologies many of the features seen in current interfaces were not yet available. Then in 2006 Motorola began to feature SMS email, IM, camera, and music capabilities along with a full color screen and a web browser (Wroblewski 9). While the list of features was impressive for the time the functionality was weak. In 2008 the initial drafts of HTML5 suggested a stronger connection between standardized UI elements and desktop applications (McCown 26). Additionally in 2008 smartphones outsold all computers combines (including laptops, desktops, and notebooks) (Wroblewski 8). Luke Wroblewski notes that in 2007 the Apple iPhone's launch with mobile internet enabled the technological landscape of today (17). Since then the 2010's have revealed the launch of new GUIs such as tablets and the rest is recent history. The latest GUI related technologies that are sure to grow in the next few years include cove command, gesture control, neurally controlled systems, and AI (Usabilla 1).

REVIEW OF CURRENT MARKET AND TECHNOLOGIES IN THE CONSTRUCTION INDUSTRY

According to the Washington Post article *What You Need to Know Before Building a Custom Home,* custom home building is "the most misunderstood segment of house hunting" (1). Despite common confusion with track and spec building, custom home building is one of the most stable segments of the residential construction market. According to a report by the National Association of Home Builders this niche of the market experienced a drastic decrease in growth after the crash of 2008, but the numbers have since remained consistent (1). The average custom home build costs upwards of $800,000 making the target market for an application within this segment,

top earners. While the market is limited due to the high price tags on such projects, the market is steady and lucrative.

Software applications within the construction industry, according to Yan Ping Feng, are primarily utilized in three ways: internal office project management, CAD renderings of architectural designs, and communication (1). Feng noted that the integration of software systems into the construction industry in the last twenty years has been a slow process primarily due to skepticism that digital systems can offer significant "productivity and economic returns." A recent study conducted by Shrestha, et al. revealed significant insights into the utilization of computer software within the construction industry (387). The study concluded that the construction industry is growing increasingly dependent upon technology (388). Research results indicated that contractors primarily utilize computers to accomplish the following tasks: scheduling and estimating.

Along with standard office tasks, artificial reality is making headway in the construction industry. Webster et al. observed that the construction industry experienced an initial shift towards the acceptance of virtual reality technologies in the late 1990s (1). Architects began to utilize VR systems in tandem with the physical world to better understand the layout of floor plans and understand the impact of proposed construction within existing cityscapes. Webster et al. argue that VR and AR provide insight into viability and maintenance, ultimately reducing costs (2).

While softwares and artificial / virtual realities have become increasingly integrated into the industry, the smallest area of software integration within construction is related to communication. Feng observes that updated, strong communication networks for data sharing are not currently in place at large (Feng). This lack of communication support can be seen clearly in the custom homebuilding segment of the residential construction market.

Today there are approximately 2 million applications available for download on the Apple Store (Statista 1). Of those, there are roughly 290 publicly available applications that directly relate to the construction industry as a whole (Software Advice 1). Approximately 120 apps are relevant to custom residential builds, and of those applications only one directly involves homeowners as an integral part of the building process. Feng notes that the fastest growing segment of the technology market as it relates to construction is "internal or external communication networks for sharing information" (2). The single app available for public purchase is JetStream a web-based app for small construction businesses. The UI is outdated and product reviews reveal mixed opinions regarding usability. Many users identify that the system does not work for cost plus builders (Capterra 1). Alternative leading softwares include PlanGrid, an app that connects general contractors, team members, and sub contractors. The app is primarily marketed to construction professionals within various industries such as heavy civil and health care for internal project management.

According to Willscott's review of the "Best Construction Apps for 2018" the next leading applications are ProCore and Fieldwire (1). ProCore provides connectivity and project management for construction teams on job sites. Its advantages include streamlined user flows and speed apart from an internet connection. Fieldwire is a favorite of many construction professionals but offers no HO integration. Thus it can be

observed that there is legitimate opportunity to develop digital systems within the custom homebuilding industry.

USER EXPERIENCE AND USER INTERFACE DESIGN BASIC PRINCIPLES FOR CONSIDERATION

Wilber O. Galtz defined User Interface (UI) as an area of study within human computer interaction that focuses on the relationship between humans and computers in so far as the computers serve a beneficial function. Interaction design at its core is an approach to design that focuses on supporting people in their everyday lives (Klemmer). A user centered approach is critical to the successful development of such systems. The current market clearly emphasizes the functions of the construction team with little regard to home owners as potential users.

When considering designing and developing new technologies within the construction industry, specifically the custom homebuilding niche, selecting the best vehicle is critical. Shrestha et. al, discovered that contractors primarily utilize laptops and smart phones for communication and information sharing (387). Smart phones proved particularly valuable because contractors are often on-site and require great mobility. Research results indicated that contractors primarily utilize computers to accomplish the following tasks: scheduling and estimating. However, it is important to consider that construction professionals, especially project managers split their time between an office and job sites. Consequently, successful digital tools and softwares must function without strong Wi-Fi connections. A trend towards the adoption of mobile construction applications can be seen in the success of PlanGrid and ProCore. Thus mobile applications should be considered for their mobility and ability to work without internet connection.

When designing an application for the custom homebuilding market one should also consider the advantages of instructional videos. Observations of the applications PlanGrid CoConstruct, and ProCore, indicated that video introductions to digital systems are not only necessary for advertising purposes, but also to explain basic processes and functions. According to Olufisaya Omojokun & Prasun Dewan, a short training period is often necessary for users when encountering new technologies (285). The websites for the apps mentioned above also provided instructional guidance and tutorial videos for existing users to assist in usage and troubleshooting. This standard is seemingly at odds with one of the founding tenants of user experience design that states when a design is simple enough to understand without labels or instructions it has succeeded (Norman 2). Cui et al. specifically emphasize the importance of the "apprehension principle" stating that the structure and content of a digital system should be understood upon initial a user's initial encounter (432). Given this conflict these principles must be considered carefully alongside construction industry standards. Shrestha, et al. noted the importance of employee training upon the introduction of new software or technology (387). According to their findings, contractors largely outsource employee technology training. Therefore, if a system was accompanied by training as a package, the cost for the contractors could potentially be reduced. Along with video on boarding and troubleshooting, one must consider the importance of flexibility within the field.

Flexibility is an important consideration for a communication application within the construction industry. According to Feng's observations of technology within the construction industry, one of the primary hurdles digital systems must overcome is that "each project is unique" (2). With no two projects being alike the problems requiring communication solutions vary greatly. Therefore, it is important for systems to work for various users and clientele. According to Scott Klemmer's lecture *Social Computing,* the most successful digital systems are light weight and allow for end-user innovations. An example of a successful implementation of this practice can be seen in the development of the hashtag on Twitter. Apps like Plan Grid include customizable features especially when reporting issues are concerned. It is important to create opportunities for customization when looking to create an app for custom home builders.

It is also important to establish clear hierarchy of information when planning the UI of an app for custom home project management. According to Cui et al. it is critical for successful UI to prioritize the presentation of adaptive content (432). Meaning that interfaces should alter the hierarchy of information presented to showcase the most frequently viewed information or to indicate change or creation. In application to construction the latest project updates or changes to schedules should be shown first when planning UI.

Notifications are useful in bringing attention to important, and occasionally time sensitive, information (Apple). It is important for designers to consider what information is of value and to simplify messages to short, concise sentences. The communication of critical information first is very important. Cooper goes so far as to state that the display of content is the most important component of interactive, technology products (288). Akan Cooper argues that physical constraints of systems are secondary. However these limitations cannot be written off. According to Luke Wroblewski, mobile design forces systems to simplify and refine the amount of information presented (19). The physical constraints of small screens forces intent concentration on hierarchy within design. The clarity of hierarchy highlights significant content. Content that must be generally understandable by large audiences.

The Apple Human Interface Guidelines suggest that avoiding technical language appeals to larger audiences, however when an application is targeted at a specific audience it may be appropriate. In considering a system for both homeowners and construction professionals it is important to utilize proper terminology respectively. For example while PlanGrid utilizes the menu item RFI (Request For Information) in its application for construction professionals, such a title would be inappropriate for a client facing app. Instead consider utilizing language that is informal, friendly and universal such as "tasks" or "check list." Understandability is important in both language and interface design of applications.

Success is often achieved by designs that are grounded through metaphors in a user's mind. Utilizing that which is familiar allows the user can more easily grasp new information (Klemmer). This concept of designing with user familiar metaphors and language is a basic design heuristic by which systems can be evaluated. Metaphors are especially important for new interfaces. The connections between new systems and existing, familiar systems of practices makes for an easy on boarding experience.

Apple emphasizes utilizing references to familiar experiences to expedite a user's learning curve. This is particularly important when users are physically interacting with a screen as seen in Apple's hand gesture designs such as drag and drop. Along with metaphors the use of iconography can assist users in grasping concepts.

Icons within GUIs play an important role in directing users through new systems by providing familiar visual cues. According to Don Norman the principle of visibility is key to affecting human behavior through design (5). The principle states that the parts necessary for action should be immediately visible and identifiable for their intended purpose. This is primarily accomplished through utilizing natural mapping (using physical analogies and cultural standards for immediate understanding). This is seen in iconography of construction applications like ProCore where an icon of a handshake is representative of "Commitments" or where folder icon is indicative of documents. According to the Smashing Magazine article "Designing for User Interfaces: Icons as visual Elements for Screen Design," icons were initial developed on Microsoft systems as a quick point of visual reference and have evolved into critical communication elements for mobile systems. This is primarily due to the need to communicate effectively within compact space constraints. Apple's Human Interface Guidelines lay out specific design principles regarding custom icons. It is important for icons to be representational and "highly-simplified" in their design. Apple recommends utilizing universally recognized imagery that directly represent the action to be achieved. For simplicity's sake Apple advises against utilizing text labels in tandem with an icon. Consequently, the icon must be able to stand alone. When considering the use of icons designers must ensure that they are understandable, maintaining simplicity and reinforcing the meaning of accompanying text.

Another area for consideration for new technologies within construction is the integration of augmented or virtual reality. The implementation AR and VR is growing in the industry and is seen as highly successful, providing construction professionals with "more efficiency, accuracy, and overall confidence in their projects" (Zitzman 1). According to Webster et al. the success of AR and VR within the construction industry are tied with the software's ability to relate to physical spaces(1). This connection of reality and augmented reality can be seen in systems that allow users to physically observe objects while digitally being presented with imagery of hidden, inner structural workings. AR could effectively serve as a check point for the structural integrity of buildings while also instructing builders on the proper way to assemble specific building components (4). While assisting construction professionals, Webster et al. argue that AR could "guide inexperienced users through complex construction operations" (6). It is important to communicate context especially when working within augmented reality. Apple suggests the utilization of text overlay as hints to clarify space or surface detections. This combined physical and digital on-site training could be applied to homeowners in the custom homebuilding process.

Apple's principles for engaging AR experiences emphasize user comfort and utilizing the user's physical environment. When considering the integration of AR with residential construction one principle to consider is the user's mobility within a constrained physical space. On job sites physical space can be limited so designers must take the limited mobility into account. Additionally, it is important to consider user

safety. Apple notes the importance of safe operation, discouraging "large or sudden movements." Additionally, feedback is integral to any UX design, even when working with Augmented reality. Apple encourages augmented reality systems to utilize sound or vibration notifications as means of confirmation. Adopting these UX best practices in the implementation of VR and AR capabilities could add great value to potential new applications within the construction industry.

Considerations For Future Exploration

Technological platforms are successful when people agree about processes and necessary tools. According to Scott Klemmer's lecture *Social Computing,* motivated users drive usage. Alan Cooper also emphasizes the importance of understanding a user's relationship with a product and their desires (11). When looking to design for this opening within the construction industry further research with potential users is necessary. Klemmer advises when choosing participants to focus on recruiting individuals who are representative of the target market. These participants may be current users of a competing system or they may have no experience with a similar system. Depending on the stage of research users can be approximated. Feng notes that digital systems within the construction industry must work for multiple participants (2). Klemmer notes that when designing for multiple users, as in the case of designing an application that involves both project managers and home owners it is important to collect research from both user groups.

When crafting interview questions it is best to keep the inquiries open ended. This prompts participants to provide more creative and thorough response. It is important to avoid questions that provide binary choices since reality may not be so. Silence should not be avoided as it provides participants with the chance to respond and add any information they see relevant. It is important for designers to understand that interview participants are not experts of design. Rather, they are experts of their own lives and experiences and questions should remain on that topic. Understanding user's goals is also important and the underlying motivations of actions often clarify later design decisions. A base list of interview questions for home owners and construction professionals can be found in APPENDIX A.

One possible avenue to better understand the construction process is to conduct a Diary Study. This method of research requires participants to maintain a diary throughout a specified duration with consistent intervals of data entry. These diaries focus on a specific task. For example one could ask a home owner currently undergoing a custom home building project to keep a diary record of all communications with a project manager. Klemmer advises that diary studies are most successful when the means of data entry are easy. For example, a journal, video series, or a set of voice recordings may be explored.

Additionally, user testing should be seriously considered when developing an application within the construction industry. User testing trumps personal instinct. It is not for the designer to allow users to learn through the process of trial and error (Norman 5). It is the designer's duty to utilize available data and provide copious

amounts of clues within the design so that users can immediately interpret and succeed in action.

APPENDIX A

Questions for Professionals
1. What is your profession and how does it relate to custom home builds?
2. What does a typical home build project look like?
3. Where do discrepancies often lie with homeowner expectations and the reality of homebuilding?
4. How long does a typical build last?
5. What causes delays typically?
6. How do you communicate with other professionals involved in a build?
7. How do you communicate with homeowners during a build?
8. What would it be helpful for home owners to understand about the build process?

Questions for Home Owners
1. What is your experience with custom home building?
2. When did your home building experience occur?
3. What was the scope of the project?
4. Did you work with a contractor or a design and build firm?
5. What was your relationship like with the contractor?
6. What was the original project deadline?
7. When did the project finish?
8. If there were delays what do you think caused them?
9. How did your relationship with the contractor change as the build progressed?
10. What was your communication with the contractor like?
11. How did you receive project status updates?
12. How often did you visit the build site?
13. What would you do differently, if anything, having gone through the process?

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