Synthesizing a three Layer Architectural Framework for Adaptive Intelligent User Interfaces for the Disabled Community

Usman Ali Khan [1]*

[1] *King Abdulaziz University Jeddah*

(**Received** 30 December 2023, ***Accepted*** *22 July 2024* , ***Published Online*** *27 July 2024*)

*Corresponding author: *ukhan@kau.edu.sa*

Abstract: Knowledge acquisition has been a bottleneck in the design for efficient User Interfaces for Disabled Community. The best suited interfaces have been oriented towards adaptability that is the User Interface needs to adapt and configure itself according to the needs and likes of the user. Such user interfaces can arouse interest in the mind of the disabled and motivate them to become an asset to the nation, and use their intellect to contribute to the society. This study pioneers an innovative approach, aiming to develop User Interfaces (UIs) for the Disabled Community. The research introduces a comprehensive three-layer architectural framework employing Learning, Trust, and Knowledge Models. Unlike conventional approaches, this Architectural Framework is designed to learn not only from the Disabled but also from their Assistants/Guides, employing principles of knowledge engineering. While the former offers static context, the latter contributes dynamic insights by observing behaviors, responses, and actions of the Disabled. This symbiotic relationship forms the foundational basis for developing intelligent adaptive UI's that not only accommodate but actively engage and motivate the Disabled Community. The proposed research methodology involves a meticulous gathering of data through extensive user studies and interactions. By using the Human Computer Interface technology, the study aims to develop a robust framework capable of comprehensively understanding the preferences, needs, and nuances of disabled users. The expected outcomes include the development of a prototype adaptive UI, validated through rigorous testing and feedback from the disabled community. Additionally, the study anticipates contributing a comprehensive set of guidelines and best practices for designing intelligent adaptive UIs, ensuring comfort and ease for impaired users, boosting their confidence and encouraging greater involvement in socio-development activities.

Keywords: Human Computer Interface, Adaptive UI for disabled, Knowledge Engineering, Android Apps

Introduction

In our increasingly digitized world, software applications serve as gateways to information, services, and communication. However, for individuals within the disabled community, especially the visually impaired, accessing and interacting with these applications pose significant challenges [1]. The inaccessibility of software interfaces creates barriers hindering their participation and engagement, underscoring the pressing need for adaptive and intelligent user interfaces tailored to their needs [2].

Blind individuals encounter formidable obstacles while navigating standard software interfaces. Graphical User Interfaces (GUIs) heavily reliant on visual elements like icons, buttons, and menus prove insurmountable hurdles for users reliant on non-visual interactions [3]. These interfaces lack the necessary adaptability and compatibility with assistive technologies, impeding effective engagement. Studies highlight the limitations of existing technologies predominantly focusing on voice or haptic inputs as alternatives for visually impaired users [4], with low Braille literacy rates [5] rendering voice interfaces [6] as the primary technology adopted. However, attempts to address these issues through specialized interfaces have often been limited in scope, targeting specific disabilities rather than offering universal solutions. While frameworks and systems like FBLIND (**F**ramework for **BL**ind **IN**terface Development), UAF (**U**niversal **A**ccessibility **F**ramework), NavTouch, TetraMail or auditory web browsers have shown promise, their usability remains confined to empirical evaluations with smaller participant pools, limiting the generalizability of their findings.

This research aims to transcend these limitations by synthesizing a comprehensive three-layer architectural framework. Drawing from existing studies and frameworks, this research endeavors to develop adaptive intelligent user interfaces tailored specifically for the disabled community, focusing on the needs of the visually impaired. By addressing the shortcomings of current studies and frameworks, this study aspires to pave the way towards a more inclusive and accessible technological landscape for individuals within the disabled community

Review of Literature

The literature review conducted focuses on examining various facets of accessibility, usability, automatic generation of user interfaces, adaptive user interfaces, touchscreens, UI design, transformation, and distributed UIs within the domain of software interfaces catering to users with disabilities. Many studies have explored and devised numerous interfaces specifically aimed at fulfilling the needs of disabled individuals. However, the mere utilization of assistive technologies doesn't ensure accessibility for blind users to the application.

Technologies assisting the visually impaired primarily rely on voice or haptic feedback, including specific keyboards, alternative pointing devices, gesture and speech recognition, screen readers and Braille displays [7]. With low Braille literacy rates, voice interfaces have become more prevalent among users with visual impairments [8]. Additionally, efforts have been made to enable hands-free computer control for disabled individuals through speech and head tracking [9], facial recognition [10], or incorporating face and hand gestures [11]. Various gesture-based interaction techniques, including flicking, rotating, flipping, and single or multi-finger gestures, have been introduced on smartphones to aid blind individuals [12]. Innovations like the slide rule [13] aim to enhance touchscreen accessibility for the visually impaired by incorporating multi-touch interaction patterns alongside other functionalities. Touch player [14] similarly enhances interaction capabilities for the blind through gestures and haptic feedback.

MessagEase [15] adopts a slide-tap model for data entry, allowing character selection through tapping and menu navigation via a sliding mechanism. NavTouch [16] employs a gesture-based interface, enabling users to utilize gestures across the screen for an enriched layout, facilitating left-to-right and horizontal/vertical navigation while leveraging vowels as intended letters with speech feedback for alphabet navigation. The Egoki System [17] presents a model for automatically generating User Interfaces (UIs) catering to people with disabilities accessing fixed ubiquitous services. This model tailors user interaction patterns for each service based on user preferences, validated through an empirical study, showcasing favorable outcomes. Similarly, the Supple System [18] efficiently deploys UIs considering disability requirements, user profiling, and device usage patterns, achieving optimal UI adaptation from abstract to final form within a short span of 20 minutes.

Krajnc et al. [19] proposed a framework designed to potentially adapt applications to accommodate visually impaired users by implementing specialized "talking touch" views. For instance, their framework introduced features like a "talking touch list" tailored for Android mobile phones, enabling swift input with audio feedback. Donker et al. [20] introduced the concept of developing an auditory web browser utilizing three-dimensionally positioned auditory objects, termed "hearcons," within an Auditory Interaction Realm (AIR). These "hearcons" represented elements of web pages following a reference model known as the "torch metaphor." The evaluation of this auditory web browser's usability involved assessment by a panel of blind experts. Dedicated systems have been crafted for monitoring physical activities in individuals with cerebral palsy [21], human-computer interfaces have been created for those with restricted body movement [22], and gesture recognition has been employed for communication among individuals affected by cerebral palsy [23]. Khan et al. introduced TetraMail [24], an email client tailored for blind users, addressing challenges related to email accessibility and usability on smartphones. The evaluation of this email client involved an empirical study with 38 blind participants engaging in 14 distinct email activities.

Adapting applications designed for sighted users to meet the needs of blind users often faces challenges in dialog design and syntax restructuring [25]. Special-purpose interfaces or dual interfaces have been proposed as solutions. Toolkits like HAWK [26] provide non-visual interaction objects tailored for blind users, while **U**ser **I**nterface **M**anagement **S**ystems (UIMS) like HOMER [27] facilitate the development of interfaces suitable for both sighted and blind users.

Leuthold et al. [28] introduced the FBLIND framework aimed at constructing user interfaces for computer applications, comprising three key elements: a collection of user interface design principles, an interface development toolkit incorporating automatically adjusted user interface objects, and a programming library facilitating **S**peech and **B**raille **I**nput and **O**utput (SBIO). The practical application of this framework was demonstrated through DABIN (a software platform designed for bilingual dictionaries catering to both blind and sighted users).

Khan and Khusro [29] introduced the **U**niversal **A**ccessibility **F**ramework (UAF), which aimed to autonomously create simplified and adaptable user interfaces from mobile application UI artifacts installed on user's smartphones. These artifacts underwent simplification based on user information and context modeling, and the information extracted from the device usage log files by utilizing reverse engineering techniques [30].

The current standard in digital interfaces, namely Graphical User Interfaces (GUIs), heavily favors sighted users, rendering them inaccessible and unusable for individuals with visual impairments [31]. Legislation like Section 508 in the US and Swiss accessibility acts aim to ensure equal access to online content for handicapped users. Websites adhering to certain accessibility standards, termed "barrier-free-websites," [32] are the focus of these legal frameworks. The **W**eb **C**ontent **A**ccessibility **G**uidelines (WCAG)[33], established by the World Wide Web Consortium's **W**eb **A**ccessibility **I**nitiative (WAI), serve as the cornerstone for web accessibility standards. These guidelines emphasize creating HTML code readable by screen readers, enhancing access for visually impaired users [34]. While WCAG is considered the industry standard, empirical evidence supporting its normative character and impact on user behavior remains scarce.

Designing interfaces for blind users necessitates a thorough examination of fundamental accessibility issues and the formulation of appropriate usability guidelines. Such guidelines should encompass general design principles, platform-specific recommendations, and be supported by empirical evidence to ensure effective design suited for blind user interaction [35, 36].

Methodology

The methodology of this project is based on the below five different phases.

a) **Requirement Analysis**: This is the first phase of our framework. In this phase we will collect the requirement from user. Based on the requirement the project will be change according to that disability.

b) **Learning Layer:** After getting the requirement, system will be enter in the layered modules. We proposed three different layers. Learning layer is the first layer of our proposed framework. Whenever user will use the system, the information and logs will be saved in the database, by these logs, system will be able to learn by itself. Basically, in this phase, system will gain the knowledge from its experience for the future use.

c) **Trust Layer**: The second layer is based on the trust layer. The preamble of this research is based on the UI. To start the development of this work, we deeply analyzed the commonly used methods of mobile app development. There is a clear indication from the different developers that in human computer interaction for differently able people that trust factor should be reflect in the app designing. This framework is based on ethics and trust, trust issues are genuinely scrutinized at this phase of the work. The trust factor is based on the different set of ethical guidelines. These guidelines can be used to convoy the methodologies in the app designing and will provide helpful rules and regulations.

d) **Knowledge Layer:** The third and final layer is based on the knowledge engineering. Under the knowledge engineering layer, the system will behave like an intelligent guide and will give the instruction to perform any type of operation or task. As of now, there are no similar methodologies available this is why we developed our own methodology named as AFUIDC (Architectural Framework of User Interface for Disabled Community). It is knowledgeable means it will be helpful not only to the disable community but there guide too. AFUIDC is simple, trustworthy, and knowledgeable that based on three different phases while the requirement analysis will take the information and make the system adaptive.

e) **Analysis Phase**: Every layer gets the information from the fifth element that is nothing but the analysis phase. This phase will develop the center of the methodology and extract the type of user and there legal and ethical scrutiny.

This project follows the round of terminology means every phase can iterated multiple times. But we recommend the max three iterations: first prototyping second is App designing, and thirds will be the evaluation of cycle. This UI supports the visually impaired people to change the interface according to their easiness. In this application they can manage the layout and the input/output pattern like as voice or touch. This mobile app is developed the different processes that usually represented in XML [37, 38]. These XML extracts the different UI tree by using the Abstraction process. Then Android package can divide the XML layouts, code and other UI resources like as jpg and mpeg files etc in real time. We can configure multiple services by using this application, but for the testing purpose, we customized the five different services, calling, E-mailing, Purchasing, Health Services, and Banking. The banking app will be selected for using the banking related activities.

The AFUIDC framework is illustrated in Fig. 1. This application uses UI decomposition process in which the UI are modified by changing unimportant application process/layouts. The prototype framework in initial round takes out all tasks, UIs layout from the desired application. The user's choice like as input-output pattern, layout, and other artifacts catches in the initial phase of the application. The application will change itself according to the user's requirements and create the similar layout of the application. The knowledge layer of the application works on the each and every process through adaptation principle. For making the secure banking service, the framework will use the digital signature and all the transaction will be under the secure socket layer. For connecting the bank user must sign in and select the bank and account type. This all process will be under through the input-output voice or user selected pattern. The visually impaired people are also supported by the screen division and customization of the different components of framework. The knowledge engineering plays the important role to map the user modeling with its adaptation methodology. If we add the context layer here than it will helpful to assign the contextual proposal. Knowledge engineering will be helpful in some daily routine works to the blind people, like as reading the newspaper or any story book, watching the movie or recording their own video clip etc.

In the Figure 2, There are different operations are mentioned that comes under the e-banking services.

3.1) Working of proposed model

We took here one example to understand the process of proposed application. If any user is using the banking application first he need to start the system and select the type of bank, these all information he can enter through the speech to text feature of our system. After logging the bank, he can do the transaction from his/her account. Here we are using the Okta service [39] for the security purpose. Fig. 3 illustrates the usability of a banking application using the framework.

3.2) Methods and Case study

We applied this framework on nearly 43 blind people for our evaluation. This included 13 aged people, 15 are from learning impairment and 15 are from the 'control' group. 21 members were females, the other 22 are males. From the aged people's group, three was aged over 80, four in their 70s, one in her 60s and five are more than 55. All members of the group suffer from various physical and mental disabilities associated with aging. These people were selected from an educational university specializing in teaching people with learning disabilities. All of these participants were less than fifty years old. This framework is helpful to the disable people through its simplicity and trustworthy process. We stored the data of users in the secured database using SQLite. In the methods of development first we divide the process into multiple tasks. We follow the SDLC life cycle in the development of this project. We selected a total of 27 participants for this evaluation exercise

3.3) Framework Design

Designing is the important part of the framework, the layout is changeable and it will be based on the context. In each context the framework customize itself and use the buttons and icons on the appropriate place by which blind user could easily identify the buttons and easily use the system. Whenever they touch the screen it start to communicate with the user, like as which part of the system they are and what process they are doing, and after using this will happen.

Application coding:

For all code we used APKs and Android 10 version with Java 1.9. This Android version can successfully operate on old smartphones. The system is also under development for the IOS users.

Database:

We used the SQLite for the database storage. We created the center table to store the data in that database. All the password and critical data are stored in the encrypted format for scrutinizing the security of the system.

Information Security:

As per the concern of security of information we used the encryption techniques for storing the data in the database. We are also using the digital signature, CSV (Computer Storage Validation) and Okta services for increasing the security of proposed system.

3.4) Case Study

We found some of the visually impaired people on the internet, those were really required the support from technology to perform the different tasks. As we mentioned above in our locality nearly 43 people are using this system and they are doing their tasks like gaming, banking, sending e-mails etc. One of the case studies we are showing here.

Abdul (name changed), Age 37, Jeddah, Saudi Arabia	
Lives in joint family Literate, and shopkeeper of grocery items	Visually impaired
Abdu is the visually impaired person. He can work on the desktop and mobile phone. has ability to understand the currency value, things identification. He is 37 years old. He is using this application since last few days. During the testing process, he can easily do the banking process, purchasing, transfer. withdrawn etc. through our proposed app. According to him, this app is easy to use, user friendly and secure.	

Case Study and Analysis

The findings presented in this section stem from data collected from 43 visually impaired individuals participating in the study. Various analytical methods were employed to discern correlations among various usability parameters such as design consistency, user-friendliness, utility of the regenerated interface, cognitive load, and overall user satisfaction. Each group of people had a set of questionnaire based on their disability to evaluate our parameters. These questions involved their daily routine works and some of them are from

Table 1. Mean Assessment by questionnaire category (range 0-4)

	Final Average	Aged People Average	Control People Average	Learning Impaired Average
Design Consistency	2.95	3.69	2.65	2.54
User-Friendliness	2.87	3.14	2.75	2.72
Regenerated Interface	2.75	3.31	2.73	2.22
Cognitive Load	2.83	2.36	2.71	3.43
User Satisfaction	2.73	2.09	3.44	3.65

transactions too. The Member's data has stored in the SQLite data storage that was linked to the cloud platform. These questions were classified according to interaction, learning and knowledge, layout, user trust and future use. Each question also encouraged qualitative comments. An outline of the results is exposed in Table 1. We also used the analysis of the variance (ANOVA) of every question in the questionnaire. This analysis found there is no major difference in the answers given by all three disables group people except one question that was whether they feel any embarrassment to use the present system or not. Learning impaired member said No wile other two group told Yes.

Ensuring the credibility of collected data, diverse methods were utilized. A MultiTrait-MultiMethod (MTMM) analysis assessed the reliability, yielding a robust Cronbach's α coefficient of 0.951, affirming the consistency and validity of the utilized Likert scales. Concurrently, Confirmatory Factor Analysis (CFA) reinforced the interrelatedness of the usability parameters, supported by a Barlett test Chi-Square value of 711.34 and a Kaiser-Meyer-Olkin index of 0.787, signifying the adequacy for factor analysis.

Employing Latent Variable Modeling through Structural Equation Modeling (SEM) techniques, Principal Component Analysis (PCA) emphasized data variance and revealed latent patterns. Rotation methods such as Quartimax and Oblimin unveiled distinct factor loadings, aligning with Kaiser's criterion of Eigenvalues surpassing 1.

Beyond conventional analyses, an **I**terative **P**roportional **F**itting (IPF) approach assessed keystroke-level data. It enabled meticulous observation of task accuracy, completion times, and navigational efficacy through a Bayesian network framework, enhancing the depth of insights. Keystroke dynamics facilitated assessing behavioral patterns and interaction nuances, offering a comprehensive understanding of user responses. Complementing the empirical study, Bayesian Inference facilitated automating responses, capturing nuances in task execution and performance variations. Bayesian networks, through Markov Chain Monte Carlo (MCMC) simulations, provided probabilistic estimates, elucidating task complexities and interface adaptability. Table 2 showcases different usability parameters and their corresponding values derived from various analytical methods.

Based on above data we calculated the value of different analytics method that is mentioned in the below the table (Table 2).

These diverse analytical methodologies, from MTMM and CFA to SEM and Bayesian Inference, synthesized a comprehensive understanding of user experiences, validating both subjective and objective assessments. This multifaceted approach ensured a robust evaluation of the proposed framework’s efficacy, emphasizing inclusivity and relevance for the visually impaired community.

These diverse analytical methodologies, from MTMM and CFA to SEM and Bayesian Inference, synthesized a comprehensive understanding of user experiences, validating both subjective and objective assessments. This multifaceted approach ensured a robust evaluation of the proposed framework’s efficacy, emphasizing inclusivity and relevance for the visually impaired community.

Table 2. Different usability parameters and analysis of various analytical methods

Usability Parameter	Cronbach’s α	Barlett Test (Chi-Square)	Kaiser-Meyer-Olkin	PCA (Eigenvalues)	Bayesian Inference (MCMC)
Utility of the Interface	0.954	688.69	0.724	4.68	0.895
User-Friendliness	0.926	701.14	0.751	4.02	0.911
Minimal Memory Load	0.942	663.81	0.739	4.22	0.902
Consistency	0.902	752.36	0.715	3.94	0.898
User Satisfaction	0.931	641.09	0.765	4.35	0.926

Result and Discussion

The obtained results from the diverse array of analytical methods employed in this study present a multifaceted understanding of the usability parameters crucial for Adaptive Intelligent User Interfaces tailored for the visually impaired community. The high reliability coefficients, notably Cronbach’s α values ranging from 0.902 to 0.954 across various usability parameters such as perceived usefulness, ease of use, minimal memory load, consistency, and user satisfaction, underscore the consistency and reliability of the assessment scales used. This reaffirms the robustness of the study's foundational metrics, indicating a strong internal consistency among participant responses. The Barlett test's Chi-Square values, ranging from 641.09 to 752.36, and the Kaiser-Meyer-Olkin indices of 0.715 to 0.765, signify the appropriateness of the dataset for factor analysis. These statistics validate the interrelatedness of the usability parameters, further supporting the feasibility of synthesizing an adaptive interface framework. The Principal Component Analysis (PCA) highlighted variations and distinct patterns within the dataset, as evidenced by Eigenvalues ranging from 3.94 to 4.68. These values indicate the importance and contribution of each usability parameter toward interface adaptability and user-centric design.

Moreover, Bayesian Inference through Markov Chain Monte Carlo (MCMC) simulations, yielding values between 0.895 and 0.926, further strengthens the findings. This probabilistic approach accentuated the nuanced behavioral nuances and interaction patterns, enhancing the comprehensive understanding of user responses and system adaptability.

Collectively, these results validate the efficacy of the proposed three-layer framework. The convergence of outcomes from diverse analytical methods emphasizes the robustness and viability of the framework, heralding a significant stride toward enhancing usability and inclusivity in technology for the visually impaired community.

Conclusion

This study presents a comprehensive exploration of Adaptive Intelligent User Interfaces (AIUIs) targeted at the visually impaired, offering insights garnered from a multifaceted analytical approach. Prior studies often grappled with limitations, primarily focusing on individual aspects or employing limited analytical methodologies which restricted the depth of insights into the complex interaction dynamics required for adaptable interfaces. However, this research advances upon these constraints by amalgamating a diverse range of analytical techniques, providing a more comprehensive understanding of usability parameters essential for AIUIs. The high reliability coefficients validate the consistency and reliability of the usability parameters, whereas Chi-Square values and Kaiser-Meyer-Olkin indices affirm their interrelatedness, emphasizing their significance for interface adaptability. Principal Component

Analysis unveiled nuanced patterns within the dataset, underlining the importance of individual parameters in shaping adaptable interfaces. Bayesian Inference, offering a probabilistic perspective, provided a holistic view of user behaviors and interface adaptability, surpassing the confines of conventional analyses.

The convergence of outcomes from diverse analytical methodologies substantiates the efficacy and robustness of the synthesized three-layer architectural framework. This comprehensive model stands poised to address the shortcomings of previous studies by offering a more holistic, adaptable, and user-centric approach towards AIUIs for the visually impaired community. The framework's potential lies in its ability to cater to diverse user needs, fostering enhanced usability, independence, and inclusivity in digital interactions for the visually impaired.

Future Work

The future trajectory in this field of research holds promising avenues for further advancements in Adaptive Intelligent User Interfaces (AIUIs) tailored for the visually impaired. One area of future enhancement lies in leveraging emerging technologies like machine learning and artificial intelligence to create more intuitive and adaptive interfaces. Integrating these technologies can enable AIUIs to dynamically learn and adapt to individual user preferences and needs, enhancing personalization and usability. Additionally, exploring the integration of novel sensory feedback mechanisms such as haptics or advanced auditory cues can further augment the user experience, enabling more immersive and intuitive interactions with digital interfaces.

Moreover, there's scope for extensive user-centered design methodologies, engaging visually impaired individuals throughout the development process. Collaboration with diverse stakeholders and continuous user feedback loops will be pivotal in refining and evolving AIUIs to meet evolving user needs, fostering greater independence and inclusivity in digital interactions for the visually impaired community.

Acknowledgment

This research work was funded by the Deanship of Scientific Research (DSR), King Abdulaziz University, Jeddah, under grant No. (D 611-009-1434). Therefore, the authors gratefully acknowledge with thanks DSR for technical and financial support.

References

[1] Manjari K, Verma M, Singal G. A survey on assistive technology for visually impaired. Internet of Things. 2020 Sep 1; pp 11:100188.

[2] Kuriakose B, Shrestha R, Sandnes FE. Tools and technologies for blind and visually impaired navigation support: a review. IETE Technical Review. 2022 Jan 2;39(1): pp 3-18.

[3] Maćkowski M, Brzoza P, Kawulok M, Meisel R,

Spinczyk D. Multimodal presentation of interactive audio-tactile graphics supporting the perception of visual information by blind people. ACM Transactions on Multimedia Computing, Communications and Applications. 2023 Jun 7, 2019: pp 1-22.
[4] Kuriakose B, Shrestha R, Sandnes FE. Multimodal navigation systems for users with visual impairments—a review and analysis. Multimodal Technologies and Interaction. 2020 Oct 16;4(4):73.
[5] Wanja S, Murugami M, Bunyasi B. Braille literacy levels among learners with visual impairment in special schools in Kenya. European Journal of Special Education Research. 2021 Apr 14;7(2).
[6] Oumard C, Kreimeier J, Götzelmann T. Pardon? An Overview of the Current State and Requirements of Voice User Interfaces for Blind and Visually Impaired Users. InInternational Conference on Computers Helping People with Special Needs 2022 Jul 1 (pp. 388-398). Cham: Springer International Publishing.
[7] Michael Paciello. Web accessibility for people with disabilities. https://goo.gl/gjpa9D, 12 2006.
[8] Plaisant C. Shneiderman B. Lazar J Zhao, H. A framework for auditory data exploration and evaluation with geo-referenced data sonification. http://hcil.cs.umd.edu/trs/2005-28/2005-28.htm, 2006
[9] Karpov, A., Ronzhin, A.: Icando: Low cost multimodal interface for hand disabled people. Journal on Multimodal User Interfaces 1(2), 21–29 (2007)
[10] Varona, J., Manresa-Yee, C., Perales, F.J.: Hands-free vision-based interface for computer accessibility. Journal of Network and Computer Applications 31(4), 357–374 (2008)
[11] Millan, J.D.R., et al.: Combining brain-computer interfaces and assistive technologies: State-of-the-art and challenges. Frontiers in Neuroscience 4, 1–15 (2010)
[12] Wu M, Balakrishnan R (2003) Multi-finger and whole hand gestural interaction techniques for multi-user tabletop displays. In: Proceedings of the 16th annual ACM symposium on user interface software and technology. ACM, pp 193–202
[13] Kane SK, Bigham JP, Wobbrock JO (2008) Slide rule: making mobile touch screens accessible to blind people using multi-touch interaction techniques. In: Proceedings of the 10th international ACM SIGACCESS conference on computers and accessibility. ACM, pp 73–80
[14] Pirhonen A, Brewster S, Holguin C (2002) Gestural and audio metaphors as a means of control for mobile devices. In: Proceedings of the SIGCHI conference on human factors in computing systems. ACM, pp 291–298
[15] Nesbat SB (2003) A system for fast, full-text entry for small electronic devices. In: Proceedings of the 5th international conference on multimodal interfaces. ACM, pp 4–11
[16] Guerreiro T, Lagoá P, Nicolau H, Gonçalves D, Jorge JA (2008) From tapping to touching: making touch screens accessible to blind users. IEEE Multimedia 15:0048–0050
[17] Gamecho B, Minón R, Aizpurua A, Cearreta I, Arrue M, Garay-Vitoria N, Abascal J (2015) Automatic generation of tailored accessible user interfaces for ubiquitous services. IEEE Transactions on HumanMachine Systems 45:612–623
[18] Gajos KZ, Long JJ, Weld DS (2006) Automatically generating custom user interfaces for users with physical disabilities. In: Proceedings of the 8th international ACM SIGACCESS conference on computers and accessibility. ACM, pp 243–244
[19] Krajnc E, Knoll M, Feiner J, Traar M. A touch sensitive user interface approach on smartphones for visually impaired and blind persons. InInformation Quality in e-Health: 7th Conference of the Workgroup Human-Computer Interaction and Usability Engineering of the Austrian Computer Society, USAB 2011, Graz, Austria, November 25-26, 2011. Proceedings 7 2011 (pp. 585-594). Springer Berlin Heidelberg.
[20] Donker H, Klante P, Gorny P. The design of auditory user interfaces for blind users. InProceedings of the second Nordic conference on Human-computer interaction 2002 Oct 19 (pp. 149-156).
[21] Ong, C., Lu, M.V., Lau, B.: A face based real time communication for physically and speech disabled people. In: Assistive and Augmentive Communication for the Disabled, pp. 70–102 (2011)
[22] Vazquez, L.J.G., Minor, M.A., Sossa, A.J.H.: Low cost human computer interface voluntary eye movement as communication system for disabled people with limited movements. In: 2011 Pan American Health Care Exchanges, pp. 165–170. IEEE (2011)
[23] Murata, Y., Yoshida, K., Suzuki, K., Takahashi, D.: Proposal of an automobile driving interface using gesture operation for disabled people. In: 6th International Conf. on Advances in Computer-Human Interactions, ACHI 2013, pp. 472–478 (2013)
[24] Khan A, Khusro S, Niazi B, Ahmad J, Alam I, Khan I (2018b) TetraMail: a usable email client for blind people. Univ Access Inf Soc:1–20
[25] Savidis, A., Stephanidis, C.: Developing dual user interfaces for integrating blind and sighted users: the HOMER UIMS. In: Proceedings of the SIGCHI conference on Human factors in computing systems, Denver, Colorado, United States (1995) 106-113

[26] Stephanidis, C., Savidis, A.: Interface Development Toolkits for Non-visual and Switchbased Interaction. ERCIM News, 46 (2001), available at URL: http://www.ercim.org/publication/Ercim_News/enw46/stephanidis2.html.

[27] Savidis, A., Stephanidis, C.: The HOMER UIMS for dual user interface development: Fusing visual and non-visual interactions, Interacting with Computers 11(1998) 173-209

[28] Stefan Leuthold, Javier A. Bargas-Avila, Klaus Opwis, Beyond web content accessibility guidelines: Design of enhanced text user interfaces for blind internet users, International Journal of Human-Computer Studies, Volume 66, Issue 4, 2008, Pages 257-270, ISSN 1071-5819, https://doi.org/10.1016/j.ijhcs.2007.10.006

[29] Khan A, Khusro S. Blind-friendly user interfaces–a pilot study on improving the accessibility of touchscreen interfaces. Multimedia Tools and Applications. 2019 Jul 15;78:17495-519.

[30] Guo A, Kong J, Rivera M, Xu FF, Bigham JP. Statelens: A reverse engineering solution for making existing dynamic touchscreens accessible. InProceedings of the 32nd Annual ACM Symposium on User Interface Software and Technology 2019 Oct 17 (pp. 371-385).

[31] Kieninger, T.G., 1996. The ‘‘growing up’’ of hyperbraille: an officeworkspace for blind people. In: 9th Annual Symposium for UserInterface Software and Technology, ACM Association for ComputingMachinery, Seattle, Washington, USA.

[32] BehiG, 2002. Bundesgesetz über die Beseitigung von Benachteiligungen von Menschen mit Behinderungen.

[33] Panda S, Chakravarty R. Evaluating the web accessibility of IIT libraries: a study of Web Content Accessibility Guidelines. Performance Measurement and Metrics. 2020 Nov 12;21(3):121-45.

[34] Panda S, Kaur N. Web Content Accessibility Guidelines 3.0: Empowering Visually Impaired Learners with Inclusive Web Design. In Closing the Educational Achievement Gap for Students with Learning Disabilities 2023 (pp. 246-269). IGI Global.

[35] Morley, S.: Design and Evaluation of Non-Visual Information Systems for Blind Users, PhD, University of Hertfordshire, UK (1999)

[36] Casali, S. P.: A physical skills-based strategy for choosing an appropriate interface method. In: Edwards, A. D. N. (ed.): Extra-ordinary Human Computer Interaction: Interfaces for people with disabilities, Cambridge University Press (1995) 315-342

[37] Paquette L, Baker RS. Comparing machine learning to knowledge engineering for student behavior modeling: a case study in gaming the system. Interactive Learning Environments. 2019 Aug 18;27(5-6):585-97.

[38] Ali A, Rashid M, Azam F, Rasheed Y, Anwar MW. A model-driven framework for android supporting cross-platform GUI development. In2021 National Computing Colleges Conference (NCCC) 2021 Mar 27 (pp. 1-6). IEEE.

[39] Saxena R, Gayathri E. A study on vulnerable risks in security of cloud computing and proposal of its remedies. In Journal of Physics: Conference Series 2021 Oct 1 (Vol. 2040, No. 1, p. 012008). IOP Publishing.

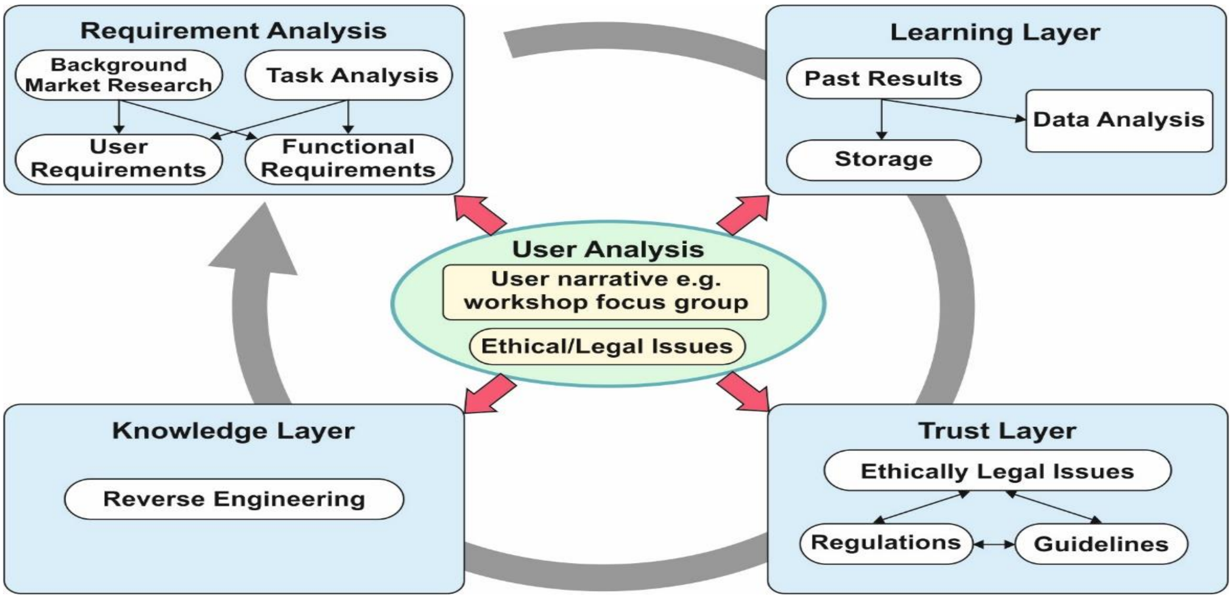

Figure 1. The AFUIDC Framework

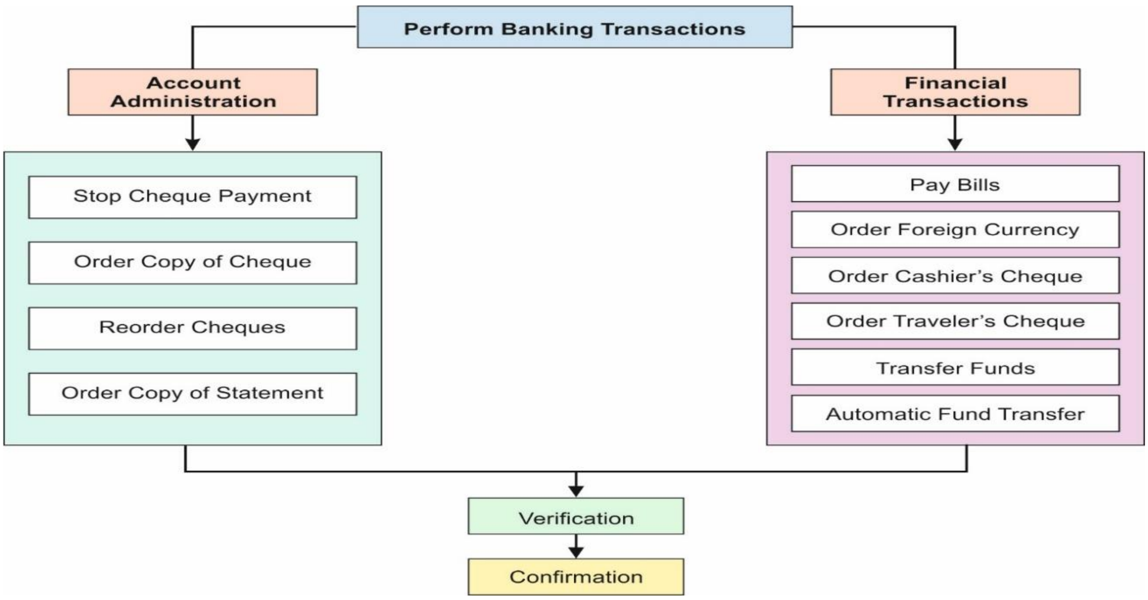

Figure 2. General features in an E-Banking application

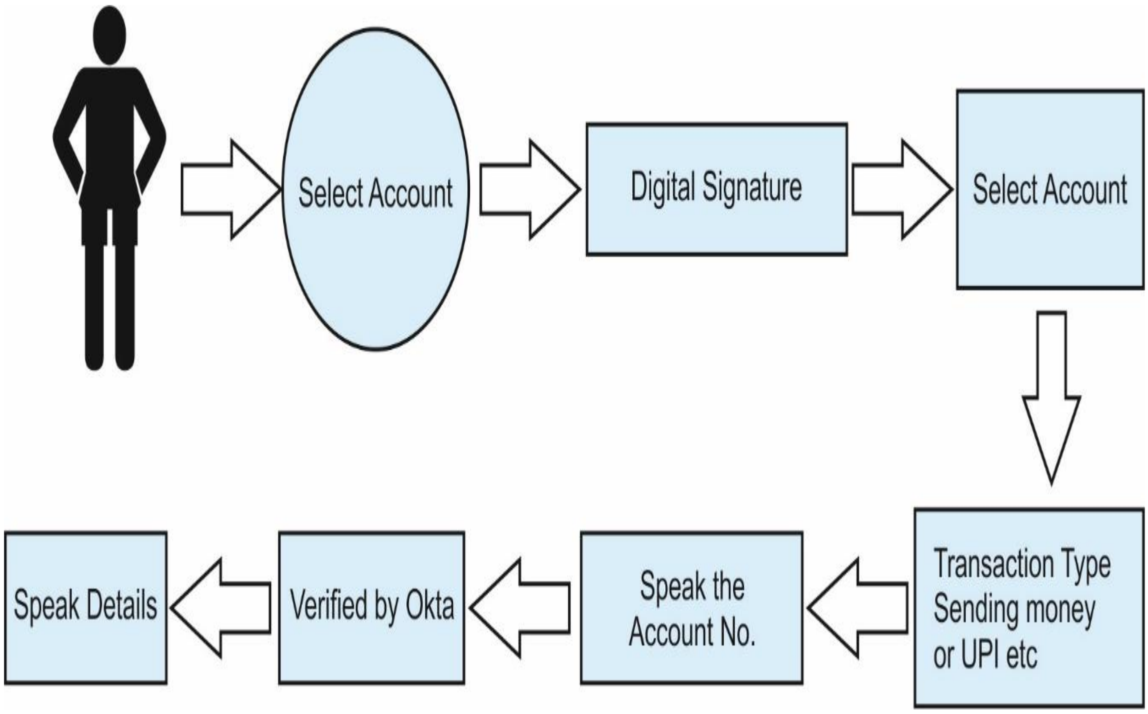

Figure 3. Regenerated interface of a banking application for visually impaired

USMAN ALI KHAN is an Associate Professor in the Information Systems Department, Faculty of Computing and Information Technology, King Abdulaziz University, Jeddah, Saudi Arabia. He received his Ph.D. in Software Engineering from the Integral University, India. Dr. Khan has been working is the field of research and teaching at graduate and undergraduate level in different Universities since 1995. His current research interest includes AI, Machine Learning, Software Engineering and Project Management He has published many research papers at national and international forums.