AI-Assisted UI Design for Blind and Low-Vision Creators

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ABSTRACT

Visual aesthetics are critical to user interface (UI) design and usability. Prior work has shown that website aesthetics—which users evaluate in a 'split second' upon page load—are a definitive factor not just in engaging users online but also in impacting opinions about usability, trustworthiness, and overall user satisfaction. Currently, however, there is limited support for blind or low-vision (BLV) creators in designing, implementing, and/or assessing the visual aesthetics of their UI creations. In this workshop paper, we consider AI-assisted user interface design as a potential solution. We provide background on related research in AI-assisted design and accessible programming, describe two preliminary studies examining BLV users' current understanding of UIs and their ability to represent them with lo-fi methods, and close by discussing key open areas such as supporting BLV creators throughout the UI design process.

Author Keywords

Visual Design; Accessibility; Artificial Intelligence

ACM Classification Keywords

H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous

INTRODUCTION

Visual aesthetics are critical to user interface (UI) design and usability. Prior work has shown that a UI's visual aesthetics—which sighted users evaluate in a 'split second'—can significantly impact the perceived usability, trustworthiness, and overall user satisfaction of an interface [10, 17, 26, 33, 34] Currently, however, there is limited support for blind or low-vision (BLV) creators to design, implement, and/or assess the visual aesthetics of their UI creations [24]. With advances in machine learning and the growing availability of large training datasets [6, 7, 14], AI-assisted visual design [7, 14, 32]—where a trained machine learning model actively monitors a design and suggests improvements or alternatives—has become feasible and is even shipping in products (*e.g.,* Microsoft PowerPoint) [22]. While not originally intended as an assistive technology, in this workshop paper, we consider how AI-assisted user interface design may support BLV creators while preserving their agency and creativity.

Designing visual UIs is a multi-step process often involving multiple creation and testing cycles progressing from low-fidelity sketches to creating mid-fi mockups and then coding hi-fi interactive prototypes [5]. Each design stage presents barriers to BLV creators as well as opportunities for AI-assisted design. Prior work on AI-assisted design has focused on several of these phases. For example, Landay and Myers pioneered the use of sketching for early phase UI design [16]. *Sketch2Code* [29] is a more modern example, which uses AI to transform sketches into HTML. For mid-fi design, Newman *et al.* used sketching to support mid-fi website design [21]. Similarly, [32, 36] is a recent example of using AI to convert sketches to high-fi designs. However most of this work has not considered the needs of BLV creators.

Given the lack of AI research that both supports UI design and BLV creators, we argue that this is an important area for future research. Can we use AI-powered systems to support the design of aesthetic, usable UIs? Our research thus far has focused on the potential for AI-based early stage UI design tools that support BLV creators as a first step in this domain. Our formative work examines how BLV creators currently perceive and engage with the visual semantics of UIs. Our research questions include: do BLV technology users understand visual semantics of user interfaces? Relatedly, how does the understanding and the desire to understand visual semantics vary across different contexts of use? As a second step in our exploration, we report preliminary results exploring how *Sketch2Code* [29] can support BLV creators. We end by discussing the potential for AI to assist UI design, and biases and implicit exclusion of BLV users in AI-assisted visual design.

BACKGROUND

Although AI-assisted, accessible UI design is not well understood, several prerequisites have been studied in some depth. Here we discuss four areas from which we can draw further insights: visual design tools for BLV creators, programming support for BLV programmers, AI-assisted UI design tools for sighted developers, and requirements for visual design.

Visual Design tools for BLV creators

Attempts to support visual design for BLV creators have extended beyond interface design, primarily in the domain of blind drawing. For example, Kamel and Landay studied blind drawing practices [12], which led to the design of a computer-aided design drawing tool called *Integrated Communication 2 Draw* (IC2D) [13]. IC2D transforms geometric information into an auditory format and uses a grid-based navigation paradigm for input. Kurze introduced *TDraw* [15], a computer-based tactile drawing tool for blind

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individuals and studied their drawing process. This body of work demonstrates that 2D visual design for BLV individuals is a challenging problem, and one that we believe would benefit from AI support.

Programming Support for BLV Creators

Researchers have also explored how to support blind developers in programming tasks. For example, *CodeTalk* [25] enumerates accessibility challenges faced by BLV developers into discoverability, navigability, glanceability, and alertability, and addresses a subset of these through UI enhancements and auditory feedback in a Visual Studio plugin. Other IDE accessibility efforts for BLV users include tools such as *StructJumper* [2], enhancements to *CodeMirror* [28] and formative efforts such as [1], which aim to study the challenges faced by BLV software developers. Recent efforts like [3, 19, 24] have begun addressing accessible visual design but do not support visual aesthetics and appeal. For example, [3] and [19] improve the accessibility of the outputs of a BLV creator's design decisions but do not inform the BLV creator on the effect an edit would have on visual appeal and aesthetics. While [24] provides feedback on the validity of a visual edit, the tool is preliminary and based on a limited set of visual attributes (color, font, and spacing). In addition, while machine learning techniques have been used in programming tools like *TabNine*, which provides auto-complete suggestions [31] to our knowledge, none of the tools have leveraged AI towards accessible programming.

AI-Assisted UI Design Tools

AI-assisted UI design is an emergent area. Recent approaches like *Expresso* [11] enable creation of responsive layouts without having to write code using keyframes—by specifying how a UI should look at different viewport sizes using a WYSIWYG editor. Swarengin *et al.* [30] present an approach to use screenshots as examples to create interfaces. More recently, machine learning has been used to enable creation of visual artifacts as seen in *Sketch2Code* [29], *PowerPoint* [20] and *AutoDraw* [9].

While the above work is promising in highlighting how AI can aid UI design, the inputs, interactions, and outputs are not accessible to BLV users. Existing machine learning approaches use methods that are not necessarily intuitive and inclusive of BLV users for input (*e.g.,* sketches) or output (*e.g.,* images). Some open questions include: Are existing AI-based approaches to generating and designing UIs and visual artifacts tolerant to inaccuracies that might occur as a result of a BLV person hand-drawing sketches? Relatedly, what are the alternative approaches to drawing that are more inclusive of a BLV user's ability to be more expressive and creative? What are implications do these alternate approaches have for machine learning techniques?

Requirements for Visual Design

Perceived visual appeal of artifacts is an essential factor in UI design, and one that needs to be supported successfully for BLV UI design to be solved. Websites with good visual design are perceived as more usable [33] and trustworthy [18]. Research also shows that users establish lasting impressions of a website's appeal within a split-second of seeing it for the first time. [26, 27]. Perceived visual appeal is subjective with the perceptions of good visual appeal varying by race, ethnicity and cultural background [27]. There do not yet exist quantifiable factors to measure perceived visual appeal [26]. Reinecke *et al.* [26, 27] show that visual complexity and colorfulness are factors that determine perceived visual appeal. AI-assisted design tools have the potential to help BLV creators emulate popular visual design patterns (*e.g.,* those mentioned in [14]), and thus increase the likely success of their designs.

To summarize, existing tools support BLV programming or BLV drawing, but do not consider the goals of accessible UI design. Given recent successes in AI-assisted UI design, and unknowns about the accessibility of these approaches, we see an opportunity for supporting BLV creators of UIs.

STUDY 1: BLV USERS' UNDERSTANDING OF UIS

As initial work exploring how we might be able to support BLV creators in designing and implementing UIs, our first study examines three important questions: First, what do BLV users and creators understand about the visual design of UIs that they use regularly? Second, how do BLV creators go about creating UIs? Third, are BLV users and creators able to express their design goals using lo-fi prototyping tools?

We performed a semi-structured interview study with nine BLV technology users aimed at gaining insight into BLV participants' perceived understanding of spatial layouts of UIs across different contexts of use. (*e.g.,* smartphone apps, web on smartphone, web on desktop). We invited participants to complete frequently performed tasks on their smartphones and the web and observed their spatial interactions (*e.g.,* the role of size, shape, layout). We also asked about the perceived importance of visual UI understanding and why. Finally, participants sketched UI designs using a lo-fi prototyping technique, which was adapted for accessibility. Specifically, participants constructed representations of familiar UI layouts using Play-Doh and Wikki Stix [35] on a poster board.

In total, we recruited 9 BLV participants (m=5, f=4) with ages between 24 and 58. All participants reported using smartphones with a touchscreen and a desktop computer with a screen reader. Four of the 9 participants had a web presence (personally maintained webpage or blog excluding social media accounts). For analysis, we followed an iterative thematic coding approach [4] on manually transcribed audio and video recordings of study sessions.

Here we report only on high-level results (a full paper is in preparation). Recall that our study had three goals—to gain insight into perceived understanding of UIs, to learn how BLV creators create UIs, and to explore how well BLV creators could express UI designs. We present results for each in order.

Perceived understanding of UIs: We found that participants were most confident in their spatial understanding of smartphone app interfaces followed by smartphone web and desktop web. For example, participants were least enthusiastic and most hesitant to sketch desktop web UIs compared with smartphone apps. From our observational analysis, we found that participants constructed webpage UIs as being vertically linear, while being more spread out on the canvas for smartphone apps.

Approach to creation of UIS: From our interviews, we learned that BLV creators typically delegate visual tasks (*e.g.,* selecting UI templates) to their sighted colleagues or friends. As one barrier to UI creation, participants expressed the need to understand visual semantics (*e.g.,* shape, size, color, and iconography) to build their own visual interfaces.

Prototyping UIs with Wikki-Stix and Play-Doh: The tactile nature of Wikki-Stix allowed participants to refer back to parts of their construction. Figure 1 shows examples of the designs participants created. To the left is a design of a smartphone app and to the right is a design of a desktop website.

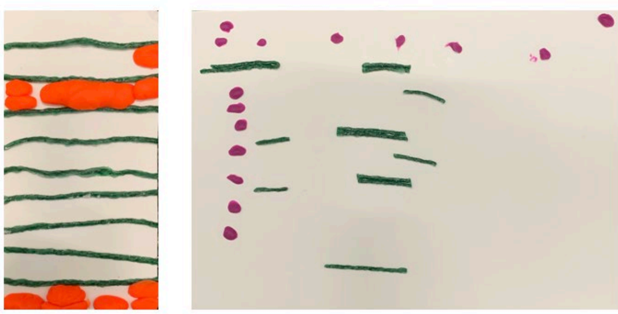

Figure 1: Example reconstructions of smartphone app by P9 (left) and desktop website by P6 (right).

We observed that participants were forced to think about how to represent the shape, size and orientation of different UI elements like buttons, links, and sliders. Though screen readers do not represent these more nuanced properties of UI elements, participants included such nuances in their mental models as well as their designs. For example, in Figure 1 we can see that participant P9 used straight lines for links and blobs of Play-Doh for buttons.

To summarize, our first study showed that there is a gap between the understanding of BLV UI users and the aesthetic requirements for UI design. This helps to highlight the importance of AI tools that can help support BLV creators in addressing these sighted needs. In addition, our study shows that tangible tools for interface sketching may be a viable lo-fi prototyping technique. However, this method does not allow the user to express color and interactivity and animations associated with interactivity. As a result, our approach does not capture the representation and understanding of color among BLV participants, an important aspect of perceived visual appeal as suggested by Reinecke *et al* [26].

STUDY 2: BLV USE OF AN AI-ASSISTED DESIGN TOOL

The goal of our second study is to explore the accessibility of a particular AI-assisted UI design tool, Sketch2Code. This is an exploratory case study which compared different styles of input to see how the Sketch2Code system would react.

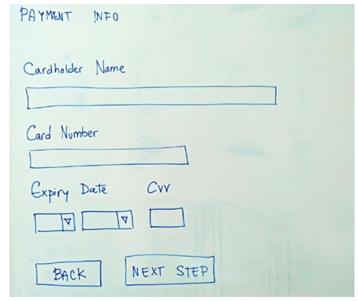

Figure 2: The goal: An example sketch provided on the sketch to code website, used as a starting place for the BLV author's sketching efforts.

We tested using hand-drawn sketches by the BLV author and Wikki-Stix as an alternative to sketches. First, a non-BLV researcher, R1, explained an example sketch given by Sketch2Code (Figure 2) to the BLV researcher. Then, the BLV Researcher typed in the text corresponding to the labels in the example in a word document. The researchers used printed labels to compensate for the fact that BLV does not hand-write words. Next, the BLV researcher created two sketches – one hand drawn, and one using Wiki Stix. These are shown in Figure 3.

Though none of the outputs were perfect, the hand-drawn sketch by the BLV researcher resulted in the most accurate result (Figure 4). Surprisingly, Sketch2Code failed to recognize some of the printed text used as a substitute for handwriting, perhaps because the recognition model was trained on handwriting.

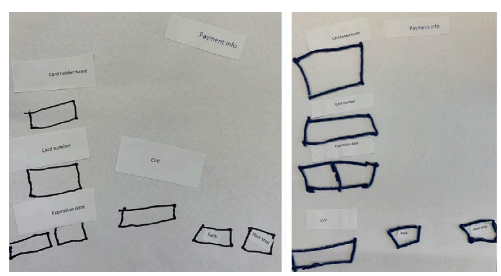

Figure 3: BLV researcher's sketches of example webpage using a marker (left) and Wikki-Stix (right).

To summarize, Sketch2Code was able to make some use of the data we fed to it, but was not designed to address all of the differences between BLV created sketches and the sketches of sighted creators. Since Sketch2Code is a proprietary system, there are several unknowns about the causes of these results. For example, we do not know whether the training data for Sketch2Code was inclusive of drawings produced by BLV individuals.

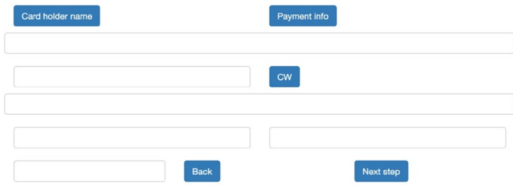

Figure 4: The most accurate result after the sketches were provided to Sketch2Code. The hand-drawn sketch was most accurate.

DISCUSSION

BLV users have been underserved in UI design related tasks and unable to effectively address aesthetic properties of UIs with existing tools. Here we discuss some specific barriers to better supporting BLV creators. First, we argue for the importance of including BLV creators in the design of AI-assisted UI design tools. Without data about and input from BLV creators, how do we prevent bias and implicit exclusion of BLV users while designing AI-powered approaches to visual design? Second, we argue for the importance of developing AI support for visual aesthetic properties of UIs as an accessibility goal, which has implications for tool design. Finally, we suggest that researchers and UI tool designers should more deeply investigate how to support BLV designers across the entire UI design process—from building lo-fidelity mockups to coding interactive prototypes—and the role of AI therein.

Inclusive Data Collection and Model Training

As programming and UI design tools increasingly incorporate machine learning to assist creators, it is important to reflect on how these ML models are trained and how this training may inadvertently impact people with disabilities. For example, Sketch2Code recognized handwritten but not preprinted labels for input. Who is providing the training data for these systems? Does it include people with disabilities? This problem is exacerbated by the push towards active learning models, which gain additional training data from deployed tools—however, if these tools are not initially accessible, they will not be able to learn from BLV use and continue to starve for more broadly inclusive examples.

AI Support for Visual Design and Aesthetics

Given the observed limitations in BLV user's understanding of visual aesthetics in the context of user interfaces, we look to AI-powered approaches to assist BLV creators. It is important to be mindful of potential biases that could be introduced into the visual designs of BLV creators if the AI powering the visual appeal recommendations is racially or gender biased. Imagine an AI-powered system providing a bright pink color scheme as a recommendation to the BLV creator for a website geared towards women (*e.g.,* [8]). Is that what is really expected in terms of color scheme? In addressing the needs of BLV creators, the AI must avoid carrying forward and systematizing other biases.

Supporting Creators Throughout the UI Design Process

Enabling BLV creators to meaningfully engage with aesthetics and visual design can open new career and research paths for BLV creators. Through assistance from AI powered systems in an unbiased, fair manner, we may have a unique opportunity to open these paths to BLV creators.

While our studies focus primarily on design specification via sketching and related activities, our vision is to support BLV creators throughout the UI design process. To achieve this goal, we see several challenges. Communication and collaboration are important aspects of design [38]. With the prevalence of visual design techniques such as story-boarding, it is important to ensure BLV creators, who could be designers are given the means to effectively communicate, collaborate and contribute to the design process. Broadly, what role can AI have to ensure meaningful participation and contribution by BLV designers in the various stages of the design process from sketching, building interactive prototypes to evaluating designs?

For lo-fi prototypes, the focus is often on general layout, information organization, and gaining feedback on initial ideas. For higher fidelity representations, the focus shifts to aesthetic characteristics (*e.g.,* color, iconography, font) and interactivity. For higher fidelity design, we must move beyond representation of initial layout ideas and aesthetics to effectively capture BLV designers' ideas of interactivity. In addition to most design tools and paradigms being visually dominant and inaccessible, how do we translate the linear, semantic models of interactivity that BLV screen readers operate on? For example, can AI be used to arrive at a mapping between screen reader interactions and associated visual interaction using datasets like [14, 6] and approaches followed in [37]?

Finally, evaluation of UIs takes many forms, from design critiques and heuristic walkthroughs, to in-lab and in-the-wild usability studies. How can AI assist BLV creators in conducting these evaluations, analyzing the data, and making changes to UIs?

CONCLUSIONS AND FUTURE WORK

We have argued for the importance of design tools that support visual, usable, aesthetically appealing UI creation by BLV creators. We believe it is important to fill the access gap that prevails in the design process for BLV creators to actively engage with and contribute to design. Our studies demonstrate the potential and the gap that currently exists for BLV creators. Given the recent trend in AI assisted design tools and processes, we feel it is important to be mindful of potential implicit and explicit exclusion of BLV creators. Our future work will focus on the development of AI-assisted accessible design tools that can enable BLV creators to produce beautiful, usable, and accessible interfaces.

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REFERENCES

1. Khaled Albusays, Stephanie Ludi, and Matt Huenerfauth. 2017. Interviews and Observation of Blind Software Developers at Work to Understand Code Navigation Challenges. In Proceedings of the 19th International ACM SIGACCESS Conference on Computers and Accessibility (ASSETS '17). ACM, New York, NY, USA, 91-100. DOI: https://doi.org/10.1145/3132525.3132550
2. Catherine M. Baker, Lauren R. Milne, and Richard E. Ladner. 2015. StructJumper: A Tool to Help Blind Programmers Navigate and Understand the Structure of Code. In Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems (CHI '15). ACM, New York, NY, USA, 3043-3052. DOI: https://doi.org/10.1145/2702123.2702589
3. Andy Borka. 2019. Developer Toolkit. Retrieved August 7, 2019 from https://addons.nvda-project.org/addons/developerToolkit.en.html
4. Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative research in psychology*, *3*(2), 77-101.
5. Buxton, B. (2010). Sketching user experiences: getting the design right and the right design. *Morgan Kaufmann.*
6. Biplab Deka, Zifeng Huang, and Ranjitha Kumar. 2016. ERICA: Interaction Mining Mobile Apps. In Proceedings of the 29th Annual Symposium on User Interface Software and Technology (UIST '16). ACM, New York, NY, USA, 767-776. DOI: https://doi.org/10.1145/2984511.2984581
7. Biplab Deka, Zifeng Huang, Chad Franzen, Joshua Hibschman, Daniel Afergan, Yang Li, Jeffrey Nichols, and Ranjitha Kumar. 2017. Rico: A Mobile App Dataset for Building Data-Driven Design Applications. In Proceedings of the 30th Annual ACM Symposium on User Interface Software and Technology (UIST '17). ACM, New York, NY, USA, 845-854. DOI: https://doi.org/10.1145/3126594.3126651
8. Financial Sites for Women Are Game-Changing—but Do They Have to Be So Pink? Retrieved July 3, 2019, from https://www.glamour.com/story/financial-sites-for-women-do-they-have-to-be-so-pink
9. Google AutoDraw. Retrieved June 23, 2019, from https://www.autodraw.com
10. Jan Hartmann, Alistair Sutcliffe, and Antonella De Angeli. 2007. Investigating attractiveness in web user interfaces. In Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '07). ACM, New York, NY, USA, 387-396. DOI: https://doi.org/10.1145/1240624.1240687
11. Rebecca Krosnick, Sang Won Lee, Walter S. Laseck, & Steve Onev,. 2018. Expresso: Building responsive interfaces with keyframes. In *2018 IEEE Symposium on Visual Languages and Human-Centric Computing (VL/HCC)* (pp. 39-47). IEEE. DOI: 10.1109/VLHCC.2018.8506516
12. Hesham M. Kamel and James A. Landay. 2000. A study of blind drawing practice: creating graphical information without the visual channel. In Proceedings of the fourth international ACM conference on Assistive technologies (Assets '00). ACM, New York, NY, USA, 34-41. DOI: https://doi.org/10.1145/354324.354334
13. Hesham M. Kamel and James A. Landay. 2002. Sketching images eyes-free: a grid-based dynamic drawing tool for the blind. In Proceedings of the fifth international ACM conference on Assistive technologies (Assets '02). ACM, New York, NY, USA, 33-40. DOI=http://dx.doi.org/10.1145/638249.638258
14. Ranjitha Kumar, Arvind Satyanarayan, Cesar Torres, Maxine Lim, Salman Ahmad, Scott R. Klemmer, and Jerry O. Talton. 2013. Webzeitgeist: design mining the web. In Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '13). ACM, New York, NY, USA, 3083-3092. DOI: https://doi.org/10.1145/2470654.2466420
15. Kurze, M. 1996. TDraw: a computer-based tactile drawing tool for blind people. In *International ACM Conference on Assistive Technologies* (pp. 131-138).
16. James A. Landay and Brad A. Myers. 1995. Interactive sketching for the early stages of user interface design. In Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '95), Irvin R. Katz, Robert Mack, Linn Marks, Mary Beth Rosson, and Jakob Nielsen (Eds.). ACM Press/Addison-Wesley Publishing Co., New York, NY, USA, 43-50. DOI: http://dx.doi.org/10.1145/223904.223910
17. T Lavie and N Tractinsky. 2004. Assessing dimensions of perceived visual aesthetics of websites. International Journal of Human-Computer Studies. 60. 3
18. Gitte Lindgaard , Gary Fernandes , Cathy Dudek & J. Brown 2006. Attention Web Designers: You have 50 Milliseconds to Make a Good First Impression!

Behaviour & Information Technology, 25:2, 115-126, DOI: 10.1080/01449290500330448

19. Jingyi Li, Son Kim, Joshua A. Miele, Maneesh Agrawala, and Sean Follmer. 2019. Editing Spatial Layouts through Tactile Templates for People with Visual Impairments. In Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems (CHI '19). ACM, New York, NY, USA, Paper 206, 11 pages. DOI: https://doi.org/10.1145/3290605.3300436
20. Make Office Work Smarter for You. Retrieved June 23, 2019, from https://support.office.com/en-us/article/make-office-work-smarter-for-you-e69ee5f5-d510-4c2c-aee3-d5410a353049
21. Mark W. Newman, James Lin, Jason I. Hong & James A. Landay (2003) DENIM: An Informal Web Site Design Tool Inspired by Observations of Practice, Human–Computer Interaction, 18:3, 259-324, DOI: 10.1207/S15327051HCI1803_3
22. Chuong Nguyen. 2019. PowerPoint is easier than ever with Microsoft's new A.I. tools. Retrieved August 7, 2019, from https://www.digitaltrends.com/computing/microsoft-powerpoint-ai-office-365/
23. Jasmine Oh. 2019. Yes, AI Will Replace Designers. Retrieved June 23, 2019, from https://medium.com/mircosoft-design/yes-ai-will-replace-designers-9d90c6e34502
24. Potluri, V., He, L., Chen, C., Froehlich, J. E., Mankoff, J. (2019). A Multi-Modal Approach for Blind and Visually Impaired Developers to Edit Webpage Designs. In *Poster Proceedings of ASSETS'19, To Appear*
25. Venkatesh Potluri, Priyan Vaithilingam, Suresh Iyengar, Y. Vidya, Manohar Swaminathan, and Gopal Srinivasa. 2018. CodeTalk: Improving Programming Environment Accessibility for Visually Impaired Developers. In Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems (CHI '18). ACM, New York, NY, USA, Paper 618, 11 pages. DOI: https://doi.org/10.1145/3173574.317419
26. Katharina Reinecke, Tom Yeh, Luke Miratrix, Rahmatri Mardiko, Yuechen Zhao, Jenny Liu, and Krzysztof Z. Gajos. 2013. Predicting users' first impressions of website aesthetics with a quantification of perceived visual complexity and colorfulness. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (CHI '13). ACM, New York, NY, USA, 2049-2058. DOI: https://doi.org/10.1145/2470654.2481281
27. Katharina Reinecke and Krzysztof Z. Gajos. 2014. Quantifying visual preferences around the world. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '14).* ACM, New York, NY, USA, 11-20. DOI: https://doi.org/10.1145/2556288.2557052
28. Emmanuel Schanzer, Sina Bahram, and Shriram Krishnamurthi. 2019. Accessible AST-Based Programming for Visually-Impaired Programmers. In Proceedings of the 50th ACM Technical Symposium on Computer Science Education (SIGCSE '19). ACM, New York, NY, USA, 773-779. DOI: https://doi.org/10.1145/3287324.3287499
29. Sketch2Code. Retrieved June 23, 2019, from https://sketch2code.azurewebsites.net
30. Amanda Swearngin, Mira Dontcheva, Wilmot Li, Joel Brandt, Morgan Dixon, and Andrew J. Ko. 2018. Rewire: Interface Design Assistance from Examples. In *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems (CHI '18).* ACM, New York, NY, USA, Paper 504, 12 pages. DOI: https://doi.org/10.1145/3173574.3174078
31. TabNine: Autocompletion with deep learning. Retrieved August 7, 2019 from https://tabnine.com/blog/deep
32. Jerry Talton, Lingfeng Yang, Ranjitha Kumar, Maxine Lim, Noah Goodman, and Radomír Měch. 2012. Learning design patterns with bayesian grammar induction. In Proceedings of the 25th annual ACM symposium on User interface software and technology (UIST '12). ACM, New York, NY, USA, 63-74. DOI: https://doi.org/10.1145/2380116.2380127
33. N Tractinsky, A.S Katz, D Ikar, What is beautiful is usable, *Interacting with Computers*, Volume 13, Issue 2, December 2000, Pages 127–145. DOI: https://doi.org/10.1016/S0953-5438(00)00031-X
34. N Tractinsky, 1997. Aesthetics and apparent usability: empirically assessing cultural and methodological issues. In Human Factors in Computing Systems CHI 97 Conference Proceedings (Atlanta GA), Pemberton S. (Ed.) ACM Press, New York, 115-122.
35. Wikki Stix. Retrieved June 23, 2019, from https://www.wikkistix.com
36. Benjamin Wilkins. Generating code from low fidelity wireframes. Retrieved August 7, 2019 from https://airbnb.design/sketching-interfaces/
37. Jeffrey P. Bigham, Anna C. Cavender, Jeremy T. Brudvik, Jacob O. Wobbrock, and Richard E. Ladner. 2007. WebinSitu: a comparative analysis of

blind and sighted browsing behavior. In Proceedings of the 9th international ACM SIGACCESS conference on Computers and accessibility (Assets '07). ACM, New York, NY, USA, 51-58. DOI: https://doi.org/10.1145/1296843.1296854
38. Branham, S. M., Wahid, S., & McCrickard, D. S. (2007). Channeling creativity: Using storyboards and claims to encourage collaborative design. In *Workshop on Tools in Support of Creative Collaboration (part of Creativity & Cognition 2007)* (pp. 1-4).