DOI:10.1145/3481623

BY CHUN YU AND JIAJUN BU

The Practice of Applying AI to Benefit Visually Impaired People in China

ACCORDING TO THE China Disabled Persons' Federation (CDPF), there are now 17 million visually impaired people in China, among which three million are totally blind, while the others are low-visioned. In the past two decades, China has experienced tremendous development of information technology. Traditional industries are incorporating information technology, with services delivered to users through websites and mobile applications. It is positive technical progress that visually impaired people can access various services without leaving home; for example, they can order food delivery online or schedule a taxi from an app-based transportation service.

However, the development of technology has also brought challenges to the visually impaired in China. First, the cost to make massive information services barrier-free is huge. Information accessibility per se is challenging due to visual impairment coupled with IT developers' poor awareness of information accessibility. These factors result in a large portion of applications that do not meet accessibility standards. Second, the development of technology has led to urbanization and a fast pace of life, and the outdoor environment is not suitable for the visually impaired to walk alone. It is also challenging to develop technology that enables visually impaired people to walk in complex outdoor environments. The development of artificial intelligence creates the opportunity to address these challenges.

CDPF works to establish and promote China's own standard system of information accessibility. The joint force combines the power of the government, universities, and enterprises like Baidu, Alibaba, and Tencent, among others. Zhejiang University, as a member of the Federation, has taken the lead in formulating China's first national Internet information accessibility standard. There are four main principles that provide the foundation for this standard: Perceivability, Operability, Understandability, and Robustness. The standard incorporates 58 standard terms for website and mobile application accessibility, which are divided into three levels based on their influence on barrier-free use, universality and scalability, and the difficulty of technical implementation. This standard can guide Internet content providers to gradually improve their accessible service capabilities. This national standard is being promoted in coordination with the World Wide Web Consortium's Web Content Accessibility Guidelines (WCAG) 2.1, and China has advertised the standard as

The Taobao app is making shopping more accessible to visually impaired users.

PHOTO COURTESY OF ALIBABA GROUP/ALIZILA.COM

"tactile paving on the Internet."

In spite of those efforts, it is still challenging to meet the accessibility standard when developing Internet products, due to the lack of accessibility awareness of developers, inadequate understanding of the real needs of users, and the inability to simulate real user behaviors. Taking advantage of artificial intelligence, media computing, and crowdsourcing technologies, Zhejiang University in Hangzhou, China, has assembled a substantial body of research on URL-clustering-based Web page sampling algorithms and active learning-based sampling algorithms,[11,12] the barrier point detection method,[7] an automatic evaluation system based on Web Accessibility Evaluation Metric (WAEM) barrier weights, evaluation task classification and scheduling algorithms[1] (shown in Figure 1), user experience prediction algorithms,[6] barrier weight optimization algorithms based on user feedback,[5] large-scale data analysis, and so forth. Figure 1 provides an overview of the task classification and scheduling algorithms, which utilize historical user data to train a model and make a correlation analysis after clustering. The result is an assignment map based on which tasks can be assigned to evaluators and how the evaluation results can be analyzed.

Figure 2 shows the overall process of this crowdsourcing-based Internet information accessibility evaluation system. The system achieves a higher accessibility evaluation accuracy with a lower labor cost and is more in line with the real user feelings of visually impaired users. Involving users' real feedback in the process can help analyze the impact of different detection items on users' intuitive experience and help the evaluation result match users' real experience as much as possible. Since 2012, more than 2,000 Chinese government websites have been evaluated annually, includ-

Figure 1. Task classification and scheduling algorithms overview.

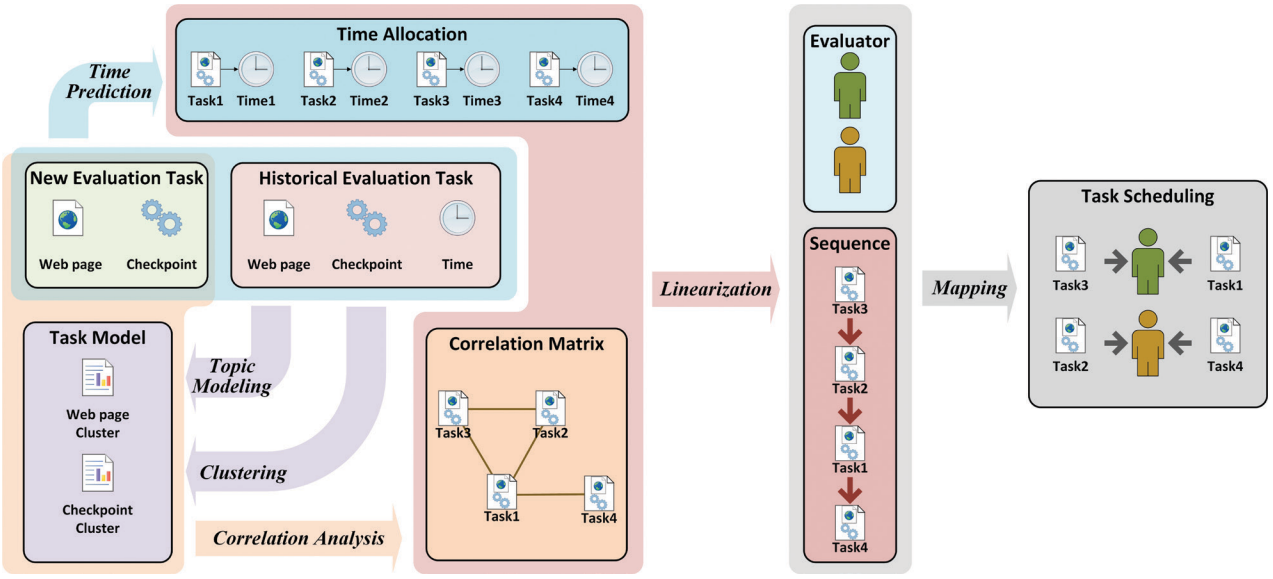


Figure 2. Zhejiang University's crowdsourcing-based Internet information accessibility evaluation system.

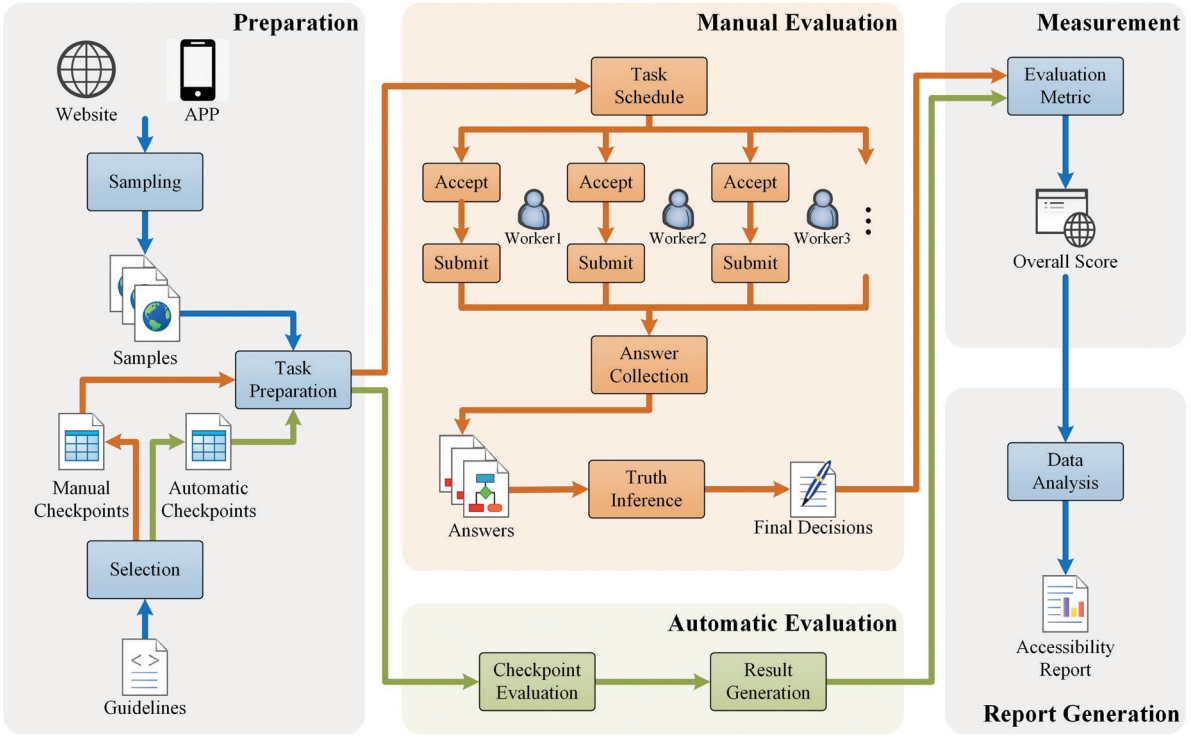


Figure 3. (Left) VIPBoard; (Right) Eartouch.

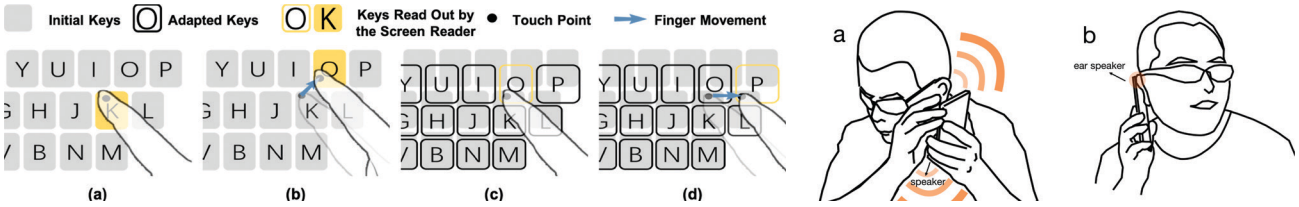
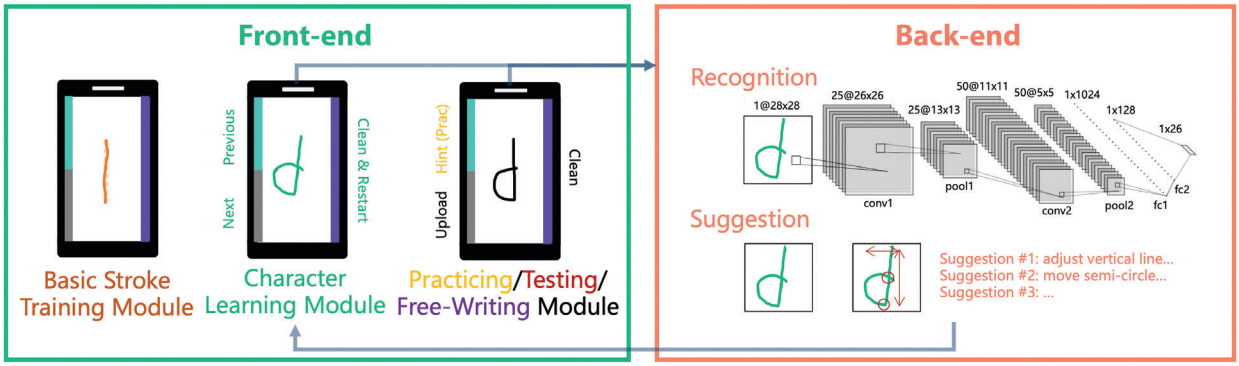


Figure 4. The architecture of LightWrite system.



ing the ministries, commissions, offices, and agencies directly under the state council, state bureaus administered by ministries or commissions, and provincial government websites in China, all promoting the Chinese government's e-service quality.

Innovating Interaction Techniques for Information Accessibility

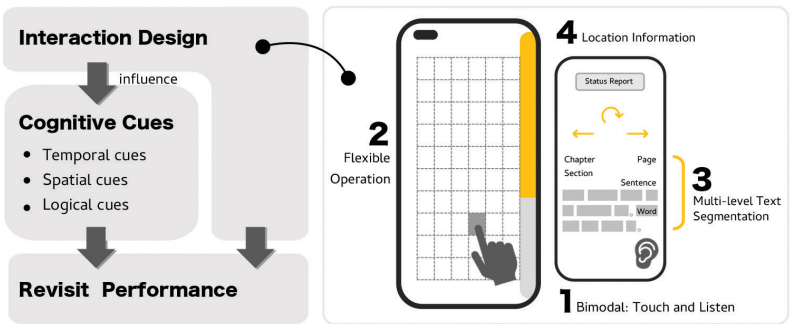
Information accessibility is a popular research area in human-computer interaction. In recent years, with the rapid development of sensing and computing technology, researchers have explored ways to break through the GUI paradigm for accessible use, innovating intelligent and higher levels of barrier-free experience. Tsinghua University represents an activist toward this direction in China; in particular, its research efforts highlight a systematic intersection of identifying user need by consulting schools for the blind, innovating interaction techniques, and deploying them into practice by collaborating with IT companies.

A good example is the VIPBoard,[3] an intelligent keyboard technique designed for visually impaired users. Visually impaired users rely on audio feedback to interact with a smartphone. This makes the word-level autocorrection algorithm of modern software keyboards unusable, because a user cannot proceed to type until hearing the wanted letter. The researchers applied their experience on intelligent input to solve this problem. They iterated a series of solutions, and finally came up with a character-level error-correction mechanism, which eliminates up to 65% of corrections and improved text entry by 11%. Then, via collaboration with Sogou Inc., the VIPBoard technique was integrated into the largest input method software in China and is now serving thousands of users daily. Similarly, to improve the usability of smartphones, the researchers propose EarTouch,[8] which leverages a capacitive screen to recognize and locate a user's ear in contact with the screen. EarTouch enables users to input content with one hand and can protect a user's privacy in public environments. EarTouch has been integrated into Smart Screen Reader, which not only benefits thousands of visually impaired users, but also serves as a platform to experiment with new ideas and innovations regarding information accessibility. VIPBoard and EarTouch (as illustrated in Figure 3) both won Honorable Mention Awards at ACM CHI 2019, the leading conference in the field of human-computer interaction.

Beyond addressing the basic input requirement of smartphones, elevating their cultural level is crucial for visually impaired people to have better job opportunities and improve their quality of life. Researchers in Tsinghua University recognize the breakthrough point to be innovating low-cost and easy-to-access techniques, so each visually impaired user can reap the benefit. LightWrite[9] is an AI teacher on smartphones that uses voice-based descriptive instruction and feedback to teach visually impaired users to write English letters and Arabian digits in a specifically designed stroke. It can teach users handwritten characters, with an average of 1.09 minutes required for each letter. LightWrite serves as a practical solution for teaching writing (see Figure 4).

To enable extensive reading, researchers focused on providing support for revisitation, which is the essential skill of comparing concepts and improving understanding. A variety of navigation gestures and multimodal feedbacks were designed and tested. The final reading interface provides multiple spatial and temporal cues so users can locate the content they have read quickly. Lab experiments showed that an app-based reader with multiple feedbacks could achieve a high level of accuracy and efficiency for revisitation in reading and outperformed the hard-

Figure 5. Revisitation model and design of the reader.



It is still challenging to meet the accessibility standard when developing Internet products, due to the lack of accessibility awareness of developers, inadequate understanding of the real needs of users, and the inability to simulate real user behaviors.

ware point display reader that costs thousands of dollars. Both techniques significantly reduce the cost for visually impaired users to improve their level of culture (see Figure 5).

Applications of Accessibility Technologies

In cooperation with Alibaba, Zhejiang University researched related technologies, such as reading order optimization and image structure understanding, to help visually impaired users obtain image information. The graph-to-sequence-based end-to-end reading order technology incorporated with the OCR-based image structure learning algorithm has been applied in the screen reader developed by CDPF. Zhejiang University also participated in the development of a detection platform for Alibaba to explore rapid solutions for Internet content, such as computer and mobile terminals. A number of Internet commercial services, such as the Taobao online shopping platform and the Alipay online payment platform, have undergone barrier-free transformation in accordance with the national standards. They have optimized 37 functions of the Taobao App, covering basic services such as login and registration, product search, product purchase, receipt confirmation, and rights protection. According to incomplete statistics, there were more than 160,000 online shops on Taobao capable of use by people with disabilities, and 2.46 million people with disabilities used them to make purchases (see Figure 6).

The China Braille Library, Alibaba groups, and Zhejiang University have set up an example of a room in an accessible smart home. The control center mainly consists of a smart speaker designed by Tmall (formerly TaoBao Mall) connecting with more than 30 smart home hardware products such as sensors, robot vacuums, and smart TVs. It improves accessibility in the security, cleaning, illumination, amusement, circular control, and kitchen areas; thus, the visually impaired can control household electrical devices via voice and realize accessible living (as shown in Figure 7). The smart office hardware enterprise represented by Alibaba groups has established an accessibility alliance on smart office hardware. The schools for the blind in 31 provinces of China have specified and deployed a batch of smart office hardware to introduce facial recognition and collaborative working technologies to the special education field. During the COVID-19 pandemic, it guaranteed teaching activities would continue normally and made communication with blind students and their parents accessible, realizing smart accessible school management.

China has increasingly developed special education in the 21st century, growing from two universities established before 2000 to 18 universities today, with many still making preparations. For example, Changchun University first proposed integrating special education into normal higher education, so that other than teaching on professional courses, students in a special educational college could obtain the same cultural quality education, public elective courses, recreational and sports activities and matches, as fully sighted students. Inclusive education is not only conducive to eliminating the unhealthy mentality of disabled students, such as fear of intimacy, and feelings of inferiority and paranoia, but also helps disabled students come in contact with cutting-edge information technology and enter first-class Internet enterprises (see Figure 8).

The China Braille Press and the Institute of Computing Technology of the Chinese Academy of Sciences have designed automated technology for two-way translation between written Chinese and braille. Traditional translation methods require a large amount of manual checking and amending, while the new translation technology combines the N-Gram language model with the rule of phrase translation and creates an improved language model, which can not only get rid of invalid homonym word strings according to braille word segmentation, but also allows full phrases in context to be translated into braille. During the translation, the new technology makes use of the tones of Chinese braille to reduce some mismatched candidates among Chinese characters. The new technology, which can attain 91.43% accuracy when translating Chinese to braille, and 90.32% accuracy when translating braille to Chinese, can be applied in real-world applications such

Figure 6. Visually impaired users shopping online.

Figure 7. An example room of an accessible smart home.

Figure 8. The classroom for special education.

as editing and publishing braille books and establishing braille instructional materials.

Prospect

China's unrestricted technology is in the stage of rapid development, characterized by the combination of innovation and practice, and supported by the China Disabled Persons' Federation and technology giants. Through the innovation and traction of universities, such technology can be put on the ground as soon as possible. In the future, more efforts will be put into making technology barrier-free, not only to support the blind, but also to better support the elderly and other groups with special needs.

The AI can help visually impaired people integrate into society and obtain information on an equal basis. In this article, we have combined the power of the government, industry, and academia. The government, in charge of establishing policy, rules, and management systems, plays a leading role, taking advantage of experts and technology from universities and research institutes to improve the key technologies. Companies in industry understand how the Internet and markets work, in the context of the development of a new assistive product and a complete system for bringing it to market, while the government can make use of and transfer the technology into products to bring them to market using mature market operation mechanisms to push products and services to end users that need them. In addition, China has many special user groups such as the Disabled Persons' Federation and the Blind Persons' Federation, which can help to assure the products and services can satisfy user requirements. C

References

1. Li, L., Wang, C., Song, S., Yu, Z., Zhou, F., and Bu, J. A task assignment strategy for crowdsourcing-based Web accessibility evaluation system. In *Proceedings of the 14th Web for All Conf. on The Future of Accessible Work*. (2017).
2. Liu, G., Xu, H., Yu, C., Xu, H., Xu, S., Yang, C., Wang, F., Mi, H., and Shi, Y. Tactile compass: Enabling visually impaired people to follow a path with continuous directional feedback. In *Proceedings from CHI 2021*, 1–13.
3. Shi, W., Yu, C., Fan, S., Wang, F., Wang, T., Yi, X., Bi, X., and Shi, Y. VIPBoard: Improving screen-reader keyboard for visually impaired people with character-level auto correction. In *Proceedings from CHI 2019*, 517.
4. Song, S., Bu, J., Artmeier, A., Shi, K., Wang, Y., Yu, Z., and Wang, C. Crowdsourcing-based Web accessibility evaluation with golden maximum likelihood inference. In *Proceedings of the 2018 ACM on Human-Computer Interaction, CSCW*, 1–21.
5. Song, S., Bu, J., Wang, Y., Yu, Z., Artmeier, A., Dai, L., and Wang, C. Web accessibility evaluation in a crowdsourcing-based system with expertise-based decision strategy. In *Proceedings of the 2018 Internet of Accessible Things*.
6. Song, S., Bu, J., Shen, C., Artmeier, A., Yu, Z., and Zhou, Q. Reliability aware web accessibility experience metric. In *Proceedings of the 2018 Internet of Accessible Things*.
7. Song, S., Wang, C., Li, L., Yu, Z., Lin, X., and Bu, J. WAEM: a web accessibility evaluation metric based on partial user experience order. In *Proceedings of the 14th Web for All Conf. The Future of Accessible Work*. (2017).
8. Wang, R., Yu, C., Yang, X., He, W., and Shi, Y. EarTouch: Facilitating Smartphone use for visually impaired people in mobile and public scenarios. In *Proceedings from CHI 2019*, 24
9. Wu, Z., Yu, C., Xu, X., Wei, T., Zou, T., Wang, R., and Shi, Y. LightWrite: Teach handwriting to the visually impaired with only a smartphone. *Proceedings from CHI 2021*, 1–15
10. Xu, S., Yang, C., Ge, W., Yu, C., and Shi, Y. Virtual Paving: Rendering a smooth path for people with visual impairment through vibrotactile and audio feedback. In *Proceedings of ACM Interact. Mob. Wearable Ubiquitous Technology* 4, 4 (2020), 99:1–99:25.
11. Yu, Z., Bu, J., Shen, C., Wang, W., Dai, L., Zhou, Q., and Zhao, C. A multi-site collaborative sampling for Web accessibility evaluation. In *Proceedings of the Intern. Conf. Computers Helping People with Special Needs*. Springer, Cham, 2020, 329–335.
12. Zhang, M., Wang, C., Bu, J., Yu, Z., Lu, Y., Zhang, R., and Chen, C. An optimal sampling method for Web accessibility quantitative metric. In *Proceedings of the 12th Web for All Conf.* (2015).

Chun Yu is an associate professor at Tsinghua University in Beijing, P.R. China.

Jiajun Bu is a professor at Zhejiang University in Hangzhou, P.R. China.