Rethinking Our Approach to Accessibility in the Era of Rapidly Emerging Technologies

Gregg Vanderheiden[1(B)], Crystal Marte[2], and Sina Bahram[3]

[1] University of Maryland, College Park, MD 20742, USA
GreggVan@umd.edu

[2] Raising the Floor, Washington, DC 20002, USA
crystal@raisingthefloor.org

[3] Prime Access Consulting, Cary, NC 27511, USA

Abstract. Accessibility has always played catch-up to the detriment of people with disabilities - and this appears to be exacerbated by the rapid advancements in technology. A key question becomes, can we better predict where technology will be in 10 or 20 years and develop a plan to be better positioned to make these new technologies accessible when they make it to market? To attempt to address this question, a "Future of Interface Workshop" was convened in February 2023, chaired by Vinton Cerf and Gregg Vanderheiden that brought together leading researchers in artificial intelligence, brain-computer interfaces, computer vision, and VR/AR/XR, and disability to both a) identify barriers these new technologies might present and how to address them, and b) how these new technologies might be tapped to address current un- or under-addressed problems and populations. This paper provides an overview of the results of the workshop as well as the current version of the R&D Agenda work that was initiated at the conference. It will also present an alternate approach to accessibility that is being proposed based on the new emerging technologies.

Keywords: Accessibility · Regulations · Policy · Equity

1 Introduction

1.1 Future of Interface Workshop

On Feb 15–16, 2023, a two-day workshop was held by co-chairs Vinton Cerf and Gregg Vanderheiden [1]. The Day 1 panels brought together top experts in their mainstream technology specialization to explore key technologies that will be used to create future interfaces and try to predict where these technologies, and where human interfaces in general, will be in 20 years. Day 2 panels brought together disability and accessibility experts, consumers, assistive technology vendors, and mainstream researchers to identify and explore barriers that these new interface technologies might present, as well as potential ways to address these barriers. The panels explored ways that these new technologies could help to address existing barriers that we are unable to adequately address today. Concluding the workshop was a kickoff to the R&D agenda creation process to lay out research that could/should be undertaken and supported to maximize the accessibility of new technologies as they emerge.

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The R&D agenda outlines a forward-thinking approach to accessibility, with a comprehensive framework spanning the next two decades. At its core, the agenda emphasizes capitalizing on emerging technologies to both help integrate accessibility into mainstream technology from the outset, as well as to provide a path to full access to technologies including access by those who are not covered by built-in access. This paradigm combines "born-accessible" for those for whom it is possible, with sure solutions for providing access for all those for whom accessibility is not provided, either because we do not know how to, or because it simply is not done by the manufacturer. Accessibility needs to be embedded into the DNA of emerging and future technologies in a way that does not exclude anyone. Digital technologies have become too integral in our lives today and going forward for them not to be accessibility by all.

Central to the agenda is significant R&D investment in artificial intelligence (AI) and machine learning technologies to create intelligent user agents. These agents would offer nuanced and context-aware assistance, autonomously detecting and adapting to the users' environment, potential dangers, or unfamiliar situations –thereby offering personalized support to users with disabilities.

Direct brain interfaces (DBIs) and extended reality (XR) represent another frontier for accessibility research. The agenda outlines the potential for non-invasive DBIs to enable individuals with severe motor impairments to interact with technology directly through neural signals. With the rapid evolution of XR, including augmented reality (AR) and virtual reality (VR), and integration into society (e.g., Meta Quest, Apple Vision Pro), it becomes essential that these technologies are accessible – and soon. The agenda calls for going beyond addressing visual and auditory experience to a multisensory virtual experience that would include the use of and access to tactile and output. The participants expect that capabilities, digital interactions could be as rich and richer and more complex as those in the physical world. At the same time, they provide an opportunity to provide accessibility options beyond what is possible in the physical world.

In addition to the technical advances, a deeper understanding of the diverse needs, constraints, and abilities of different types, degrees, and combinations of disabilities than we have is also needed so that we can develop more personalized and effective assistive technologies for all types, degrees, and combinations of disability that we do not currently serve.

The draft R&D agenda also includes a need for research on the societal, ethical, and policy implications of technology advancements for people with disabilities, such as data privacy, the economic barriers to access, and the pervasive issue of bias in AI datasets. These technologies pose potential risks and challenges to an already vulnerable population, so there is a need for robust bias, privacy, and security frameworks and measures to ensure these technology environments are safe, appropriate, and effective for all users.

Understanding current and future barriers and opportunities is crucial for creating technologies that are accessible to all and can help remove obstacles that individuals with disabilities face today and might encounter tomorrow. The goal of the workshop and the continuing goal of the R&D Agenda development is to contribute to a collaborative roadmap for researchers, developers, and policymakers, outlining priority

areas for investment, development, and policy advocacy; collaboration is of the utmost importance.

One key result was a discussion of whether emerging technologies would allow us to take alternative approaches. In particular, was the concern that current approaches were not resulting in even a substantial percentage of products being accessible, and those that were, were only accessible to some people with some type, degree, and combination of disability. Further, this was not seen as being solvable using existing approaches with new technologies.

2 Is There a Need for a Change in Approach?

2.1 Access to Technology is no Longer an Option - but a Requirement for Daily Living

With the continued integration of computers and digital technologies into all aspects of our lives, including education, employment, health, and social connection, the ability to use digital interfaces has become critical to all aspects of living. Currently, 76% of U.S. hospitals connect with patients and consulting practitioners at a distance through video and other technology [2]. Patients now use online portals to schedule appointments, access medical records, and communicate with doctors. Nearly one in four adults in the US reported using telehealth from April 2021 to August 2022 [3]. When looking at K-12 schools, 75–85% used online textbooks to some extent, according to the National Center for Education Statistics. Additionally, 95% of schools reported that, to some extent, they use technology for classroom activities that would otherwise not be possible [4]. A 2015 Pew Research study found that digital resources were critical to Americans' ability to research and apply for jobs. Specifically, most Americans (54%) went online to look for information about a job, and nearly as many (45%) applied for a job online [5]. In addition to needing access to digital technologies to search, apply for, and acquire a job, there is an overwhelming demand for digital skills when looking at opportunities in the job market, with 92 percent of all job ads requiring digital skills [6].

2.2 Our Current Approach(es) is not Providing Access to Most ICT - and None for Many

To ensure that products with digital interfaces are accessible to people with disabilities, a series of guidelines, standards, and regulations have been developed for computers, websites, telephones, software, medical devices, self-service transaction machines, and consumer products [7–10] Many large companies (e.g., Apple, Google, IBM, Microsoft) have dedicated teams to improve accessibility and have built significant accessibility features directly into their products [11–14] The growing emphasis on accessibility in the industry has given rise to consultants, accessibility evaluation and remediation companies, and programs aimed at developing, training, and certifying accessibility specialists [15–17].

Despite all the progress in accessibility, however, we have barely made a dent in making all of the products that people with disabilities encounter accessible.

Cumulative data on overall product accessibility are sparse, but where we do have data, the results are discouraging. For example, looking at web accessibility, where an entire industry has evolved, with numerous organizations, training courses, specialized consulting firms, and tools (e.g., authoring, evaluation, testing, repairing, etc.), as well as regulations and lawsuits – we still find that the percentage of websites that are accessible is quite low. A 2023 study by WebAIM evaluated website homepages and found that less than 4% achieved full Web Content Accessibility Guidelines 2 Level AA compliance based on automated scanning. And this study only looked at guidelines that could be automatically checked [18].

Furthermore, a 2012 study by the University of York revealed that "only 50.4% of the problems encountered by [blind] users were even covered by Success Criteria in the Web Content Accessibility Guidelines [WCAG] 2.0 [19]. In other words, even pages that do comply with minimum accessibility guidelines like WCAG aren't necessarily accessible and usable by all people with disabilities. The WCAG working group confirms this, as they explicitly state in the introduction of WCAG:

"…even content that conforms at the highest level (AAA) will not be accessible to individuals with all types, degrees, or combinations of disability, particularly in the cognitive, language, and learning areas. Authors are encouraged to consider the full range of techniques, including the advisory techniques in "Making Content Usable for People with Cognitive and Learning Disabilities," as well as to seek relevant advice about current best practices to ensure that Web content is accessible, as far as possible, to this community." [8].

One reason is that it is difficult to establish testable requirements for some groups, such as cognitive, language, and learning disabilities. For example, using plain language is an important recommendation for this group, but there are no reliable measures for plain language, making it hard to set a testable criterion for it. Although there are advisory techniques for CLL disabilities (e.g., the W3C document on "Making Content Usable for People with Cognitive and Learning Disabilities" these are not technical standards and are therefore not able to be used in regulations or other requirements [20].

Mobile apps are similarly not accessible. Yan and Ramachandran used the IBM Mobile Accessibility Checker to analyze the accessibility of 479 Android apps across 23 categories and calculate the degree of violation. They found that 94.8% had violations and 97.5% had potential violations [21]. Ross et al. found that 100% of 100 popular mobile applications had at least one accessibility problem, and 72% had 5 or 6 accessibility problems [22].

Emerging technologies such as virtual and augmented reality are also presenting new challenges. By design, they capitalize on the simultaneous use of sight, hearing, and motor control. These new technologies and their interface techniques can exclude many people with both single and multiple disabilities. Even companies with large accessibility teams struggle to make their cutting-edge technologies, such as VR, accessible, as do many VR researchers and developers [23].

Although corporations like Apple, Google, and Microsoft appear to prioritize accessibility and have accessibility teams that develop products with a range of accessibility

features built-in [12–14], they are the exception. Studies have found that many companies do not prioritize accessibility and report a lack of expertise and resources (e.g., staff or tools) that would enable or facilitate the development of accessible products [24–26].

And even products that have *built-in accessibility features* only address some individuals with some disabilities. For example, accessibility features available in smartphones are typically focused on one or another disability type, which doesn't account for people who may have multiple disabilities (and are unable to use many of these techniques). People with multiple disabilities have received less attention compared to research on specific disabilities. In reviewing the accessibility features in phones, some disabilities like cognitive, language, and learning disabilities are noticeably less covered. Furthermore, these built-in features don't consider the spectrum that exists within disability groups and may only be applicable to those who have a more severe limitation or who are more technically adept. Bowman et al. found that people with mild-to-moderate dexterity were not well-accommodated by existing motor assistive technology and suggested that this may be because research and design have typically focused on people with more acute motor needs (e.g., switches and voice input) [27] use the products.

In short, we have come a long way from zero accessibility 40 years ago, but in all this time using our current approaches, we have only managed to provide access to people with some disabilities to a small percentage of the products they encounter – and now need to use to succeed in school, work, social participation, travel, or even independent living.

Moreover, even though only a small percentage of information and communication technologies (ICT) and products with digital interfaces are accessible, progress seems to be slowing rather than accelerating.

3 Current Approach vs. Proposed New Approach

3.1 Current Approach

Our current approach to accessibility has basically been to:

1. **For all products** - require that products be made directly accessible as much as possible/practical
2. **For open products (with accessibility APIs)** - use assistive technologies to cover those who aren't reached with built-in accessibility features
3. **For closed products or functionality (where assistive technology cannot be used)** - build accessibility into the product as you can for key disabilities

Unfortunately,

- Most companies do not do #1 or #2 above for their products – because the investment of time, expertise, or effort required does not compete within the company against investing in a new feature or other measures that increase marketability or profit. Also, many companies feel they are too small to do this.
- Even for those that do #2, assistive technologies only exist for some disabilities (and even those features often require moderate to higher technical skills).

- For closed products, built-in accessibility features are usually minimal and don't address all disabilities. And for those who are not addressed, nothing else is possible since the products are closed to assistive technologies.

For example, most of the computers, websites, and even smartphones that "are accessible to people who are blind" (e.g., have screen reading built into them) are only usable by individuals who are blind but who also possess a certain level of technical proficiency and fine motor control. There are large numbers of individuals who are blind who are unable to use screen readers or any of the built-in access features in modern smartphones designed for people who are blind. Many find screen readers (including built-in screen readers in mobile devices) too complicated to use or require physical gestures they cannot remember or cannot reliably perform due to physical limitations.

Some of the other big gaps in the current approach are:

1. Most people designing products do not know how to create their products to be usable across disability. Furthermore, training the people involved in the design of every product – across all disabilities – is difficult, even to a basic level. Disability experts, including this paper's authors, find that they need to consult with colleagues whenever they are faced with having to design a product for cross-disability. If this is true for the authors who focus just on this, how can the constantly changing designers in companies be kept up to the challenge?
2. Even when the current design guidelines are met, they are only "minimum accessibility guidelines." Meeting them leaves many individuals with disabilities unable to use the products. In addition, populations like cognitive, language, and learning disabilities are not fully covered in minimum accessibility standards because, as a field we do not know how to make enforceable, testable guidelines to meet their needs. And 'no regulations' means no pressure to include features or characteristics these users need.
3. We are increasingly finding digital interfaces on closed products. Closed products are products where it's not possible to install or attach assistive technologies. These products also often have minimal or no built-in accessibility. Therefore, closed products or products with closed functionality are inaccessible to many, and nothing can be done for those who can't use them as they are designed.
4. Even for the relatively few products that are fairly accessible, users with more severe cognitive disabilities, or multiple disabilities, are usually not addressed. Sometimes, there are features for more severe disabilities (e.g., physical) but not for mild-moderate disabilities [26]

Ultimately, this results in a large portion of the population being unable to use the digital interfaces they find on products all around them. And there is very little chance that companies will or even know how to make all products, both open and closed, accessible to people with all types, degrees, and combinations of disability.

3.2 Proposed Approach

The proposal is to shift the PRIMARY focus of accessibility efforts…

FROM (currently)

- getting all companies to try to build their products inclusively to meet the needs of all types, degrees, and combinations of disability.
- PLUS (as a safety net for those for whom one is not done) - getting all companies to make their products compatible with all AT for anyone they cannot, or do not accommodate, directly.
- EXCEPT if the product is closed or has closed functionality - in which case there is no safety net.

TO (proposed)

- Creating an information-robot (Info-bot) functionality that can understand and operate the standard user interface on any product a person encounters – thus requiring no cooperation or action by product manufacturers at all in order to work.
- PLUS - creating Individual User Interface Generators (IUIGs) that are tuned to the specific abilities of each individual person - regardless of types, degrees, and combinations of disability - and can take output from the Info-bot and use it to generate an optimized interface that person for each product that person encounters.
- WHERE - the Info-bot functionality would be open-source and free to use for both companies (for testing and training) and users. And that it runs locally so that there is no data leakage from the user to the cloud from its use or person-specific training or learning.

This proposed approach would not mean companies should discontinue building accessibility directly into their products. For the people whose needs are fully met by the built-in accessibility, this approach works, it is most convenient, and allows direct access to the products.

However, for all products where a) built-in accessibility is not provided, b) built-in accessibility does not meet a person's needs, or c) where compatibility with assistive technologies is not provided, this alternate approach would work. It would also work for all those products that have none of the above, or where the manufacturer is unaware or does not make any attempt to make their product accessible (Table 1).

3.3 One Possible Implementation of the General Proposed Approach

This approach would augment our current strategies with a new technology that can interact with digital interfaces without requiring any special APIs and using only the standard interface provided to all mainstream users. That is, it would use computer vision, hearing, and intelligence as input and present the user with an interface tailored specifically to their needs and abilities.

Table 1. A comparison of the two approaches

	Current Approach	Proposed Approach
Primary focus	Built-in direct accessibility	Info-bot + Individual User Interface Generators
Secondary focus	Build in compatibility with assistive technologies PLUS Assuming availability of assistive technologies for each type of disability	Built-in direct accessibility
What safety net is provided if Primary and Secondary focus do not work?	None - for any product where AT compatibility is not provided None - for all closed products	No need for a safety net if IUIGs are available As long as the median user without disabilities can operate the product the Info-bot can, and IUIGs will provide match individuals
Assumptions	all companies will be able to and build in accessibility for all types, degrees, and combinations of disability OR all companies will build open products AND there will be AT that works for all types, degrees, and combinations of disability	An Info-bot can be created that can operate any standard user interface that a median user without disabilities can IUIGs will be designed (or can self-evolve) to match the needs and abilities of people with all types, degrees, and combinations of disability
Percentage of products that are likely to be directly accessible, (meet minimum accessibility standards)	5–10%, perhaps 10–20% with AI assistance	99% (i.e., the percentage of products that have a standard interface useable by median user)
Percentage of types, degrees, and combinations of disability accommodated	3–6% (% of products that are accessible directly or work with assistive technologies)	Limited only by the number and variety of Individual User Interface Generators (IUIGs) created
Probability that the approach would be adopted	100% by the accessibility field (it is the approach today) 6–10% by companies	Probability in short term is not known. Probably it is 100% in 50 years. But sooner? How much sooner?

(*continued*)

Table 1. (*continued*)

	Current Approach	Proposed Approach
Need to change accessibility policy and regulations	None - continue as now	Potentially large change in accessibility policy required (unless standards / regulations are written as outcomes at the user end and not at product ship or purchase time.)
Need to invest R&D to achieve	Needed for incremental improvement and for new technologies Massive if more than the current small % of coverage is desired	Large amount needed - although much will be done as part of normal AI work Much is also needed to understand what IUIGs need to look like for each type, degree, and combination of disability

Specifically, the two major functions described above could be implemented as follows (see also Fig. 1):

1. **The information robot (Info-bot)** (or information robot functionality) would be a single, open-source intelligent agent – that can be pointed at any interface, and it would be able to understand and operate the interface as well as 50% of the population. It would not be as smart as the best human or even the top 30% of humans. But it would be as smart or as able as the median user of a product at understanding and using the interface on the product.
2. **The individual user interface generators (IUIGs)** would be specific to an individual and take the information from the Info-bot and create an interface for each product a user encounters that would be tailored to that individual's abilities, limitations, knowledge, background, culture, and preferences.

Key to this is that the Info-bot does not require anything or any action on the manufacturer's part for it to work since it works directly off of the standard user interface. Any product that has a standard user interface that can be used by half of the population could be understood and operated by the Info-bot.

1. Manufacturers would not have to understand or make specific provisions for accessibility.
2. They would not have to train their staff.
3. They would not have to implement accessibility standards.
   a. They would not even have to know about disabilities or accessibility standards or guidelines.

And if an IUIG existed for a person - regardless of their type, degree, and combination of disability - any product would be useable by that person.

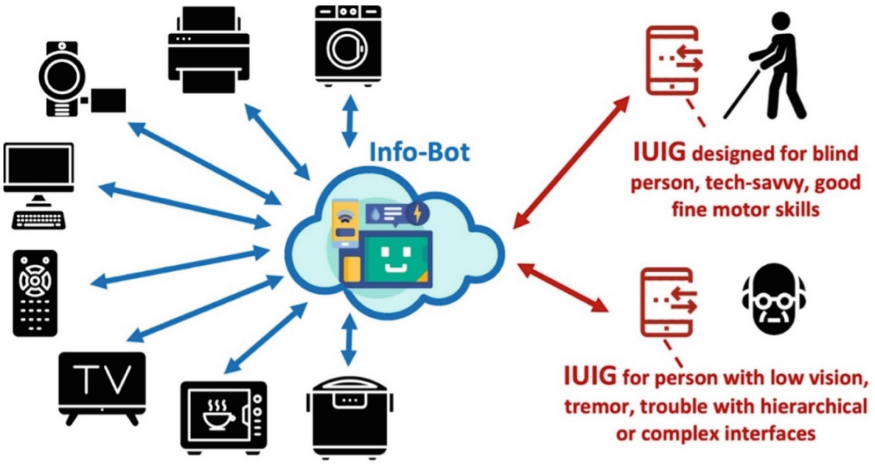

Fig. 1. Diagram showing the relation of devices in the environment, the Info-bot, and Individual User Interface Generators (IUIGs) for two people.

4 Potential Benefits of Such an Approach

4.1 Benefits from a User Perspective

Some potential benefits to users include:

Universally Compatible. Because it would rely only on the standard interface, this strategy does not require any special API to work. Therefore, the system would work on all products everywhere - providing access to essentially 100% of the interfaces a person encounters.

Near Total Accessibility. Because of universal compatibility, the info-bot plus IUIG would provide a major leap forward for accessibility, giving people with disabilities access to **all** the same products in the same places as everyone else.

Unified Interface for Similar Products. Users would only need to learn one interface for products with the same or similar functions. The Info-bot/IUIG could offer a consistent and familiar experience across all similar devices or services. (e.g., all microwaves, all streaming services on TV, thermostats, or any other product – even a new one encountered at a location while traveling would have the same interface presented to the user for the same functionality.)

Control Over [Unsolicited] Changes. The IUIG would generate an interface that remains unchanged for the user, even if the interface of a product undergoes an update or change. The system may prompt users to try out the new interface features, but they would not be forced to use them.

Standardized Mental Model. The IUIG would present familiar interface elements across different devices, whether it's pull-down menus or twisting dials, thus standardizing an individual's user experience across different devices. (e.g., a user encountering a new type of product would see its functionality presented with familiar interface components and behaviors).

Adaptability. The IUIG could be designed to adapt to individual needs as user needs change. For example, as someone gains new skills, the interface might adjust accordingly. Conversely, if someone's abilities decline or if they're struggling due to aging or other factors, the interface would adapt to those changes - even when they change daily or within the same day.

Cognitive, Language, and Learning Disabilities. Our cognitive abilities aren't static. It is a familiar experience for someone to not understand some concept until it is presented more simply, often with a simple example. Once that is grasped, we often find we can grasp the more complex concept. This also applies to individuals who have cognitive, language, and learning disabilities. So, setting a static bar at a low level to allow initial understanding can deny people with intellectual disabilities the opportunity to understand a concept more fully. Instead, the IUIGs could start at a level the user understands and then gradually increase in complexity as a user grasps the concept – allowing every user to engage with technology and content successfully and more fully.

Neurodivergent Users. Neurodivergent users vary widely in their needs. Some require interfaces without flashing. Others need interfaces that are stable and do not change. For others, they need to be able to control how things are presented to them – and to have things done in a consistent way across products from different manufacturers. Some require unique interaction patterns. The proposed approach is ideal for these users in that the interfaces they experience will be tailored for them and be stable over time and across both product types and manufacturers within a product type.

Reducing the Learning Curve. Just as introducing content at a lower level and then raising it, IUIGs could start by using interface paradigms that are simpler or already familiar to the user when they encounter a new device or task. Then, as a person achieves skill and understands the task - more efficient interface elements could be introduced for adoption or rejection by the user.

4.2 Benefits to Industries

Some of the benefits to industry would include:

Decreased Burden. The Info-bot/IUIG would not require anyone to have a deep understanding (or actually any understanding) of disability or accessibility principles in order to ensure wide accessibility coverage for their products. It would also reduce the burden of constantly training staff.

This does not mean that companies should cease developing products that are accessible out of the box for as many people as they can. It does mean, however, that they would be able to reach a much broader range of users - and have a safety net for those

who previously were not able to use a company's products (no matter how hard they have tried or how successful they were).

Simplified Design Process. Designers could focus on what they do best rather than trying to learn and design for every type, degree, and combination of disability.

Higher Compliance and Reduced Litigation Risks. The Info-bot and IUIG act as a sort of super-AT to provide an alternate accessible interface to a much wider range of users than is possible by the current strategies. In fact, the range of users that could effectively use a company's products would only be limited by the quality and diversity of IUIGs available to users.

Helps Address the Closed Product or Closed Functionality Problem. Currently, there are an increasing number of products that are "closed" or have 'close functionality' that does not allow the connection or use of assistive technologies. Traditionally, this has led to many people who rely on assistive technologies being unable to use the products. Some products have built-in accessibility features, but those are limited in who they can all reach. However, since the Info-bot doesn't need any API, there are essentially no products that are "closed" to the Info-bot. The problem of closed products and closed functionality would, therefore, not exist at all if this approach were implemented.

Wider Market Reach and Coverage. The Info-bot and IUIG would be able to reach a much wider audience and cover a much wider range of disabilities than current accessibility approaches. The range of users who can use a product would be limited only by the availability of IUIGs for different types of users and the ability of the user to understand the underlying function of the product. Reaching a wider range of users can both increase profits and improve the brand's reputation.

4.3 Benefits to Government and Society

The potential benefits to government and society include:

Fewer Regulations. Accessibility regulations are becoming increasingly complex and difficult to comply with as more and more types of ICT have emerged, and more products are "closed" to assistive technologies. Current guidelines and standards run from 50 to nearly 300 different specific guidelines or requirements. This has both made it difficult for industry and reduced industry's motivation to try to meet them all.

An Info-bot/IUIG approach would remove the need for many new requirements by eliminating the "closed" nature of products. The Info-bot and IUIG can provide an assistive technology-like functionality - whose only "API" is the standard human interface as input. Therefore, there would be no closed products for such an approach. This would make it easier for companies to comply with accessibility standards and would make new technologies accessible to more people.

Fewer Lawsuits. The Info-bot and IUIG could reduce the number of lawsuits around ICT accessibility by making it easier for companies to comply with accessibility standards.

More People Would Be Able to Use New Technologies and Live, Work, and Participate More Independently. An Info-bot/IUIG could make new technologies accessible, more understandable, and operable to people who have trouble or cannot use standard digital interfaces. This would increase the percentage of our population that is able to participate in daily life, work, and society better and more successfully.

Equity would not be a challenge since the Info-bot proposed would be open source and available to everyone free of charge. Thus, it would be available to those with the most and the least resources and available in all countries, languages, and cultures.

5 Questions, Problems, and Issues with the New Approach

The following concerns or potential issues have been identified to date with the proposed approach.

Feasibility. Everything can look easy on paper before it is actually implemented. Many of the capabilities needed to create the Info-bot functionality or Individual User Interface Generators (IUIGs) do not exist today.

Timeline. While all experts consulted had no doubt that everything described could be done someday - it is not clear how soon some of the more difficult aspects, like fully understanding a human interface, will be possible (rather than just successfully recognizing interface elements - which is being done today).

Privacy. The initial implementations are likely to be cloud-based, and this raises the question of data leakage and privacy. To be safe, cloud-based systems would have to be used only for training and generalized learning. A downloadable version that can run locally and that keeps all information learned from the user (and all user training) local and not shared would be required for privacy. This may slow the advancement of the core but is essential for preventing disability information from being exploited.

Funding. If the Info-bot is open-source and free (to companies and users), it will need some source of funding to grow and maintain it. Although its operation would be a fraction of the cost saved by companies and society, this does not mean that companies would invest those savings in the development of the technology. And there would be no savings until it was fully operational - which would come sometime after the initial costs to create it.

Timing of Adoption. A concern expressed by people with disabilities, and one they have previously experienced, is excitement by policymakers and implementers that leads to pressure on consumers to accept a new and unproven (or not yet ready for prime time) solution that causes existing, working solutions to be abandoned or not as well supported. Since new solutions often take much longer than anticipated. This can leave people with disabilities without any good solution while the new one is still in development if support or enforcement of the existing one is diminished or dropped. Until the new approach is mature and proven, it is unlikely that consumers will be anything but wary and concerned.

Cost of IUIGs. While the Info-bot functionality may be a common open-source effort that is free for all to access and use, the Individual User Interface Generators (IUIGs)

need to be developed for all the different types, degrees, and combinations of disability. While AI might facilitate or automate this in the future, it is anticipated that this advance will come much later than Info-bot functionality is achieved. This is because there are no large data repositories of interface patterns for each of the very diverse types, degrees, and combinations of disability.

Distributive Justice. If IUIGs are created by the private sector and sold like assistive technologies are today, then there will be a problem with all people with disabilities being able to get the IUIG they need. This may be no worse than with assistive technologies today. But if this approach leads to less accessibility being built-in and more reliance on IUIGs - this could make the problem of distributive justice worse if something is not done to make universal access to IUIGs possible.

Need for Extensive Research on IUIGs for All Types, Degrees, and Combinations of Disability. Although we have extensive guidelines on general strategies for making things more accessible to different disability groups, we are less able to say what the optimum interface for individuals with combinations of disabilities or who have trouble understanding and using technologies, in general, should look like.

Disruption of the Accessibility Market and Industries. "There is nothing more difficult to take in hand, more perilous to conduct, or more uncertain in its success, than to take the lead in the introduction of a new order of things. For the innovator has enemies in all those who profit by the old order, and only lukewarm defenders in all those who would profit by the new order, this lukewarmness arising partly from fear of their adversaries who were favoured by the existing laws, and partly from the incredulity of mankind, who do not truly believe in anything new until they have had actual experience of it".

Niccolò Machiavelli 1513

A significant number of large, successful, and profitable companies now exist whose business model is based on the current accessibility paradigm and helping companies understand and conform. A shift to the approach proposed could present a considerable risk to their business models, which are based on repairing the accessibility of companies' websites or products. Initially, these AI accessibility advancements will make their jobs easier, more efficient, and more effective, leading to higher throughput and profits. But if the shift eventually happens or companies bring these tools in-house, it can lead to a decrease in the need for their services. This will be truer if their business model is based on fear of lawsuit and less so if their business is driven by a desire to have products "born accessible" to more people. Hopefully, those who are based on lawsuit risk will be able to shift to other areas, like all other industries do to accommodate changing technologies and markets. Until then, it is unlikely they will be supporters of such a shift.

Need to rEthink Existing Policy and Regulations. Policy, laws, standards, and regulations are all things that take a long time to create and are hard to change. The rapid pace of technology evolution is already challenging them in so many ways, some because we do not even have good experimental strategies for dealing with the technology, for example VR. This proposed approach may require a complete re-think of accessibility laws and regulations. However, it is possible that, to the extent that current standards

and regulations are based on outcomes (what should be true in the end) rather than prescriptive (how things should be done), the standards could continue to be applied, with the Info-bot and IUIGs used as a strategy to meet them (when and where it is, in fact, effective at meeting them).

Being Confused With Overlays. Overlays are actually very old and have been around for decades. They provide limited accessibility features to single pages by embedding JavaScript into each page. However, recently, they have been marketed along with some simple auto-repair tools as a means of avoiding accessibility lawsuits. The problems with them include a) they sometimes interfere with users' assistive technologies, b) they only work on a single page/site - leaving the user without access to any other pages - including pages needed to get to the site, c) they do not address all of the accessibility problems that pages have - just ones that are automatically detectable, and d) their repairs are sometimes not very good and aimed more at passing the automated test than actually meeting the full set of accessibility guidelines. The fact that they are marketed as making pages accessible when they do not, that some interfere with users' AT, and that they are sold with language suggesting that they will prevent lawsuits has caused a backlash in the disability and accessibility communities.

The proposed approach is completely different. Some of the ways include: a) it works on all pages and all technologies (as well as all aspects of the product outside of the browser), b) it creates an interface for each individual that is bespoke for that individual, c) it would not interfere with any user AT - because it does not change the original interface in any way, it simply provides a separate custom interface, fit to each user. In addition to not affecting the original interface so it can't interfere with people's existing AT, the premise is that it would not be released until it was acceptable to people with disabilities as an alternate solution.

6 Theme and Variation for the New Approach

Although the approach in its basic form is described as a full post-product-release, user-run-time solution for accessibility, its components can be used at all stages of product development, deployment, and use.

For example:

1. At the development stage to increase the number of products that are "born accessible" to more users
   a. The Info-bot could be used as part of the design process to identify ways to build accessibility in.
   b. The Info-bot could also be used to both review and repair designs prior to release.
2. Creating accessibility at delivery
   a. The Info-bot functionality could be used as an intermediary at the time of delivery. For example, it could be built into web browsers to repair the accessibility of any page encountered.
   b. It could also be combined with some IUIG-like features to give "overlay" like abilities to every page visited.

3. Combining these could provide "built-in" access to some people (sort of like built-in access in smartphones) while repairing any bad pages so they are compatible with AT
4. Born accessible to AT
   a. The Info-bot could create, repair, or populate an accessibility API for AT pre-release.
5. Provide real-time (or pre-stored and buffered) interface socket
   a. The Info-bot could create an interface socket for IUIGs to plug into to access a product.
   b. (this is the basic role described above for the Info-bot)
6. Real-time creation of Individual Interfaces (Info-bot that is also an IUIG)
   a. The Info-bot could be extended to include both Info-bot and IUIG functionality so that it directly creates user-specific interfaces for each product for each user.

For both 4 and 5 (and to some extent all), the Info-bot needs to learn a product's interface only once - unless the interface itself (not the content) changes. This can actually be done at the manufacturer during product testing, or by the first user to use a product. It can then be stored, saving real-time compute cycles and the need to allow the Info-bot to peruse the interface to learn it each time.

7 Conclusion

It is difficult to estimate how easy or hard this will be to do overall or the timeline for it to be feasible. It does appear from industry discussions during and after the Future of Interface Workshop [1] that this would eventually be doable. But that, too, needs further exploration and determination. There are already some underpinnings under development and prototypes of early implementations of the concept in existence [28, 29].

We believe a concerted effort by the field to explore and build the proposed approach will have two key benefits:

1. It will spin up a variety of advances that will have an immediate impact on underserved populations today. These may take the form of new assistive technologies for these populations. It may involve advances that will allow these populations to take advantage of some of the current APIs available for other disability groups, such as individuals who are blind.
2. In the long term, it can provide near-ubiquitous access – i.e., access to essentially all devices and individual encounters in their daily life – for persons with a much, much wider range of types, degrees, and combinations of disabilities than we can dream of today.

However, such an effort could be disruptive at the time of implementation and would need careful study and even more careful implementation to avoid the problems cited above for consumers. It would also be complicated both because of existing markets and interests and due to the number of different stakeholders that would need to be involved.

The best approach would be if an incremental path could be found that keeps enhancing existing approaches until they can evolve into the new approach. Also, key would

be if it was possible to continue but satisfy the old requirements with the new approach as an option for automatically meeting many of the requirements.

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