A 20-year Prospective View of Accessibility and ICT

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Abstract. Over the past 40 years, the field of ICT accessibility has seen significant progress. What started with "special devices for special people" evolved into public and company-specific accessibility guidelines, international standards, and accessibility laws both in Europe and the U.S. Many large companies have dedicated teams to improve accessibility and have built significant accessibility features directly into their products. The growing emphasis on accessibility in the industry has given rise to consultants, accessibility evaluation and remediation companies, and training programs aimed at developing, training, and certifying accessibility specialists. Despite all of the progress in accessibility, however, there are still major shortcomings. Audits of the field reveal that a low percentage of websites and products are accessible. Moreover, while some products have built-in accessibility features, they are only accessible to some individuals with disabilities. For example, smartphone screen readers with their gesture controls are fantastic for some blind users but are too complicated or physically impossible for others who are blind. Additionally, many products do not effectively address the range of cognitive, language, and learning disabilities, even though this is cumulatively the largest disability group (Disability and Health Data System 2021). While we've made great progress from essentially zero products accessible to anyone 40 years ago, today, there are still only a fraction of products that are accessible. Even the best among these are still inaccessible to a wide range of individuals. In sum:

1. There are no products that are accessible across all of the different types, degrees, and combinations of disability.
2. There are a small number of products that are reasonably accessible across disabilities. But even those are only accessible to more typical or able individuals (e.g., those who are blind but are more digitally adroit versus the full range of people who are blind and who may have other disabilities).

While it is essential to continue moving forward with our traditional methods, there is also a need to consider augmenting them with new approaches that:

- can reach the large number of individuals who are currently left out and
- require less effort, so more companies are willing and able to make their products accessible.

Recent and emerging technological advances may give us the tools to do this. In this chapter, we will briefly discuss the evolution of ICT accessibility before introducing an alternate approach to accessibility, its potential benefits, and what might be required to implement such an approach.

Ein 20-Jahres-Rückblick auf Barrierefreiheit und IKT

Zusammenfassung. In den letzten 40 Jahren wurden auf dem Gebiet der IKT-Zugänglichkeit erhebliche Fortschritte erzielt. Was mit "speziellen Geräten für spezielle Menschen" begann, entwickelte sich zu öffentlichen und unternehmensspezifischen Barrierefreiheitsrichtlinien, internationalen Normen und Barrierefreiheitsgesetzen sowohl in Europa als auch in den USA. Viele große Unternehmen haben eigene Teams zur Verbesserung der Barrierefreiheit eingesetzt und wichtige Barrierefreiheitsfunktionen direkt in ihre Produkte eingebaut. Der wachsende Stellenwert der Barrierefreiheit in der Branche hat dazu geführt, dass Berater*innen, Unternehmen für die Bewertung und Behebung von Problemen mit der Barrierefreiheit sowie Schulungsprogramme für die Entwicklung, Schulung und Zertifizierung von Barrierefreiheitsspezialist*innen entstanden sind.

Trotz aller Fortschritte im Bereich der Barrierefreiheit gibt es jedoch immer noch große Mängel. Prüfungen in diesem Bereich haben ergeben, dass nur ein geringer Prozentsatz der Websites und Produkte barrierefrei ist. Darüber hinaus verfügen einige Produkte zwar über integrierte Barrierefreiheitsfunktionen, sind aber nur für einen Teil der Menschen mit Behinderungen zugänglich. So sind z. B. Smartphone-Bildschirmlesegeräte mit ihren Gestensteuerungen für einige blinde Nutzer*innen fantastisch, für andere blinde Menschen jedoch zu kompliziert oder physisch unmöglich. Darüber hinaus gehen viele/ die meisten Produkte nicht auf die verschiedenen kognitiven, sprachlichen und Lernbeeinträchtigungen ein, obwohl dies insgesamt die größte Gruppe von Behinderungen ist (Disability and Health Data System 2021).

Obwohl wir große Fortschritte gemacht haben, nachdem es vor 40 Jahren praktisch keine Produkte gab, die für jeden zugänglich waren, ist heute immer noch nur ein Bruchteil der Produkte barrierefrei. Selbst die besten unter ihnen sind immer noch für eine Vielzahl von Menschen unzugänglich. Zusammengefasst:

1. Es gibt keine Produkte, die für alle Arten, Grade und Kombinationen von Behinderungen zugänglich sind.
2. Es gibt eine kleine Anzahl von Produkten, die einigermaßen behinderungsübergreifend zugänglich sind, aber selbst diese sind nur für eher typische oder fähigere Menschen zugänglich (z. B. für blinde Menschen, die digital geschickter sind, im Gegensatz zu blinden Menschen, die möglicherweise andere Behinderungen haben).

Es ist zwar wichtig, dass wir mit unseren traditionellen Methoden weitermachen, aber wir müssen auch darüber nachdenken, sie durch neue Ansätze zu ergänzen, die:

- die große Zahl von Personen erreichen können, die derzeit nicht berücksichtigt werden, und
- weniger Aufwand erfordern, so dass mehr Unternehmen bereit und in der Lage sind, ihre Produkte zugänglich zu machen.

Jüngste und sich abzeichnende Fortschritte in der Technologie könnten uns die Instrumente dafür liefern.

In diesem Kapitel werden wir kurz die Entwicklung der IKT-Barrierefreiheit diskutieren und, bevor wir einen alternativen Ansatz zur Barrierefreiheit vorstellen, seine potenziellen Vorteile und was es möglicherweise erfordert, um einen solchen Ansatz umzusetzen.

1 The Evolution of ICT Accessibility

The technology and disability story began with "special products for special people" using mainstream tech to create assistive tools. In the 1960s, people repurposed telephone relays and solenoid-equipped typewriters for communication by those with limited mobility (Copeland 1974; Vanderheiden and Grilley 1976).
Digital logic and microprocessors led to solid-state communication aids. The first microprocessor-controlled device, AutoCom, was launched in 1973 by the Trace Center (Vanderheiden, Volk, and Geisler 1973).
Efforts at computer access began in earnest with the introduction of personal computers (Atari, TRS-80, Commodore, Apple, etc.) in the 1970s. People began writing programs that would turn microcomputers into dedicated ATs, such as talking terminals and typewriters. IBM's release of the PC prompted Jim Thatcher and Jim Wright to develop the PCSAID, the first known screen reader (Thatcher 1994). PCSAID was the PC version of Al Overby's SAID (Synthetic Audio Interface Driver) system, which connected an IBM terminal to a telephone keypad and Votrax synthesizer eventually becoming IBM’s Talking Terminal. The PCSAID later evolved into the IBM Screen Reader for DOS, released in 1986 (Keates 2006).
It quickly became apparent that there was a need for ‘transparent access’, which allows people with disabilities to access computers in the same manner as everyone else and use alternate input methods that the computer could not differentiate from standard inputs (Vanderheiden 1983). With transparent access techniques, people with disabilities can fully use the computer for all of the same reasons and with all of the same software as everyone else.

An early example of transparent access was the Dual Nested Computer Approach proposed by Vanderheiden (1981). This approach used two computers, with the first computer acting as a special interface to the second computer. The first computer could then inject keystrokes into the second computer without the second computer knowing that the keystrokes were not coming from the standard keyboard. As a result, the individuals could use the second computer to do all the same things that anyone else was able to do.
A notable innovation was the Adaptive Firmware Card (AFC) for the Apple IIe by Paul Schwejda (Schwejda and Vanderheiden 1982). Since the Apple IIe lacked an operating system, software would directly read user keystrokes from the hardware keyboard encoder. As a result, it was not possible for assistive technologies (AT) to inject themselves between the keyboard and the software, as is done in modern operating systems. Schwejda's design allowed the AFC to intercept memory reads from the memory-mapped keyboard encoder and seamlessly insert alternative input methods, like sip-and-puff Morse code, as if they were standard keystrokes. This was the first instance of a single computer, with the AFC, that offered transparent access to all software running on the computer. The AFC also enabled game speed adjustment for accessibility.

This concept evolved into interfaces that could emulate both keyboards and mice, leading to the development of standards by the Trace Center: the Keyboard Emulating Interface (KEI) and later the General Input Device Emulating Interface (GIDEI) standard (10). GIDEI was later adopted in Access Pack for Windows, AccessDOS, Serial Keys, and an independent program called AACkeys (Vanderheiden et al. 2022).

Modern desktop operating systems allow assistive software, screen readers, and alternate input methods to run on the same computer using multitasking and Application Programming Interfaces (API)s provided by the operating system. This has eliminated the need for hardware-based input-emulating interfaces in most cases.

Mobile device operating systems, on the other hand, are typically closed. In other words, each application is sandboxed, which prevents apps from affecting each other. This security measure protects mobile devices from malware, but it also prevents the use of third-party assistive technologies. To address this problem, companies like Apple and Google have started building assistive technologies directly into their mobile platforms (Apple 2024). The benefit of this is that these assistive technologies are free and built into every product. However, the disadvantage is that if a user's disability is not covered by the assistive technologies built into their mobile device, there is no way for a third party to create an AT for them.

Not just computers and phones

Beyond computers and mobile devices, the proliferation of digital interfaces on everything from home appliances and security systems to automobiles is creating a new challenge for people with disabilities. Many of these products are closed products with no accessibility features, and there is no way for others to add accessibility. This puts them out of reach of anybody who needs AT to use them.

Where we are

Digital interfaces are now essential for education, employment, daily living, healthcare, and even car operation – functions that did not require digital interaction 40 years ago. Today, independence and effectiveness in society hinge on the ability to use these interfaces. Given that few products are fully accessible to individuals with all types, degrees, and combinations of disabilities, there is a pressing need for alternative solutions to access the increasing number of systems and products with digital interfaces that:

- People need access to but do not have accommodations for,
- Are closed systems impervious to current assistive technologies,
- Have built-in accessibility features but are still not accessible to people with different types, degrees, and combinations of disabilities

A big question to be explored later is whether emerging technologies can help solve these accessibility challenges. A brief overview of such emerging technologies will set the stage for discussing their potential role in addressing these issues.

1.1 Guidelines, Policies, and Standards

Starting in 1985, the Trace Center developed a series of guidelines to make ICT accessible, followed by hardware and software guidelines for Apple, IBM, consumer products, and guidelines for Web content. These guidelines were adopted by Microsoft and other companies, and later became part of broader standards such as W3C WCAG, Section 508, ISO/IEC standards, and other standards and regulatory documents (Vanderheiden et al. 2022).

Today, there is a wide range of accessibility standards and regulations, but despite this and legal enforcement efforts, the vast majority of websites and products are not accessible. Furthermore, even those deemed accessible often are not accessible to a large number of people with multiple disabilities and even to some with a single disability.

1.2 Closing the Loop in Design Strategies

At first, accessibility work was focused on individuals, with solutions being designed for that individual, and only later generalized for broader sale. Over time, the focus broadened, with mainstream companies building accessibility into their products (with AT filling in the gaps). This approach (inclusive design plus AT as a safety net) then became the basic approach in practice and, when they came, in accessibility regulations and procurement requirements. Unfortunately, both the available AT and accessibility features built into mainstream products, for market reasons on both fronts, tend to focus on the greatest number of people with a particular disability or the ones who are most able. The result is both mainstream products and AT that are designed for people with "typical" "average" or "most common form of" a disability, leaving out those on the edges with multiple disabilities or less technical skills. For example, there are no good solutions to computer access for all those who are blind but are unable to understand or use screen readers. This is true for both desktop and mobile devices.

Recently, there has been a resurgence of the more individualized approach. "Ability-based design" focuses on individual users and creating general interfaces that can be adapted to a range of individual users (Wobbrock et al. 2018). Another approach, "solve for one - extend to many," is similar in that it focuses on the individual at first, and the design is generalized to a broader range (Holmes 2018).

The ultimate goal is auto-hyper-personalization: automated creation of bespoke interfaces for each person, aligning with their unique preferences, needs, and abilities. Manually creating individualized interfaces is not practical, so a mechanism for automating the process of creating individual user interfaces for each product, representing the optimum interface for that individual person with their skills and abilities at that specific time and circumstance, would be the only way to achieve this.

2 An Alternate (Supplemental) Approach to Accessibility Using Auto-hyper-personalization

What if the interfaces we experience fit us – exactly, rather than us having to try to adapt to and understand them?

As an alternate approach to interface accessibility and usability, we propose a combination of an **Info-Bot functionality** with **Individual User Interface Generators** (IUIGs) (Vanderheiden and Marte 2024).

What is proposed is to:

A. create a single, open-source intelligent agent – the **Info-Bot** – that can be pointed at any interface and would be able to understand and operate the interface as well as 50 % of the population. It would not be as smart as people -

just as smart as the median person in figuring out that interface. The Info-Bot would be coupled to an individual user interface generator (IUIG).

B. create a range of **Individual User Interface Generators** (IUIGs) that can take the information from the Info-Bot – and create an interface that would be tailored to an individual – for each product they encounter. Different people would have different IUIGs based on each person's abilities, limitations, knowledge, background, culture, and preferences.

2.1 The Info-Bot

The Info-Bot function would take any interface that it was exposed to, including an immersive 3D interface, and be able to understand and abstract it so that an alternate interface can be created (by an Individual User Interface Generator – (see IUIG below) that may be totally different (to meet each user's unique needs) but accomplishes the same functionality. For example, in the case of a user who is blind, a typical visual interface could be abstracted so that a completely optimized audio interface could be created from it by that person's Individual User Interface Generator.

Since the Info-Bot would have the capabilities of the median user for perceiving and understanding digital interfaces, the Info-Bot could be able to perceive and understand any controls, texts, and visuals that the average (median) user is able to. Assuming that a product was designed to be usable by the median person (at least half of the population), the Info-Bot would work with any product with a digital interface. For specialized equipment (e.g., scanning electron microscopes), it will be useable depending on the complexity of the interface (not the product but the interface), the knowledge of the user, and any special 'training' that the Info-Bot has been given for that device's interface.

Some potential characteristics of the proposed Info-Bot:

- free for all to use – as individuals – or for incorporation into product architectures.
- is able to understand interfaces at least as well as the 50th percentile human (the median)
    - companies, therefore, would have to design a product that could be understood and used by at least half of the population (but no more) in order to have it understood by the Info-Bot
    - if the Info-Bot could not understand some new feature of a company's product, the Info-Bot would be open-source so the company can improve it so that it could.
- open source (perhaps the GNU Lesser General Public License - LGPL) so all can improve it and benefit from improvements. LGPL allows the use of the licensed code within proprietary software without requiring the entire software to be open-sourced, offering more flexibility in how the code can be integrated and used. Using LGPL may be important for compatibility and interoperability.
- actively supported by industry and government(s) so it stays up to date and functioning at "50 % or better" level of the population.
- since it would be a centralized resource, it can be exposed to new interfaces by manufacturers or others and once it has seen and learned an interface once – it knows it for all instances of the product being used by anyone, anywhere.

- since it would be open-source, if it has trouble with any completely new interface technique introduced by a company, the company (or others) can teach the Info-Bot about that interface technique. However, most new products use interface techniques known to 50 % or more of the population, even if the product is entirely new.
- runs in the cloud initially – but runs locally in the future
    - this allows continual updating from the cloud,
    - but running locally can assure privacy when there is no back-collection of data
- is initially separate from IUIGs but may merge with them later.
- can take output from the IUIGs and operate the product interface.
    - this may be via API or direct simulation of human control movements that the product is expecting.
- funding to maintain the Info-Bot would come from government funding – or from industry as part of a social contract for industry being able to rely on the Info-Bot to address accessibility for those who cannot use the standard interface on their products.

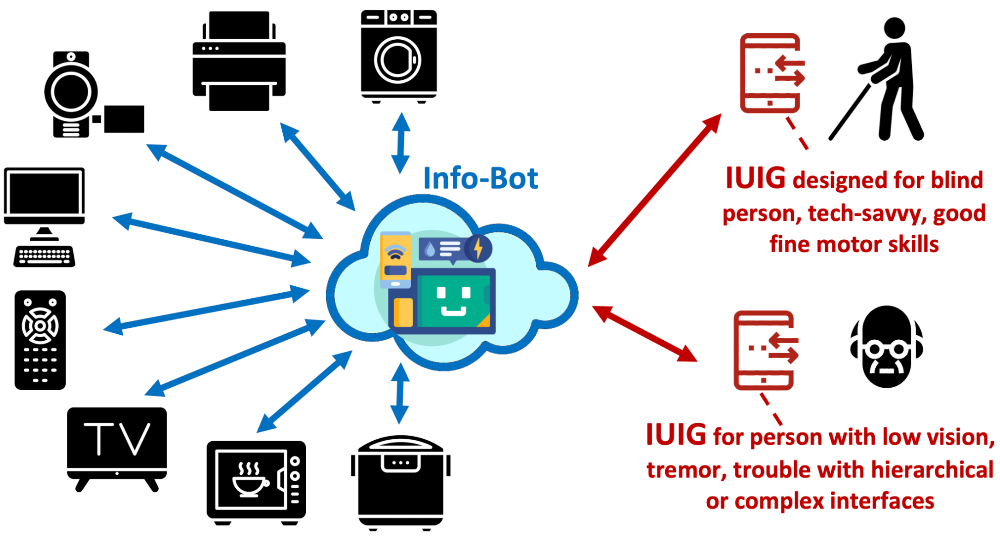

Figure 1 Info-Bot and IUIG

2.2 IUIGs

Individual User Interface Generators (IUIGs) interact with the Info-Bot and create a custom interface for each individual that is optimized for their abilities at that moment. This interface would not be a sensory transformation of the original interface into a different modality (i.e., it would not be an auditory presentation of a visual interface like current screen readers). Instead, it would be an interface that would be completely optimized for that individual. It would be, for example, the interface that standard products would have if everyone in the world were exactly like this individual. If they were very smart, technically adroit, and loved massively parallel interfaces, that would be what it would present. If they had trouble with technology and complexity, it would present a different interface more tuned to their abilities, possibly involving more groups of fewer elements to choose from – and a more guided interface. The interfaces may be more direct command-oriented or more interaction-oriented depending on the preferences and skills of the user with each device.

Some characteristics of the envisioned IUIGs:

- each IUIG would be specific to an individual
- for products with the same functionality, but different interfaces, the IUIG would present the same (familiar, optimized) interface to the user – with just a different name.
    - for example, the user would see the same interface for all microwave ovens – with the only difference being features added or missing if they were present or missing from a particular microwave.
    - Ditto for all TV streaming services. The choices, favorites, continue watching, search, sign in, etc. would all be presented and operate the same familiar way.
    - if a TV streaming service changed its interface–the IUIG interface would not change unless the user wanted it to. If there were new features – they would be added to an interface that otherwise did not change.
- products with very different functionality would have different interfaces, but they would operate with user controls and metaphors that were familiar to the user.
- initially – IUIGs would be hand-designed by experts – and individuals would select (or have selected for them) the IUIG that is best suited to their abilities and preferences.
- over time – AI could be used to help adapt and adjust IUIGs to be hyper-personalized for each individual.
    - If an IUIG does not perfectly align with a user's needs, they have the power to give feedback (e.g., "That was too fast," or "That was confusing," or “Too many choices”) and have their feedback used to refine and enhance their IUIG. The focus here is on the individual's preferences and their lived experiences.
- all changes to the IUIG behavior would be under user control. This includes the ability to explore different IUIGs to see if they like other interface approaches better, and the ability to reject any change suggested by or for the IUIG.
- Similar to today’s assistive technologies, IUIGs would include both free and commercial versions.
- IUIGs that account for different languages, cultures, etc., would also be available.

IUIGs would present the interface for any product the individual encounters in the form best suited to them. This may be visual, voice, tactile, simple, complex, few choices at a time, many choices at a time, using gestures, not requiring gestures, with large controls, with tiny controls requiring minimum movement, operable with eye-gaze, operable with thought, etc.
The key is that the individual would have an interface they could use with ANY product they encounter <u>without the product manufacturer needing any understanding</u> of their particular type, degree, or combination of abilities/disabilities.

IUIGs could be created by assistive technology vendors, researchers, consumers, family members, disability organizations, or anyone else with the skills required – to meet the needs of a person or people with different types, degrees, and combinations of disabilities.

At first, IUIGs would likely resemble the current spectrum of interfaces provided by assistive technologies. And they would leave the same gaps as our current assistive technologies – reflecting our lack of understanding of exactly how to design interfaces for many underserved groups. There are excellent general descriptions of the types of things that would help different underserved groups (W3C 2021) but no specific designs for each different type, degree, and combination of disability – for different products. Later, as we conduct more research and develop targeted IUIGs for particular people in response to this new capability, a richer array of IUIGs that can address previously unaddressed and under-addressed users will emerge. The incorporation of AI may also allow us to address the problems presented by people whose abilities are changing rapidly – or whose abilities change from day to day or even over the course of each day.
It is important to note that although the Info-Bot and the IUIGs would be separate in the beginning – they may eventually merge to provide a more optimum information exchange or tighter integration.

2.3 Interface Activation

One challenge with the Info-Bot/IUIG approach is the activation of the standard interface by the Info-Bot. As the user operates their IUIG interface, those actions need to be communicated back to the standard product interface.
There are currently three approaches being discussed for doing this. Two are API-free, and one uses a very simple API that requires no knowledge of disability.

Direct activation by the Info-Bot. The Info-Bot itself could be outfitted with manipulators that could directly operate the standard user interface. The BrushLens (Liang et al. 2023) and TouchA11y (Li et al. 2023) projects both involve a device that scans a touchscreen, provides an alternate (non-visual) interface to the user, and then has two different mechanisms that activate the touch screen – TouchA11y uses an extendable tape on a swivel that extends and positions a touch probe over the desired button and then activates it. With BrushLens, the device instructs the user to move their device to the approximate location on the screen, and then one or more auto clicker(s) on the device that is over the desired button is activated, which registers a touch on the specific part of the touchscreen. For the universal operation of different types of product interfaces, a manipulator that can provide a wider range of human articulation may be required.

Cuing of the user. A second approach involves directing the user to operate the device. After the user makes their choices on the IUIG, the Info-Bot directs them to operate the standard interface. It might use a directed beam of light, where the user simply pushes whichever buttons or keys the Info-Bot shines a light on. It might do this with actual light – or it may just highlight the buttons on the screen with a “virtual ring light,” and the person looks at the augmented video on screen as they use their hand to push, twist, flip, or otherwise operate physical controls. For individuals who are blind, it can use audio cues, including spatial (if they have good binaural hearing), tonal, and beep rates, to direct the user's hand movements. In a very short period of time, the cues would become almost reflexive and quick without requiring thought or interpretation of the audio cues.

Very simple X-Y-Z API. The third approach does require an API but a very simple one that can be implemented by engineers with no knowledge of disability or accessibility. It can also provide a very valuable interface for product testing – so it will have benefits to the company besides accessibility. With this approach, each product (with a two-dimensional interface) would be able to accept an x and y position and an action at that position. If the product has a touch screen with simple button presses, then it would only have to accept an x and y coordinate and a 'press' or 'click' command. If the length of time a button was pressed also had meaning, it would include 'press-down' and 'press-release' etc. Each product would also include two reference points visible to cameras that the Info-Bot could use as references for the x-y coordinates. A very simple yet secure method for connecting this Info-Bot interface on the product to the Info-Bot itself will be required. For security, perhaps a dynamic number/QR code and a lockout to allow only local operation and only one person access at a time, or some other method, will be required.

3 Benefits of the Alternate Approach

The benefits from such an approach would include benefits to users, product designers, and government/society.

3.1 Benefits from a User Perspective

Near Total Accessibility: The Info-Bot and IUIG would provide a major leap forward for accessibility, giving people with disabilities the same opportunities as everyone else. It would rely on the standard interface, so it would work on all products everywhere.

Universally Compatible: Because it would rely only on the standard interface for input, this strategy does not require any special API to work. The system would therefore work on all products everywhere – providing access to essentially 100 % of the devices they encounter rather than the current estimated 3 % or so.

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 would offer a consistent and familiar experience across all of the similar services.

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 could 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 the devices, whether it is pull-down menus or twisting dials, thus standardizing an individual's user experience across different devices.

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

Cognitive, Language, and Learning Disabilities: Our cognitive abilities are not static. All of us often fail to understand a 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 the lower level to allow initial understanding can deny them the ability to understand it more fully. 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.

Reducing the Learning Curve: Just as it is a common human strategy for teaching complex information to introduce it 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.

3.2 Benefits to Industry

Some of the benefits to industry would include:

A decreased Burden on Industry: The Info-Bot/IUIG would not require anyone to have a deep understanding of accessibility or disability expertise 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 not continue to create 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 have not been able to use their products no matter how hard they have tried.

Simplified Design Process: Designers could focus on what they do best without trying to learn and design for every type, degree, and combination of disability. By providing a framework where the Info-Bot can provide access, they would reach their current and a much broader audience.

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 use the interface on their products would only be limited by the quality and diversity of available IUIGs.

Helps Address the Closed Product or Closed Functionality problem: Currently, an increasing number of products are "closed" or do not allow the connection of AT. This makes them much harder to make accessible with today's accessibility approaches. However, the Info-Bot and IUIG use only the standard interface as input and can thus provide access that meets or exceeds the abilities of plug-in or installed AT without requiring anything to be plugged in or installed.

Scalability and Wider Market Reach: The Info-Bot and IUIG would be exponentially more scalable 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 user's ability to understand the underlying function of the product. Reaching a wider range of users can both increase profits and improve the brand's reputation.

3.3 Benefits to Government and Society

The potential benefits to government and society include fewer regulations, fewer lawsuits, and more people being able to participate in society.

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 AT. This has put a burden on the industry and has led to decreased accessibility for users.

An Info-Bot/IUIG approach would remove the need for many of these new requirements by eliminating the "closed" nature of products. The Info-Bot would provide an API for AT that only requires the standard human interface as input. 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 better and more successfully participate in daily life, work, and society.

4 What is needed to make this possible?

The Info-Bot/IUIG concept, while simple in principle, poses challenges in its implementation. Recent research and technological advances hint at its feasibility, and ongoing projects lay the groundwork for it. However, key advances are needed, including:

1. **Abstracting User Interfaces:** Abstracting user interfaces (UIs) in Human-Computer Interaction (HCI) separates presentation from application functions, allowing greater flexibility in presenting information to different users, devices, and contexts. ISO 24752, a standard for a "Universal Remote Console" (URC), aimed to standardize and abstract UIs for personalization and adaptation to user needs and devices (International Organization for Standardization 2006). However, it was impractical to integrate a standard interface socket across all devices, and manufacturers were resistant to having someone "control our product while looking at someone else's logo." The Info-Bot/IUIG approach circumvents this and requires no API. However, the ISO 24752 work highlights

the complexities of creating an abstract UI socket, which may be required for communication between the Info-Bot and IUIGs.

2. **Artificial Intelligence:** Advanced generative capabilities are key for dynamic interface creation, requiring AI systems to seamlessly integrate visual, auditory, and tactile information (i.e., multimodal integration). Current AI systems can extrapolate from existing data, but they do not truly understand interfaces, so significant advances in AI will be needed before AI can interpret and generate interfaces as well as humans. Additionally, a repository of good examples of interfaces for a wide variety of disabilities will be required.
3. **Understanding in Computer Vision:** Beyond object recognition, computer vision must understand context extracting intent behind visual elements, not just their appearance (e.g., distinguishing between and understanding the roles of a volume slider and a scroll bar).
4. **Local Artificial Intelligence:** AI technology is moving from the cloud to local devices, such as smartphones and laptops. This is possible due to hardware advances, such as more efficient processors and memory, new types of memory, and specialized AI accelerator chips. Using local AI will be important for protecting user privacy and allowing users to benefit from AI capabilities without compromising their personal data.
5. **Self-Adaptation:** IUIGs must self-adapt over time based on user interaction and environmental changes without compromising user control.
6. **User Interface (UI) Understanding:** The ability to derive the user-interface intent and functionality from just UI components is essential for Info-Bot and IUIG development. This involves using computer vision and machine learning to decipher the components without knowing the underlying structure. For example, Info-Bot would only receive pixels as input for a graphical UI and audio waveforms for a voice UI.

   Apple has already taken steps in this direction with its Screen Recognition tool, which helps users navigate apps by identifying on-screen elements. However, it cannot understand UI components. Wu et al.'s Never-ending UI Learner is an emerging solution to this as it consists of an automated mechanism to infer semantic properties of UIs. It crawls apps from a mobile app store and interacts with UI elements to learn from different scenarios and constantly update its model (Wu et al. 2023).
7. **Mapping User Intent into Actions:** Unlike current assistants, advanced personal agents will need to feature dialogic interfaces that use conversation to understand meaning. They will monitor the user's state in near-real-time and use natural language processing to deduce the user's intent without exact commands. For example, instead of saying, "Raise the temperature," a user could simply express that they are cold.

   Current technology allows us to map home automation technology to user assertions using AI. For example, a user could converse with ChatGPT, which would then generate programmatic code to interact with their smart home. While the system could currently turn on the lights without needing a prompt, a better model would ask the user if they wanted the lights on. The key is the ability to identify user needs without specific instruction. This demonstrates the growing capacity of AI-driven systems to directly map user statements to appropriate actions. Given the trajectory of technological advancements, we can expect to see a steady growth in the level of automated comprehension and intent mapping.

8. **Content-Based Understanding:** AI systems are already performing tasks like summarizing charts and converting bullet points into presentations. In the future, they will be able to perform more complex content-based transformations across formats to make them more accessible to people with disabilities or functional limitations. For example, an AI system could answer a query like "Which restaurant did Tom and I last dine at?" by asking clarifying questions about the context. It could then use your calendar or charge card history to identify the exact restaurant. This type of functionality, which is currently limited to pre-scripted scenarios, could be used to assist people with a variety of disabilities, such as dementia, visual processing difficulties, learning disabilities, or people who may not understand how to operate the interface.
9. **Multimodal Integration:** Having a framework that can seamlessly integrate and process diverse data streams, such as visual, auditory, and tactile data, is essential to the functionality of the Info-Bot and IUIG. Currently, Microsoft Research is developing an open-source framework called the Platform for Situated Intelligence to address the engineering challenges of developing systems and applications that process multimodal streaming sensor data and make it easier for developers to build AI that can perceive, understand, and act in the real world (Bohus et al. 2021).
10. **Understanding how to design an interface for each and every different individual:** Many Info-Bot and IUIG research needs fall outside of mainstream ICT/AI research, requiring advances in understanding disability and adaptive interfaces. Developing Info-Bot and IUIG will require a significant increase in our understanding of how to design effective interfaces for people with every type, degree, and combination of disabilities, especially people with multiple disabilities. We need to define the best approaches for all permutations and combinations of disabilities before IUIGs can be created to generate the interfaces these individuals need.
11. **Automatic Generation of User Interfaces:** Automatic generation of UIs is at the core of IUIGs, and any advances in this area, regardless of whether they are disability-related, will benefit IUIG development. However, IUIGs for people with disabilities require much more diverse UIs, with far fewer (or no) existing UIs to use as models for each different type, degree, and combination of disability.

These challenges and opportunities are integral to realizing the Info-Bot/IUIG concept, and continued research and innovation are essential for its success.

Note on 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 ready for market’) 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.

5 Conclusion

Technology often excludes users who do not fit the typical profile of the young, able-bodied, and those with good vision and hearing. Despite efforts, achieving universal product accessibility remains a challenge, with only about 3-5 % of products currently accessible, and this accessibility only addresses a small subset of people with disabilities. As a result, it will be tremendously difficult to close the gap if we only rely on traditional approaches that require accessibility be built-in or require access to the infrastructure layer of products.

To make technology more accessible to everyone, a new approach is necessary, focusing on individualized interfaces tailored to each user's needs, cognitive abilities, and preferences. The Info-Bot and IUIG aim to do just such a thing by dynamically creating accessible interfaces without requiring access to a product's internals, offering numerous benefits for both users and industry, such as achieving near-total accessibility, standardizing mental models, and increasing scalability and profitability.

The Info-Bot and IUIG have the potential to address current accessibility issues and future interface challenges, even providing access to products lacking built-in accessibility. It could provide a path for users to access all products, even when the accessibility required by law is not provided.

However, the feasibility, practicality, and limitations require further exploration and a new social contract between developers and consumers will be essential. And any implementation needs to be aware of unintended consequences and the concerns of the disability community that the old regulations and practices for accessibility should not be abandoned until the new are up, running and proven to take their place. This shift could impact accessibility policies and regulations, simplifying implementation and addressing some of the emerging unsolved issues (e.g., closed products and immersive environments). The best approach may be an incremental path that uses these techniques and technologies to keep enhancing existing approaches until they can evolve into the new approach. Also, key would be if it was possible to continue to satisfy the old requirements using the new approach as an option for automatically meeting many of the existing requirements.

Further exploration of the concept is underway. For more information, see the Info-Bot webpage (Cerf and Vanderheiden 2023).

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