Towards Ubiquitous Accessibility: Capability-based Profiles and Adaptations, Delivered via the Semantic Web

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ABSTRACT

The continuing proliferation of mobile devices, content and applications presents barriers to the mainstreaming of Assistive Technologies (ATs), despite their potential utility for users in demanding situations or with minor-to-moderate impairments. We have previously proposed that user profiling based on human rather than machine-oriented capabilities, coupled with a shift from conspicuous ATs to considering a broader range of *adaptations* presents opportunities for platform and AT vendors to support many more users. However there has not been a standard, consistent and, most importantly, straightforward way to deliver these benefits. We propose that this delivery gap can be bridged by using the semantic web and related technologies, so the potential benefits of the capability-based approach may be realised.

Categories and Subject Descriptors

H.5.4 [**Information Systems**]: Hypertext/Hypermedia—*User issues*; K.4.2 [**Computing Milieux**]: Computers and Society—*Assistive technologies for persons with disabilities*

Keywords

Adaptation, Capability, OWL, Profile, RDF, Semantic, User

1. INTRODUCTION

Users have an increasingly large choice of ways to access digital content and are spreading their time across multiple devices. We (and others, as discussed in [5]) proposed that an adaptive approach to interface design allows the user more control to personalise their interaction providing better ubiquitous [6] accessibility.

Currently the assistive technology landscape is vast and users may find it difficult to find the right assistive technology for them. When a solution is found it then has to be checked not only for compatibility with the system, but that it does not disrupt the user through an unintended side-effect. For the technical work-package of the wider, sociotechnical Sus-IT project[1] we have employed an adaptive support system allowing assistance to be offered that is appropriate to the user given their capabilities [1].

In order to facilitate this kind of system, reasoning must be carried out as close to the problem domain as possible and flexible storage needs to be implemented that is able to aggregate the often disparate data needed to make decisions and match assistive technology with a user in need. Modelling the user based on their capabilities, a holistic storage framework was developed [2].

1.1 Contributions

Here we argue that capability-based reasoning about adaptations, *delivered via the semantic web,* will both open up accessibility to the wider population and enable many stakeholder organisations to benefit.

Due to its rise in popularity and potential to provide cross-platform services, the semantic web has been chosen as the delivery method for the proposed storage system. In particular the Resource Description Framework (RDF) combined with the Web Ontology Language (OWL) have been chosen due to their flexible and descriptive nature, as well as the potential to use inference capabilities.

1.2 Trends and Opportunities

Three converging trends create the opportunity for capability-based reasoning, delivered via the semantic web, to bring improvements in accessibility for the wider population.

- Ubiquitous and differentiated devices. (Requires supporting a more diverse user group and profiles that are more portable across devices.)
- Service-based content and application delivery. (Requires accessibility delivery to be web-compatible.[2])
- More adaptable/mutable applications, e.g. mash-ups. (Requires smaller, “Micro-ATs” [6] which, along with other customisation options and traditional ATs, we call adaptations.)

A wide range of research projects work in these areas; Table 1 provides an overview of the goals of some of these.

[1] `http://sus-it.lboro.ac.uk/`
[2] A number, such as ATbar (`http://atbar.org/`) already are, but are not easily discoverable by novice users.

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Table 1: Overview of the goals of some related projects

Project	Includes hardware	Based on human capabilities	Easy user self-identification	Roaming profiles	(Subtle) adaptations	Adaptation discovery
SNAPI[1]	Yes	No	Yes (smartcard)	Possible	Hardcoded	Out of scope
CC/PP[2]	No	No	Out of scope	Possible	Hardcoded	Out of scope
GUIDE[3]	Yes	Yes (not standardised)	Possible	Possible	Yes (inc. dev. toolkit)	No
GPII[4]	No	Possible	Possible	Yes	Yes (Micro-ATs)	Yes
Sus-IT	No	Yes	Possible	Yes	Yes	Yes

Note: as the projects' goals differ, this is an overview of the field; not a like-for-like comparison: 1: `http://snapi.org.uk/` 2: `http://www.w3.org/TR/2004/REC-CCPP-struct-vocab-20040115/` 3: `http://guide-project.eu/` 4: `http://gpii.net/`

2. PROPOSALS

2.1 Human Capabilities and Reasoning

Device functionality changes rapidly, e.g. mice had scrolling wheels added to them, but are now being supplanted in some areas by touch-based input. In order to maintain a user profile that can be of use across a range of devices and applications, it is necessary to store that profile in terms of human capabilities, using ratified standards such as ICF from the World Health Organisation [7] and associated standard medical units of measure, rather than machine-specific quantities (such as pixel depth). Recording details about the user's fine motor dexterity can tell us how likely it is they will be able to use a mouse wheel *or* form certain touch gestures (as discussed in [1]).

A person's visual acuity enables us to determine a minimum sensible font size for any device, at any resolution or screen size, given an assumed or pre-measured reading distance. The user's visual acuity need not be actively probed by the system; it can be estimated based on the known *physical* size of text on a given device. The goal is to progressively refine estimates for the boundaries of a user's capability range in order to suggest appropriate assistance–*not* to make abrupt and noticeable adaptations–so a passive, "ball-park" approach is preferable to one that is more accurate but constantly questions or tests the user. (Bootstrapping is discussed in [5, sec. 4.3].)

Cognitive problems are, inherently, more challenging to resolve as they require the co-operation of content authors to a much higher degree. These are touched upon later.

2.2 Adaptations: Generalised ATs

Adaptations, as proposed in [5, sec. 4] and [1, sec. 3], are generalised ATs. They range from sometimes in-built customisations such as the base font size for GUI widgets (or web content), through Vanderheiden's "Micro-ATs" [6], to monolithic ATs such as alternative keyboards or screen readers. By considering the whole range of possible adaptations, suggestions for assistance can be made for people experiencing transient impairments. A cultural, as well as technical, expectation of adaptivity in systems can help ensure their architecture is sufficiently open for more specialist ATs [6].

The mechanism of effecting changes may be platform-specific (e.g. using existing accessibility APIs) or agnostic (e.g. using the DOM, for content). The DOM is a prime example of a mature, simple but powerful interface enabling many types of adaptations to a range of content.[3] However, the reasoning process for matching capabilities to adaptations needs to know only the following in order to make suggestions.

- Capability: requirements of the situation and content; levels of the user; capacity of the adaptations.
- Side-effects of the adaptations; essentially the degree to which the adaptation obstructs the flow of information from the device (e.g. zooming the screen reduces the amount that can be seen, resulting in a capability burden on motor and cognition, due to panning).

2.3 Semantic Web Delivery

RDF is a set of web standards for expressing data and metadata by making statements in the form of triples. OWL provides language to impose rules on the data, extending RDF to allow new statements to be inferred (via rules) from existing ones. RDF has been successfully applied to user modelling [4] and forms the basis of CC/PP.

A strength of this approach is its ability to draw upon metadata. Compiling a holistic profile for a user using a traditional "static" method would be difficult, as even if a complete profile could be gathered in a timely manner, it would quickly become out-of-date as the environment changes or the user gains experience. More appropriately a user profile will be gradually assembled from data provided both by the user and the system they are using; as new and changing capabilities are captured, the profile is kept up-to-date. Issues raised when relying on a static profile become powerful opportunities when viewed through a semantic lens.

With semantic profiles, available data are processed along with associated metadata, with the reasoning process continually assessing their worth to provide a confidence judgement for any decisions made. When data are deemed "out-of-date" (either due to the passage of time, or conflicting capability readings arising) they can be archived and patterns can be inferred to plot capability change, e.g. decline, allowing pre-emptive accessibility solutions to be invoked. This can prevent the user from suffering the loss of service (and associated threat of abandonment) typical when reactive support is provided. If data are missing altogether, it may be possible to use inference from generic profiles aggregated across all users, *or those with similar capabilities.*

Existing standards can be used and extended as necessary; the tree structure of WHO's ICF [7] (which runs from gross modalities of interaction to specific individual capabilities) makes it ideal, as content, adaptations and even users can be marked up to as fine a level of granularity as possible, or as justifiable by manufacturers and developers, whom may adopt the approach incrementally.

[3] As used by (X)HTML and GUI toolkits such as Mozilla's XUL (`http://developer.mozilla.org/en/XUL`).

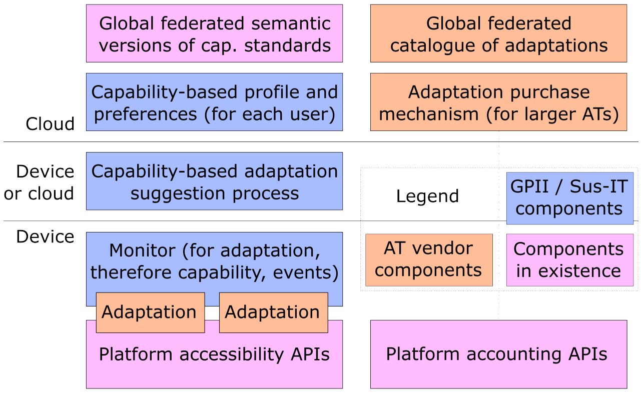

Figure 1: Architecture overview.

2.4 Burden on Developers and Authors

A common view amongst development or authoring organisations is that implementing accessibility will not produce sufficient return on investment. As researchers, we are aware that improving accessibility can improve the experience for all users, particularly in mobile (potentially demanding or adverse) situations. Unfortunately, even those platform vendors that have ATs built into their products (e.g. Apple's iPhone[4]) segregate these into "Accessibility" settings, of which most users remain unaware. Further, when these ATs are employed, they often drastically change the way the device must be used (zooming in and panning the screen rather than just increasing the size of widget text and reflowing the interface, for example).

The ubiquitous accessibility infrastructure proposed here and depicted in Figure 1 is designed to support discovery of appropriate adaptations for most people out-of-the-box. Adopting it would also enable specialist ATs for those with recognised disabilities, should they be available for the platform, to function more seamlessly (as hooks into the system would be provided to them). Further, as it is based on existing ratified standards, it would not require as much effort to implement as the (complimentary) existing accessibility APIs that are already present on most contemporary devices—and it would improve the return on the investment in those APIs by enabling more people to discover adaptations that use them.

Platform vendors must include the capability reasoning library [5, sec. 5.1] in their operating system. They must also mark up the capability requirements of the in-built features of their system, and capabilities addressed by any ATs it includes. This can be done to any level of granularity as the ICF is tree-structured.

Devices must have capability requirements mark-up.

Application and Content authors may optionally mark up their content, to any level of granularity. By default the reasoning process will fall back to reasoning about the suitability of the modalities of the elements in the document. Alternative content may be required to support cognitive impairments as presentation adaptations may be insufficient.

Adaptations must enumerate the capabilities they assist.

Due to the trends discussed in section 1.2, it is surmised that this extra effort will be seen to be cost-effective in the near future. Our reasoning processes provide drop-in candidates for the proposed GPII's *matchmaker* and *preferences storage* components[5], thus increasing their potential usefulness in the eyes of platform and AT vendors.

3. APPLICATIONS AND ADVANTAGES

The theme of the proposed technique is to build bridges between existing recognised standards and forms of assistance, in order to make them more discoverable to users.

3.1 Using Existing Standards

The key bridge to be built (described in [1]) is between the established standards for human capabilities, such as WHO's classification of functioning, disability and health [7] and those for the technical adjustments that can be made to machines, such as ISO 24751 [3]. Existing profiling methods (e.g. SNAPI; CC/PP; [4]) tend to express profiles at the more technical end of the spectrum, which is not as portable to new types of device as capability data. The following sections are all based on this central reasoning technique.

3.2 User–Adaptations

By considering users' preferences as well as the potential gap between the capabilities required by the content, device and situation and those possessed by the user, we can suggest appropriate adaptations (settings changes; micro-ATs or ATs). "Preferences" are the trade-offs the user is willing to make when an adaptation is made, as adaptations often impede the flow of information in order to make that information that *is* presented clearer in some way.

When presented with a choice, would the user prefer, e.g., 2D scrolling, keeping the normal visual layout, or would they prefer 1D scrolling, at the cost of re-flowing the layout (making it different to that experienced by other users). These trade-offs are encoded in the abstract, allowing the reasoner, in this example, to determine that 2D scrolling causes higher cognitive and motor load. If the user had dexterity problems too, then the re-flowed 1D scrolling alternative would be more highly recommended than 2D scrolling.

3.3 User–Device

We can generalise this to a situation in which the user is free to choose the most suitable device. For example, a new smartphone could be recommended based on the users' and devices' relative capability match. This could present an incentive for retailers to support the proposed user profiling technique–and would not be possible unless the profiles were based on existing ratified and impartial standards such as [7], nor available on the web in a ubiquitous interchange format such as RDF.

3.4 Product Vendor–AT Developer

As noted by Vanderheiden [6], an open market for adaptations could be created (an effective "Accessibility App Store"—though we submit that it should be tightly integrated into the host platform, rather than segregated, for the reasons of user awareness given in section 2.4). AT developers could increase their potential market massively by

[4] `http://www.apple.com/accessibility/iphone/`

[5] `http://gpii.net/components`

moving to micro-ATs based on user capabilities. Platform vendors would intrinsically gain improved access for a more diverse user population, which would improve as more adaptations are developed. Ethical matters around recommendations and profile security are discussed in [5, sec. 4.4].

4. CONCLUSIONS

This paper proposes the union of three techniques to aid the provision of accessibility solutions. AT provision should be made via adaptations rather than the traditional conspicuous and monolithic ATs. This both increases the impact the chosen adaptation has, due to smaller ATs being more focused on specific problems, and decreases undesirable impact through conflicts with other hardware and software.

Storing user profiles and marking up content and adaptations in human capability terms allows problem-centred reasoning; finding the right adaptation for the problem becomes a comparison between needs and abilities, albeit with the discussed preference (trade-off), and relevant device, constraints. The possible solutions may be ranked against these constraints to evaluate the potential benefit available.

Using the semantic web as the the delivery mechanism for the established capability standards, as well as profiles and adaptation catalogues provides a flexible descriptive language that is easily transported, platform-independent and can inherently make use of inference, as described.

Should platforms also adopt integrated adaptation directories/marketplaces, appropriate adaptations may be suggested for any given device and situation. The likelihood of technology abandonment may be significantly reduced as cross-device optimisation of users' interactions is possible, based upon a dynamic portable personal profile.

4.1 Illustrative Example

Imagine a user with fine motor dexterity problems. Recording an ability to use a mouse, but not its scroll wheel, is too device-specific. Given the capability-centred approach we would store information regarding the capabilities of the user's finger. The inability is indicative of a finger dexterity problem reduced capacity in fine motor skills. On trying to use a public multi-touch terminal, the user may find their reduced dexterity a problem, as it may preclude using pinch-to-zoom gestures. Although the user may never have used a multi-touch device before, inference can be made from their lack of fine motor capability that the pinch gesture could be unattainable. A zoom widget, such as a large slider bar, can be provided for the user. On a small device such as a tablet, where screen space is at a premium, this would not be provided for most users. On a public information terminal there is likely more space, but given the popular design aesthetic of minimising screen clutter, an explicit zoom widget may not have otherwise been provided. Further: if a user is not known to have experience with multitouch interaction—therefore lacking the appropriate mental model—the terminal can be adjusted to offer explanation.

It is the combination of capability based profiling, semantic storage and adaptive accessibility that make this approach so powerful.

4.2 Future Work

We developed a capability-based adaptation system for Sus-IT (with acceptance testing complete and longitudinal testing ongoing). We now wish to: (1) prepare this for delivery using the techniques proposed here, with the goal of wider adoption and (2) improve tools for developing cognitive adaptations.

In order to support cognitive adaptations, such as context-and-capability-sensitive help for applications, more mutable applications are needed (to provide hooks for such adaptations), as is additional work from content authors. Examples of such adaptations include reminders or tutorials on how to use programs.[6] It would be possible to employ a crowd-sourcing approach to the creation, storage and capability-based recommendation of such help material, though more accessible authoring tools will be required to lower the barriers to creating them.

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[6]These could be automatically adapted so that they are rendered appropriately for some users, though alternative content may be required for those with cognitive impairments.