# Towards an Ontology-based Representation of Accessibility Profiles for Learners

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**Abstract.** Web accessibility has gained significant attention over the past decades due to the widespread use of the internet, which has urged web developers to address the needs and preferences of a variety of users. In e-learning contexts, learner profiles can be used to describe the needs and preferences of users and adapt the educational resources accordingly. We propose the use of ontologies to represent accessibility needs and preferences in learner profiles in order to structure the knowledge and to access the information for recommendations and adaptations in OpenCourseWare systems. In particular, we propose to use and extend the ACCESSIBLE ontology containing knowledge about disabilities and web accessibility standards. In this work, we extend the ACCESSIBLE ontology to represent accessibility knowledge and requirements for learning contexts with respect to the standards of the IMS Global Learning Consortium.

**Keywords:** Accessibility, OpenCourseWare, OCW, Semantic Web, Disabilities, Ontologies, Web Accessibility, Learner Profile, IMS AfA, ACCESSIBLE.

## 1 Introduction

Accessibility is a key requirement for developing web applications, especially in e-learning contexts [1]. One emerging type of e-learning systems are OpenCourseWare (OCW) systems, which provide means for distributing free educational content to a wide range of learners over the web. These learners include people with disabilities who have diverse needs, in terms of the type and severity of their disabilities, which must be addressed by OCW systems. In addition, they have different preferences: for example, one blind user might want to use a screen reader while another blind user might prefer a braille display—or both might want to use the same device but with different configurations (e.g., different text reading speeds). Defining and representing the needs and preferences of disabled learners with the help of learner profiles in order to adapt the OCW system and educational content accordingly is still an open area of research.

We propose the use of ontologies to describe the accessibility knowledge required to represent learner profiles and fostering the development of accessible OCW systems. Formally representing this knowledge by means of ontologies can ease sharing, integration, reuse, and reasoning as well as steer the adaptation of the OCW system and educational content.

In our previous work [5], we identified the ACCESSIBLE ontology [6] to be very suitable to represent learner profiles in OCW contexts, as it covers many relevant accessibility aspects (i.e., disability characteristics, assistive devices, guidelines, and standards). In this work, we extended the ACCESSIBLE ontology to include further accessibility aspects that are needed to fully represent profiles of learners with disabilities. In particular, we added relevant concepts from the accessibility specifications of the IMS Global Learning Consortium [2].

The remainder of this paper is organized as follows: Section 2 summarizes relevant background knowledge on web accessibility and learner profiles. Section 3 introduces the IMS AfA concepts and presents our extension of the ACCESSIBLE ontology. Section 4 outlines the envisioned personalization system, before the paper is concluded in Section 5.

## 2 Related Work

As we are interested in how accessibility information can be integrated into learner profiles using ontologies, we examined existing standards for learner profiles and ontologies related to accessibility and learning objects.

### 2.1 Standards for Learner Profiles

Since we are focusing on the accessibility needs and preferences of learners, two accessibility standards are most relevant: IEEE PAPI and IMS LIP. The "IEEE Standard for Learning Technology – Public and Private Information for Learners (PAPI Learner)" [9] was first published in 2001. It describes portable learner records in order to exchange learner profiles among different systems. It is composed of six categories: *personal*, *relational*, *security*, *preference*, *performance*, and *portfolio* information. Accessibility is not explicitly addressed in the PAPI profiles, but corresponding aspects can be implicitly represented in the *preference* category.

The IMS Learner Information Package (LIP) specification [3] is composed of a number of categories, including one for accessibility aspects. This *accessibility* category is described in detail by the IMS Access For All (IMS AfA) specification [2]. IMS AfA is a guideline and metadata specification, based on the ISO/IEC 24751-1:2008 standard, for developing accessible learning applications and resources with respect to the learner needs and preferences. It links the accessibility preferences of a learner through the AfA Personal Needs & Preferences (PNP) model to the learning objects defined by the AfA Digital Resource Description (DRD). The main idea is to use similar properties and terms for representing learner preferences and features of digital resources in order to ease their mapping.

We decided to base our work on IMS LIP because it explicitly defines web accessibility concepts in accordance with the W3C WCAG standards and guidelines [4]. Also, the properties are implemented and used to enrich the educational resources metadata at *schema.org*[3].

[3] http://schema.org/accessibilityFeature

### 2.2 Ontologies for Accessibility and Learning Objects

A number of ontologies have been developed to represent accessibility knowledge and requirements. Some ontologies focus on the characteristics of disabilities, web accessibility standards, and guidelines, while others define mappings of user preferences to assistive devices [5]. Among those ontologies, we identified the ACCESSIBLE ontology to be most suitable to represent learner profiles. It has been developed within the EU project ACCESSIBLE[4] and comprises characteristics of disabled users according to the "International Classification of Functioning, Disability and Health (ICF)" of the WHO[5], descriptions of assistive devices and software applications, web accessibility standards and guidelines (WAI-ARIA and WCAG 2.0), as well as assessment rules for mapping user requirements and constraints. We also decided for this ontology because the concepts are defined with respect to a number of widely accepted and applied standards and guidelines (the aforementioned ICF, WAI, etc.).

Other ontologies have been developed specifically for e-learning contexts, and also take learner profiles into account: The Learning Object Context Ontologies (LOCO) are a group of ontologies developed for an e-learning framework [7] to ease the exchange of data among multiple educational services. Among the LOCO ontologies is also one for representing learning preferences in accordance with the aforementioned IMS LIP standard, but accessibility aspects are not explicitly addressed. Another related ontology is ADOOLES (Ability and Disability Ontology for Online Learning and Services) that has been developed to annotate learning resources [10]. It is based on the ADOLENA ontology [8], which has been used to enhance search capabilities by Ontology-Based Data Access (OBDA). ADOOLES represents knowledge in the domain of e-learning and also includes a set of concepts describing disabilities. However, the number and types of disabilities covered by ADOOLES are very limited and given as a simple class hierarchy without any properties and further linking.

## 3 Extending the ACCESSIBLE Ontology with IMS Concepts

We reuse and extend the ACCESSIBLE ontology to represent domain knowledge of disability types, characteristics, functional limitations, and their relations to devices and web accessibility standards. Our ultimate goal is to recommend and apply accessibility configurations with respect to the needs and preferences of individual learners, and let the OCW system adapt itself and/or the educational content accordingly. In particular, we use the "IMS Learner Information Package Accessibility" for the aforementioned LIP model (ACCLIP) to generate learner profiles based on the IMS concepts. In the IMS specifications, the learners are represented with respect to the assistive technologies they are using rather than with their disabilities.

One of the aims is to extend the "Access for All (AfA)" concept with additional properties and preferences to support the use of different resources depending on the situation and context. IMS AfA groups the user needs and preferences into three categories: 1) *display*, 2) *control*, and 3) *content*, as illustrated in Figure 1. The *display*

[4] `http://www.accessible-eu.org`
[5] `http://www.who.int/classifications/icf/en/`

category describes the user's preferences for previewing and presenting information, whereas *control* defines the input devices preferred by the user. The *content* category contains preferences for the content format, such as a preference for audio or visual resources.

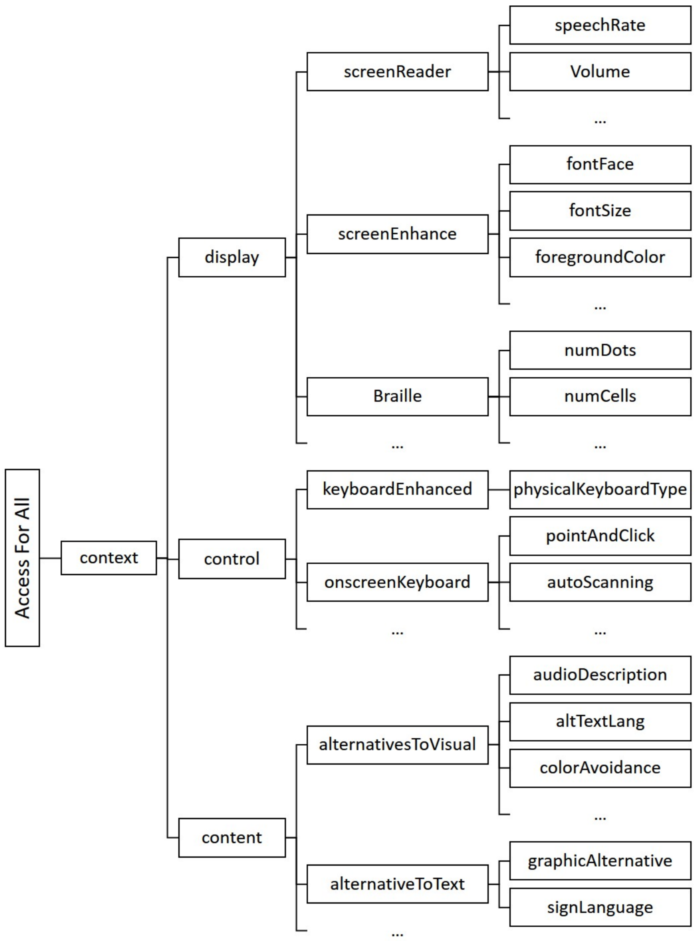


**Fig. 1.** Basic information model of the IMS Access for All specification

The IMS accessibility standards include two central concepts that are not contained in the ACCESSIBLE ontology: one containing properties of assistive technologies (e.g., the number of dots and cells of a braille device) and the other representing user characteristics (e.g., education level, language). These concepts can be directly added to the ACCESSIBLE ontology, since it already contains appropriate classes, as we will detail in the following.

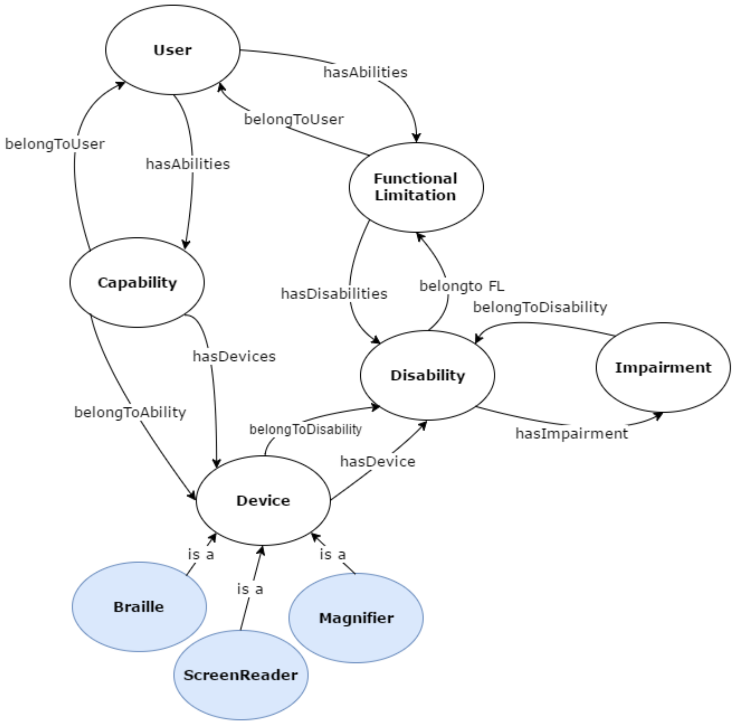


**Fig. 2.** Excerpt from the ACCESSIBLE ontology

### 3.1 Represent Assistive Technologies

Figure 2 shows a part of the ACCESSIBLE ontology. For representing the assistive technologies defined by the IMS standards, we extended the `Device` class of the ontology. The `Device` class has a number of sub-classes (e.g., `Braille`, `Screen Reader`, and `Magnifier`) that have, however, only a limited number of properties, namely the type and name of the device. The class misses other properties and information about the devices. For instance, screen readers usually have a number of properties that can be configured in accordance with the preferences of the users, such as the speech rate or volume. The device properties are important for representing learner disabilities and preferences in accordance with IMS AfA. Adding the properties of the AfA information model (cf. Figure 1) to the `Device` class of the ACCESSIBLE ontology allows to capture the learner disabilities and preferences in more detail and aligns the ontology better with the IMS AfA specifications.

A benefit of representing accessibility knowledge in ontologies is that suitable devices and properties can be inferred from the type of disability. For instance, the ontologies can be used to recommend assistive devices and preferences to the learner based on SPARQL queries. Listing 1.1 shows a simple SPARQL query retrieving a list of devices that might be suitable for an autistic user. Similar SPARQL queries may be used to retrieve the properties and possible user preferences for the devices, after we added the information of IMS AfA to the ACCESSIBLE ontology. Since the device class is linked with concepts from web accessibility standards (e.g., WCAG 2.0), we can also use it to retrieve the required checklists and techniques.

```
PREFIX acc: <http://www.Acces[...]ogy.com/GenericOntology.owl#>
SELECT *
WHERE {
        acc:Autism acc:Disability_has_Device ?device.
}
```

**Listing 1.1.** Simple SPARQL query retrieving assistive devices suitable for autistic users

However, before we can retrieve information about suitable devices and properties, we need to collect information about the user's disabilities. A possible dialog asking the user to enter this information is given in Figure 3, showing the needs and preferences entered by a color-blind user as an example. The extended version of the ACCESSIBLE ontology can be used to automatically generate such a form asking the user for input about disabilities, available devices, and personal preferences. Users could enter that information (or it could partly be automatically inferred from the context), and the ontology could be populated accordingly.

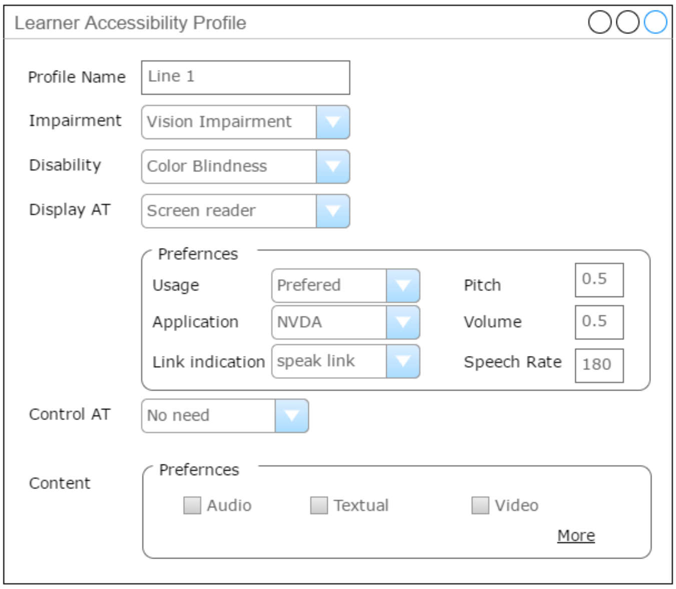


**Fig. 3.** Dialog asking for information about the user's disabilities

Furthermore, the ontology contains knowledge about user limitations and required web accessibility success criteria, which can be used not only to generate IMS AfA terms but also to personalize web content in OCW contexts. For example, in the given case of a color-blind user, success criterion 1.4.6 of WCAG 2.0 requires to check if the foreground and background color (or image) have a contrast ratio of at least 7:1. This could be automatically validated by the OCW system, and the colors could be adapted accordingly if they do not meet the requirements.

Finally, it must be considered that learners might have multiple disabilities. Thus, they must be enabled to enter all their impairments and the OCW system should adapt accordingly, which might require to perform some reasoning on the ontology to find the best combination of adaptations. A learner should also be able to define several profiles; for example, a person with visual impairments might prefer to use a braille device at work but a screen reader at home.

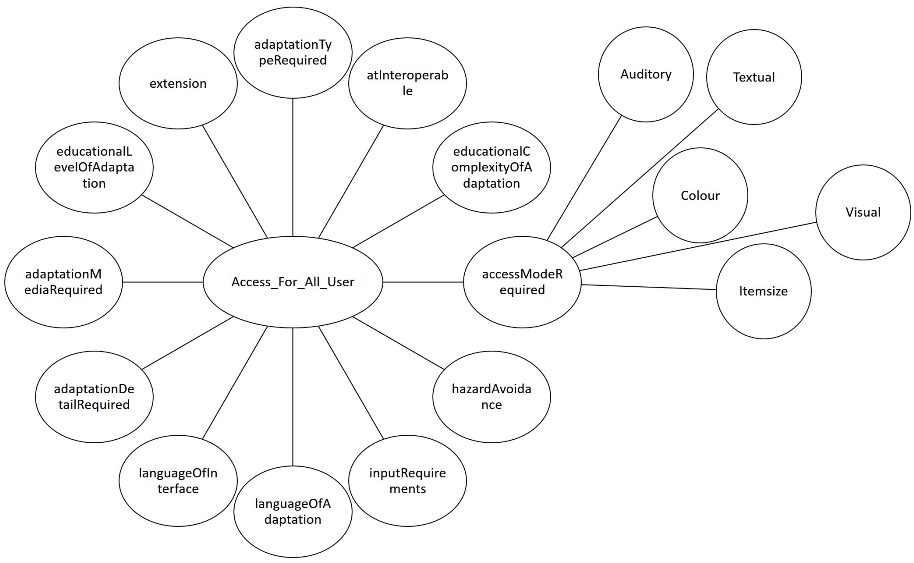


**Fig. 4.** Main part of the information model of IMS AfA PNP

### 3.2 IMS PNP Learner Specifications

Figure 4 shows a part of the information model of IMS PNP, which contains the learner preferences in IMS AfA. We extracted this information from the XML schema that contains all AfA terms. Some properties can be directly added to the user class of the ACCESSIBLE ontology (e.g., `educationLevelofAdaptation`), whereas others can be inferred from the proposed user dialog, such as `atInteroperable` referring to the assistive technology used. Yet other properties are a combination of both, i.e., the recommendation resulting from querying the ontology and the preference selected by the user, such as `accessModeRequired`. As an example for a visually impaired user, by querying the ACCESSIBLE ontology, we can conclude that she might want to use a braille device, magnifier, or screen reader. We may recommend that the user should use textual or audio resources, while she decides for audio resources according to the preferences she stated in her profile.

At the end, all of these properties and preferences should be mapped to the PNP XML schema structure and terms, as it is a unified structure used by IMS AfA to represent and map the information of learner preferences to educational resources.

## 4 Envisioned Personalization System

Our ultimate goal is to personalize the educational content and materials of OCW systems with respect to the accessibility needs and preferences given in ontology-based learner profiles. Figure 5 illustrates the architecture of the envisioned personalization system. It makes use of the extended ACCESSIBLE ontology, incorporating the IMS AFA specifications as described in the previous section.

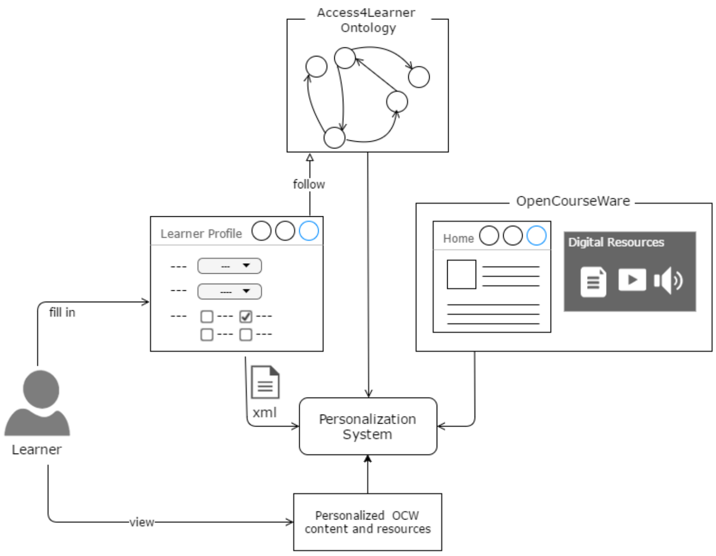


**Fig. 5.** Architecture of the envisioned personalization system

In a first step, the ontology is used to feed the fields of the learner profile dialog with the related data and preferences, as described in Section 3.1. The learner creates a personal profile by selecting his or her preferences in the dialog, and the input is saved in an XML file. The XML file structure is based on the format specified by IMS PNP in order to use it for the mappings to the properties of the educational resources represented in the IMS DRD format.

The personalization system module takes the profile and the ontology as an input to capture the preferences, assistive technology requirements, accessibility guidelines and standards related to a learner. It adapts the OCW content to these requirements, needs, and preferences, and suggests appropriate educational resources to the learner.

## 5 Conclusion

In this paper, we proposed using the ACCESSIBLE ontology to represent learner needs and preferences with respect to the accessibility requirements of the IMS AfA specifications. IMS AfA is concerned with annotating digital resources and learner preferences with terms that can be easily mapped. IMS AfA is mainly addressing visually and hearing impaired users. Combining it with the ACCESSIBLE ontology will make it more extendable and not limited to special types of disabilities. The combination of IMS AfA and the ACCESSIBLE ontology provides more detailed descriptions of disabilities, assistive technologies, and user preferences. Moreover, it allows to add descriptions of other disabilities, such as cognitive impairments, which are relevant in learning contexts, and suggests mappings to educational resources. In our future work, we plan to implement the presented approach in the OCW system SlideWiki, and evaluate it with disabled users.

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