Ontology-based Representation of Learner Profiles for Accessible OpenCourseWare Systems*

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Abstract. The development of accessible web applications has gained significant attention over the past couple of years due to the widespread use of the Internet and the equality laws enforced by governments. Particularly in e-learning contexts, web accessibility plays an important role, as e-learning often requires to be inclusive, addressing all types of learners, including those with disabilities. However, there is still no comprehensive formal representation of learners with disabilities and their particular accessibility needs in e-learning contexts. We propose the use of ontologies to represent accessibility needs and preferences of learners in order to structure the knowledge and to access the information for recommendations and adaptations in e-learning contexts. In particular, we reused the concepts of the ACCESSIBLE ontology and extended them with concepts defined by the IMS Global Learning Consortium. We show how OpenCourseWare systems can be adapted based on this ontology to improve accessibility.

1 Introduction

Web accessibility has become a fundamental requirement in the development of web applications. It basically refers to the practice of making websites usable to people with disabilities. An example is the use of alternative text descriptions for images in order to enable screen readers to read aloud the text (using some text-to-speech technique) for people with vision impairments. A lot of knowledge, standards, guidelines, and techniques with regard to web accessibility are available in the literature that can be consulted when developing accessible web applications. In our previous work [10], we reviewed and classified the state of the art and identified the most relevant standards related to web accessibility in e-learning contexts.

In this paper, we present an ontology-based approach to reuse and integrate this accessibility knowledge in order to develop adaptable OpenCourseWare (OCW) considering the learners' accessibility needs and preferences. We are using ontologies to represent the accessibility concepts in a structured way in order to enable access to this

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knowledge for recommendations and adaptations in OpenCourseWare systems. In particular, we are reusing and extending concepts from the ACCESSIBLE ontology [11] to represent users with disabilities along with the accessibility specifications of e-learning systems as defined by the IMS Global Learning Consortium [2].

The remainder of this paper is organized as follows: In Section 2, we introduce the main components of OCW systems and outline related accessibility requirements. Section 3 presents our approach and methodology proposal for accessible OCW systems; it also defines the main components addressed in the paper. Section 4 describes the ontology, its concepts and structure. Section 5 presents a user dialogue we implemented to capture accessibility profiles of learners. In Section 6, we evaluate the approach and ontology with standard persona types defined by the W3C and examples of educational resources. Section 7 reviews the related work on learner profiles and ontologies, before the paper is concluded in Section 8.

2 Accessible OpenCourseWare

Open Educational Resources (OER) are openly licensed and freely accessible learning materials that can be used in e-learning contexts and beyond. Often, OER are published on the web in the form of OpenCourseWare (OCW) organized in courses and complemented by tools for collaboration and evaluation. OCW systems thus provide means for distributing free educational content to a wide range of learners over the web [4]. 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 that aim to be *inclusive*. Designing one system that meets the needs of all learners is usually not possible, as learners have different needs and preferences, in particular disabled learners. For instance, 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).

Basically, the components of most OCW systems can be divided into four categories, as illustrated in Figure 1: 1) website, 2) digital resources, 3) assessments, and 4) communication and collaboration tools. When addressing accessibility of OCW systems, the individual peculiarities of each component must be considered.

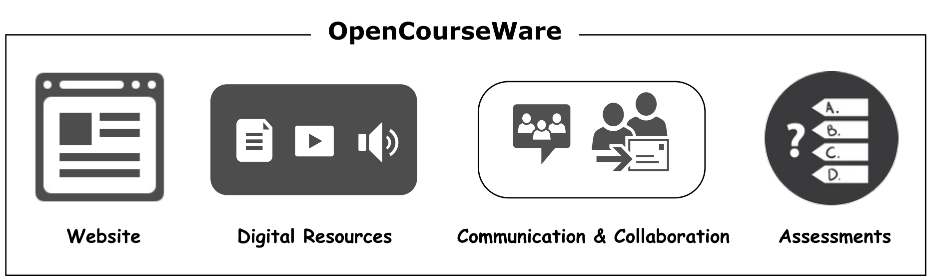

Fig. 1. Typical components of OpenCourseWare systems

Website. The website is the starting point which indexes, previews, and presents the OCW contents. The display and structure of the contents, metadata, and navigation are important elements of an accessible web interface. There are a number of accessibility standards and guidelines that can be followed (e.g., WCAG 2.0 [8] and WAI-ARIA [7]) in order to provide a website that is accessible by different types of users. For example, blinking icons and pop-up windows may be considered distracting elements by some people with cognitive disabilities and should therefore better be avoided in accessible OCW contexts.

Digital Resources. Open Educational Resources (OER) are provided as digital resources in different types of media (e.g., slides, audio, video, etc.) used to represent the course material. The design, representation, and management of these files and formats are crucial for addressing the user needs and preferences. For example, if some educational resources are only available in auditory format and no alternative text transcripts are provided, they are not accessible to deaf learners.

Communication and Collaboration Tools. This category is concerned with providing accessible means for the communication and collaboration of learners in OCW systems to allow for an inclusive collaborative learning experience. Common features in OCW systems, such as commenting functions or discussion boards, should be accessible to all types of learners. For example, the navigation between the entries in a discussion board and the contribution of own entries should be possible with a keyboard only [9].

Assessments. Designing the assessment of the learning material in an accessible way is another challenge. Providing alternative forms of assessment and evaluation is helpful to address different learning styles and disabilities of learners. To give an example, time restrictions of assessments might cause problems to people with cognitive or motor disabilities, since they usually need more time than common learners. Thus, avoiding time restrictions or allowing time extensions should be considered for these types of learners [13].

3 Approach and Methodology

Our research is conducted in the context of the SlideWiki project[4], which is concerned with the development of an accessible OpenCourseWare system making use of semantic technologies. A central goal of the envisioned OCW system is that it can be adapted to the various learners' needs and preferences. Our first step to achieve this goal is to represent the learners' needs and references in an ontology. We are using profiles to describe the learners and recommend educational resources accordingly. The knowledge in the ontology will be used to infer and recommend the most appropriate resources and allow for adaptations of the website.

The overall system architecture of the envisioned adaptive accessibility component of the SlideWiki system is thus composed of an ontology (which we call the *AccessibleOCW ontology*), learner profiles, representations of the OCW components, and a personalization module, as it is illustrated in Figure 2.

[4] `https://slidewiki.eu`

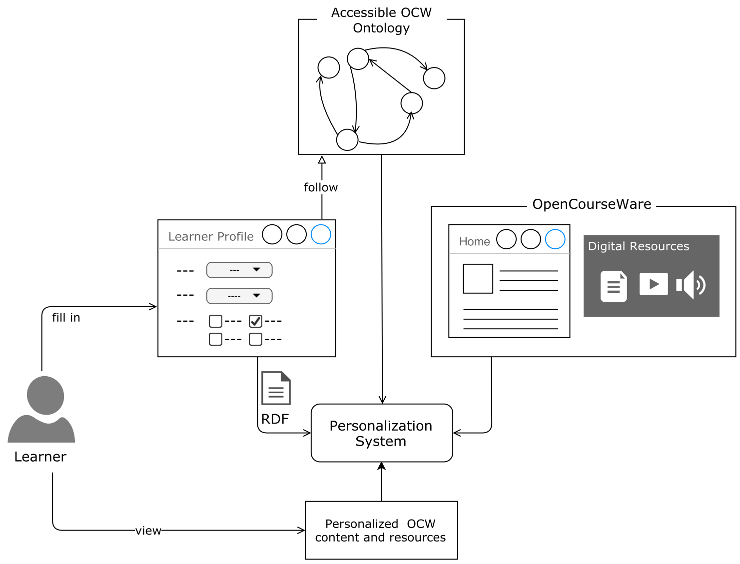

Fig. 2. Architecture of the OCW accessibility module

- **AccessibleOCW ontology**: our proposed ontology that contains the relevant accessibility knowledge required in OCW contexts (e.g., disability types, assistive technologies, accessibility guidelines, e-learning standards, etc.)
- **Learner profile**: a representation of learners, including information about their disabilities. The disabilities can be either automatically detected or manually entered by the learners (or their caregivers) using a form. Other needs and preferences of the learners can then be inferred from their disabilities using the ontology.
- **OCW components**: these are the website, educational resources, assessments, and collaboration tools, as illustrated in Figure 1. The OCW components are adapted according to the learner profiles.
- **Personalization module**: processes the profile and ontology as an input to retrieve the preferences, assistive technology requirements, accessibility guidelines and standards related to the learners. Based on this information, it adapts the OCW content to the individual needs and preferences of the learners, and suggests the most appropriate educational resources to them.

Before we started development, we surveyed the available web accessibility and e-learning standards, guidelines, and ontologies [10]. We were particularly interested in the following aspects:

- Web accessibility guidelines and recommendations (e.g., WCAG 2.0, BBC);
- Disabilities, abilities, and limitations of users (e.g., ICF, FMA);
- E-learning and educational resources (e.g., IMS AfA, ISO24751);
- Assistive technologies and specifications (hardware and software).

We reviewed eleven web accessibility standards, guidelines, and techniques, and examined 20 ontologies that are available in the literature and on the web. As a result of the survey, we defined a set of OCW accessibility needs and requirements, and identified the most relevant standards and ontologies that meet the requirements. These standards and ontologies are the ACCESSIBLE ontology, IMS AfA, and WCAG2.

The overall methodology we follow can be divided into four phases:

1. *Defining and representing learner needs and preferences*. This is done by describing the different types of disabilities, their functional limitations, capabilities, and the related assistive technologies, also allowing the learners to enter any additional preferences. This is realized by representing the knowledge in the ontology and providing an input dialogue for learner profiles.
2. *Representing web accessibility needs*. The web accessibility needs (e.g., standards, techniques, approaches), which are related to the different disabilities, are also defined and represented in the ontology.
3. *Creating and managing educational resources*. This step is concerned with providing guidelines for creating accessible material with respect to the targeted learners, allowing for alternative representations of learning resources. Annotations are used for mapping suitable resources to the learners' needs.
4. *Adapting the website*. This concerns the adaptation of the content and structure of the website with respect to the learners' needs, as well as the validation of the communication and collaboration tools to be appropriate with the learners' capabilities.
5. *Assessment design*. Realizing alternative assessment types and styles to address different types of disabilities and assuring the support of assistive technologies.

This paper focuses on the learner profile and educational resources, and the AccessibleOCW Ontology we developed to represent and map this information.

4 AccessibleOCW Ontology

We are reusing the ACCESSIBLE ontology to represent domain knowledge of disability types, characteristics, and functional limitations. The ACCESSIBLE ontology contains knowledge about web accessibility standards and assistive technologies. For example, in the 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.

We extended the *User* concept of the ACCESSIBLE ontology with the *Learner* concept by adding properties that are needed to describe learners (e.g., education level, complexity level and preferred language of learning resources). We added properties and classes in accordance with the IMS AfA Personal Needs & Preferences (PNP) specification [2] to integrate accessibility needs in e-learning. The educational materials and resources are defined with respect to the IMS AfA Digital Resource Description (DRD) specification. The IMS AfA specifications implement the main guidelines of WCAG 2.0. For example, the access mode property represents the guidelines by describing the accessibility needs of a user with regard to digital resources (e.g., visual, audio). This property can be used for mappings between user needs and resources.

Our AccessibleOCW Ontology is currently composed of 16 classes.[5] We developed the ontology by parsing the IMS AfA specifications and schema documents to create the classes, properties, relationships, and individuals. The central **Learner** class describes the learners' properties together with their needs and preferences. It is a subclass of the *User* class of the ACCESSIBLE ontology. We extended this class to represent the disability information; thus, we can deduce the needs of users from their characteristics.

The learner properties are designed according to the IMS PNP specification. Some properties are directly added to the Learner class, whereas others are inferred from the ACCESSIBLE ontology, such as *isAtInteroperable* referring to the assistive technology used. This can be done by SWRL rules, such as the one shown below which describes an inference rule to conclude the *isAtInteroperable* property from the ACCESSIBLE ontology concepts. It states that if the user has a disability and this disability type is using an assistive device, then *isAtInteroperable* property is considered to be true.

```
User_has_Disability(?x,?y)^Disability_has_Device(?y,?z)
->isAtInteroperable(?x,true)
```

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 *RequiredAccessMode*. Consider the example of a visually impaired learner: by querying the ACCESSIBLE ontology, we can conclude that the learner might want to use a braille device, magnifier, or screen reader. Accordingly, we may recommend that the learner should use textual or audio resources, while the learner might decide to go for audio resources according to the preferences stated in her profile.

The **Learner** class is defined by a number of properties: *hasRequiredAccessMode* is the access mode required by a learner; here, the learners define their preference for the resource representation. For instance, a learner may define that if the resource is a visual one, she would prefer a textual representation.

The property *hasLanguageOfAdaptation* expresses the learner's language for the contents in the educational resources. The property *hasLanguageOfInterface* also represents the preferred language, but for the website itself and not for the educational resources, although the preferred language of both will mostly be the same.

The property *isAtInteroperable* has a boolean value indicating the usage of assistive technologies; when being true, all resources that are compatible with assistive technologies are returned.

The property *hasEducationalLevelOfAdaptation* indicates the educational level of the learners; at best, it should refer to a specific educational system definition (e.g., ASN Educational Level Vocabulary[6]). The property helps in guiding learners to the most appropriate educational resources with respect to their educational level.

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[5] The ontology is available and deployed in a VoCol [12] environment at `http://vocol.iais.fraunhofer.de/accessibilityOnto/`. A visual representation created with WebVOWL [16] is shown in Figure 4 in the Appendix of this paper.

[6] `http://purl.org/ASN/scheme/ASNEducationLevel/`

The **Learner** class is linked with the **DigitalResource** class through an *hasAccess* relation, which is used to filter the accessible educational resources according to the user-defined disabilities and preferences. An example of using this relation will be given in Section 6.

The **DigitalResource** class defines the properties of an individual educational resource. The properties are designed based on the IMS DRD specification. They describe the resource access mode (e.g., visual, auditory) and define if a resource has adapted versions (e.g., if there is an alternative transcript file to an auditory file). It also defines properties like complexity of content, to provide authors the opportunity to offer a simplified version of the learning resource next to the normal one (*isAdaptationof, hasAdaptation, isAtInteroperable*, and *hasLanguageOfAdaptation*).

The property *hasAdaptedAccessMode* represents the adaptation format of a resource (e.g., visual); the type of adaptation is limited to the instances of AccessModeType.

The class *DisplayTransformabilityType* defines those components of a resource that can be easily adapted. The instances of this class include *backgroundColour, cursorPresentation, fontFace, fontSize, fontWeight, foregroundColour, highlightPresentation, layout, letterSpacing, lineHeight, structurePresentation*, and *wordSpacing*.

The following classes are related to both the **Learner** and **DigitalResource**:

The class *AccessModeType* defines the representation value, either for the resource or the requirements of the learner. The instances of this class include: *auditory, colour, itemSize, textual, visual, position, tactile*, and *textOnImage*.

The *RequiredAdaptationType* class describes the type of the adaptation required for special types of representations (e.g., if *auditory_caption* is set for an auditory format, an adapted caption is required).

The *AdaptationType* class represents the available types of adaptations. The instances of this class include: *alternativeText, audioDescription, captions, e-book, haptic, highContrast, longDescription, signLanguage*, and *transcript*.

The *ControlFlexibilityType* class describes the input requirements of the learners and resources, i.e., whether *fullKeyboardControl* or *fullMouseControl*.

The *EducationalComplexityType* class defines the level of complexity required by the learners and provided by the resources (e.g., *simplified*, *enriched*).

The *HazardType* class describes modes that should be avoided for some users, such as flashing, motionSimulation, olfactoryHazard, and sound.

5 Applying the Ontology

We designed an input dialogue to collect the disability information of learners. The learners are supposed to enter their profile information, which could also be automatically inferred from the context in parts. The form of the input dialogue is generated from our AccessibleOCW ontology using SPARQL queries. It asks the learners to input their disabilities, available devices, and personal preferences.

The learners create their personal profiles by selecting their preferences, as illustrated in Figure 3. This example shows a learner profile for the user “Anna” who has dyslexia, which is a type of learning disability. The default language of Anna is English. She prefers visual representations over textual representations of the educational resources, while avoiding elements that are flashing. The user input is saved in an RDF file, which is compatible to the specifications of IMS PNP in order to use it for mapping to the properties of the educational resources represented in the IMS DRD format.

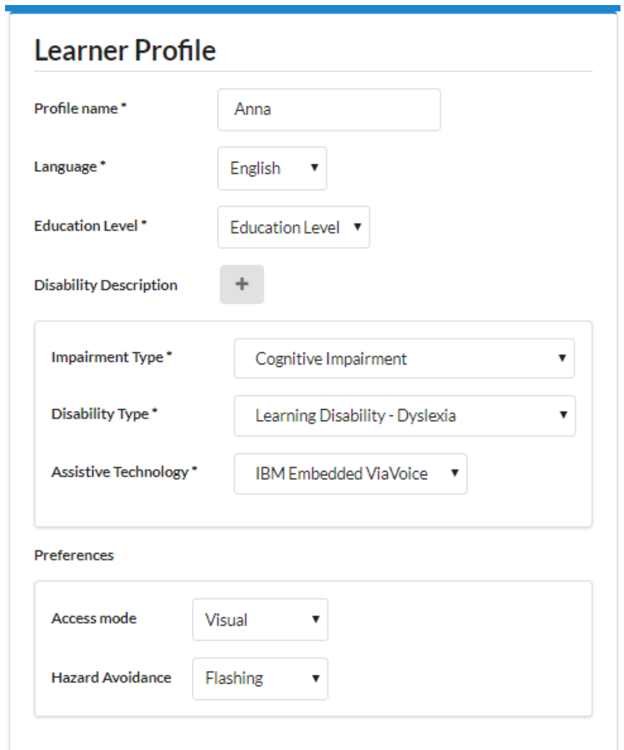

Fig. 3. Learner input profile

We implemented a prototype of the dialogue using the JavaScript library React [5]. We decided for React as it already supports some of the accessibility concepts, such as ARIA attributes, and as it is widely used in web development nowadays. It furthermore supports the development of websites as separate components. This component structure will be useful when adapting the web interface.

We used SPARQL [6] to query the ontology, using Fuseki as the SPARQL server [1]. We created a SPARQL client in React that accesses our ontology on the Fuseki server. The SPARQL query in Listing 1 is an example of the queries that were used to feed the input fields of the profile dialogue. It retrieves the impairments, disabilities and assistive technologies that are related to each other with respect to the user's selection. As we mentioned before, several of the IMS properties can be automatically filled by SWRL rules based on the disability information entered by the users. In Listing 1, we added the IMS property *acc_ocw:isAtInteroperable*, making use of the SWRL rule defined in

Section 4. According to the SWRL rule, the property is true whenever the selected type of disability has an assistive technology.

```
PREFIX acc: <http://www.Acces[...]ogy.com/GenericOntology.owl#>.
PREFIX acc_ocw: <http://purl.org/accessible_ocw#>.
SELECT ?impairment ?disability ?device ?ims_AT
WHERE {
?impairment a acc:Impairment.
?disability acc:Disability_belongsTo_Impairment ?impairment.
OPTIONAL  {?device acc:Device_belongsTo_Disability ?disability}.
OPTIONAL  {?disability acc:Disability_has_Device ?device}.
OPTIONAL {?ims_AT a acc_ocw:isAtInteroperable}.
}
```

Listing 1. SPARQL query retrieving impairments, their related disabilities and assistive technologies from our AccessibleOCW ontology

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 and consistency of adaptations. In our learner profile dialogue shown in Figure 3, we therefore allow for the input of multiple disabilities. In addition, 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.

6 Evaluation

We designed a use case to evaluate our ontology and approach. It is composed of several examples from reliable sources. For the representation of learners, we used examples from W3C specifications, and for the educational resources, we used examples from the Accessibility Metadata Project [19]. This section will be divided into three parts: the first focuses on representing users profiles, the second focuses on educational resources, while the third addresses mappings between the both.

6.1 Representing Learners

We evaluated the developed ontology using the *personas* methodology. In particular, we used the personas that were created by W3C to test different types of user-centered systems.[7] We selected two personas for the evaluation: a hard hearing and a totally blind user. We used the descriptions to create corresponding instances in our ontology. The classes and properties used are a combination of the ACCESSIBLE ontology, representing the disability types and their characteristics, and the IMS concepts representing the accessibility needs in an e-learning system.

Persona 1 – Ms. Martinez is an old woman with hard hearing problems since her birth. She is trained in using sign language next to written language. She has problems with audio material; she requires audio contents to have a transcript and videos to have subtitles.

[7] https://www.w3.org/WAI/intro/people-use-web/stories

```
:Learner_1 a owl:NamedIndividual , :Learner;
   GenericOntology:hasName "Ms.␣Martinez"^^xsd:string;
   GenericOntology:hasAge "62"^^xsd:int;
   GenericOntology:User_has_Disability :Deafness;
   :hasLanguageOfAdaptation "English"^^xsd:string;
   :hasLanguageOfInterface "English"^^xsd:string;
   :hasReqAccessMode :auditory_textual;
   :hasReqAdaptationDetail :auditory_verbatim;
   :hasReqAdaptationType :auditory_caption.
```

Listing 2. Profile of a deaf user

Listing 2 depicts the representation of Ms. Martinez (Persona 1) in our ontology. The properties and classes of the ACCESSIBLE ontology start with the term *Generic-Ontology*. For example, we use the property "User_has_Disability" from the ACCESSIBLE ontology to define the user's disability. This property has a well-defined list of disabilities with respect to the ICF standard classification, as mentioned before. When this property is defined, other properties can be concluded from the ACCESSIBLE ontology, such as the devices that can be used by this type of disability, and the limitations resulting from this disability. The remaining properties are defined for IMS purposes; some of these properties require input by the user, while others can be concluded and recommended from the context or ACCESSIBLE ontology. For example, the *hasReqAccessMode* of this persona requires textual representations for resources that are of auditory type.

Persona 2 – Ms. Laitinen is a blind person. She uses a screen reader and only uses web browsers that can be fully controlled with a keyboard. She did not learn how to use a Braille device.

```
:Learner_2 a owl:NamedIndividual , :Learner ;
    GenericOntology:hasName "Ms.␣Laitinen"^^xsd:string;
    GenericOntology:hasAge "20"^^xsd:int;
    GenericOntology:hasJob "Chief␣accountant"^^xsd:string;
    GenericOntology:User_has_Disability :Blindness;
    :hasReqAccessMode :visual_textual;
    :hasReqAdaptationType :visual_alternativeText,:visual_audioDiscription;
    :isAtInteroperable "true"^^xsd:boolean;
    :hasInputRequirements :fullKeyboardControl.
```

Listing 3. Profile of a blind user

Listing 3 shows the user profile of Persona 2. The attributes of the user are defined using the classes and properties of the ACCESSIBLE ontology. The needs of a blind person are defined by the IMS concepts, where *hasReqAccessMode* states that a textual representation is required for visual resources, and *hasReqAdaptationType* states to use this textual representation instead of the visual one.

In this subsection, we illustrated how to use the developed ontology to represent disabled learners on two example personas defined by W3C. We utilized the descriptions of disabilities from the ACCESSIBLE ontology to infer IMS properties using basic reasoning, whereas other properties are based on direct user input. Creating learner profiles with respect to disability description standards, web accessibility standards, and e-learning accessibility standards has not been done before and is still an open area of research to the best of our knowledge.

```
:digitalResource1 rdf:type owl:NamedIndividual , :DigitalResource ;
:hasAccessMode :visual ;
:hasControlFlexibility :fullKeyboardControl ;
:hasDisplayTransformability :backgroundColour ;
:hasEducationalComplexityOfAdaptation_dr :enriched ;
:hashazard :flashing ;
:isAtInteroperable_dr "true"^^xsd:boolean ;
:hasAdaptation "digitalResource2_URI"^^xsd:anyURI ,
"digitalResource3_URI"^^xsd:anyURI .

:digitalResource2 rdf:type owl:NamedIndividual ,
:DigitalResource ;
:hasAccessMode :textual ;
:hasAdaptedAccessMode :tactile ;
:hasAdaptationMediaType :braille ;
:hasControlFlexibility :fullKeyboardControl ;
:hasEducationalComplexityOfAdaptation_dr :enriched ;
:isAtInteroperable_dr "true"^^xsd:boolean ;

:digitalResource3 rdf:type owl:NamedIndividual ,
:DigitalResource ;
:hasAccessMode :auditory ;
:hasControlFlexibility :fullKeyboardControl ;
:hasEducationalComplexityOfAdaptation_dr :enriched ;
:isAtInteroperable_dr "true"^^xsd:boolean ;
:isAdaptationOf "digitalResource1_URI"^^xsd:anyURI .
```

Listing 4. Representation of a digital resource

6.2 Representing Educational Resources

For evaluating our digital resources representation, we used examples from the Accessibility Metadata Project[8]. It provides several examples to represent various properties of digital resources based on the IMS AfA properties that are included in *schema.org*. In Listing 4, we give an example of a digital resource representation using our ontology. It shows one digital resource with three different representations: video, text, and audio. The source file *digitalResource1* is a video with a visual access mode property. This digital resource is available in two alternative forms for better accessibility: *digitalResource2* is a textual resource that can be tactually accessed, and *digitalResource3* is an auditory resource with full keyboard control.

The main idea is to store every educational resource with all the properties which it can support (e.g. keyboard access), together with all alternative resources and their properties with the structure described in our ontology. With this structure, we can use rules to filter the resources which can be used for a specific learner with respect to the described preferences.

6.3 Mapping Learners to Educational Resources

We can now use the above structure and data to map learners to the appropriate educational resources. In particular, we apply SWRL rules to represent these mappings. Listing 5 gives an example rule which defines the accessibility of resources in terms of

[8] https://wiki.benetech.org/display/a11ymetadata/Properties+Examples

validating the learners' access mode adaptations required with the available digital resources properties. The rule retrieves the type of resources which the learner can access together with the learners adaptation requests; it then maps them to the existing access mode of the educational resources or one of its appropriate adaptations.

For instance, Persona 2 requires a textual alternative for any visual resource; hence, only *digitalResource2* is an appropriate content format for this learner.

```
hasReqAccessMode(?x,?m)^accessMode_existingAccessMode(?m,?e)^
accessMode_adaptionRequest(?m,?a)^hasAccessMode(?y,?a)
->hasAccess(?x,?y)

hasReqAccessMode(?x,?m)^accessMode_existingAccessMode(?m,?e)^
accessMode_adaptionRequest(?m,?a)^hasAdaptedAccessMode(?y,?a)
->hasAccess(?x,?y)
```

Listing 5. SWRL rule mapping digital resources to disabled learners

In this section, we validated that the structure and annotations of the proposed ontology can be effectively used to represent common personas together with educational resource descriptions. More accessibility information for adaptations can be retrieved by querying the ontology to map learners to the most appropriate resources in an OCW system.

7 Related Work

This section reports on related work and is divided into two parts: The first discusses the state of the art in representing learner profiles in accessibility contexts, including the IMS AfA specification which our approach is based on. The second part reports on the most relevant ontologies addressing accessibility concepts in e-learning systems.

7.1 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)" [17] was first published in 2001. It describes portable learner records that allow to exchange learner profiles among different systems. Accessibility is not explicitly addressed in the PAPI profiles, but related 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 the 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 e-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).

We use similar properties and terms for representing learner preferences and features of digital resources in the ontology 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 [8].

7.2 Accessibility Ontologies for e-Learning

A number of ontologies have been developed to represent accessibility knowledge and requirements. A comprehensive survey of such ontologies can be found in our previous work [10].

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[9] and comprises characteristics of disabled users according to the "International Classification of Functioning, Disability and Health (ICF)" of the WHO[10], 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.

Other ontologies have been developed specifically for e-learning contexts. They also take learner profiles into account: The Learning Object Context Ontologies (LOCO) are a group of ontologies developed for an e-learning framework to ease the exchange of data among multiple educational services [14]. Among the LOCO ontologies is also one for representing learning preferences in accordance with the aforementioned IMS LIP standard, but accessibility aspects were 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 [18]. It is based on the ADOLENA ontology [15], 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.

8 Conclusions and Future Work

In this paper, we presented an ontology that addresses accessibility in OCW systems. We reused and extended 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 to achieve a better accessibility. Combining it with the ACCESSIBLE ontology makes it more extendable and does not limit it 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. Furthermore, it allows to add concepts of other disabilities, such as cognitive impairments, which are relevant in learning contexts, and suggests mappings to educational resources.

In our future work, we will be focusing on two directions: First, integrating further accessibility guidelines and techniques into the ontology, also considering some

[9] http://www.accessible-eu.org

[10] http://www.who.int/classifications/icf/en/

concepts and best practices not (yet) included in the existing standards, such as recommendations for users with cognitive disabilities. Second, working on the personalization module to adapt the content presentation according to the learners' needs. Meanwhile, we are implementing the presented approach and ontology in the SlideWiki project with the goal to adapt the developed OCW system with respect to the learner preferences. The implementation of this approach will be evaluated in the trials of the SlideWiki project.

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References

1. Apache Jena Fuseki. `https://jena.apache.org/documentation/fuseki2/`
2. IMS Access for All (AfA). `https://www.imsglobal.org/activity/accessibility`
3. IMS Learner Information Package Specification. `http://www.imsglobal.org/profiles/index.html`
4. Open education consortium: What is open courseware? `http://www.oeconsortium.org/faq/what-is-open-courseware/`
5. React (JavaScript library). `https://facebook.github.io/react/`
6. SPARQL Query Language. `https://www.w3.org/TR/rdf-sparql-query/`
7. WAI-ARIA. `https://www.w3.org/WAI/intro/aria.php`
8. Web Content Accessibility Guidelines 2.0. `https://www.w3.org/TR/WCAG20/`
9. Calvo, R., Iglesias, B., Gil, A., Iglesias, A.: Accessibility evaluation of chats and forums in e-learning environments. In: Proceedings of the 2013 International Conference on Frontiers in Education: Computer Science & Computer Engineering (FECS 2013): WORLDCOMP'13. pp. 133–139. CSREA Press (2013)
10. Elias, M., Lohmann, S., Auer, S.: Fostering accessibility for OpenCourseWare with semantic technologies - a literature review. In: 7th International Conference on Knowledge Engineering and Semantic Web (KESW '16). pp. 241–256. Springer (2016)
11. Grammati-Eirini, K., Lopes, R.: Deliverable 4.1 - A set of formalisms and taxonomies for accessibility assessment procedures and their inherent meta models. Tech. rep., ACCESSIBLE (Grant Agreement No. 224145) (2009)
12. Halilaj, L., Petersen, N., Grangel-González, I., Lange, C., Auer, S., Coskun, G., Lohmann, S.: VoCol: An Integrated Environment to Support Version-Controlled Vocabulary Development. In: 20th International Conference on Knowledge Engineering and Knowledge Management (EKAW 2016). pp. 303–319. Springer (2016)
13. Heiman, T., Precel, K.: Students with learning disabilities in higher education: Academic strategies profile. Journal of learning disabilities 36(3), 248–258 (2003)
14. Jovanović, J., Gašević, D., Devedžić, V.: Dynamic assembly of personalized learning content on the semantic web. In: 3rd European Semantic Web Conference (ESWC '06). pp. 545–559. Springer (2006), ontologies at `http://jelenajovanovic.net/ontologies/`
15. Keet, C.M., Alberts, R., Gerber, A., Chimamiwa, G.: Enhancing Web Portals with Ontology-Based Data Access: The Case Study of South Africa's Accessibility Portal for People with Disabilities. In: OWL: Experiences and Direction (OWLED '08). CEUR-WS, vol. 432 (2008)

16. Lohmann, S., Link, V., Marbach, E., Negru, S.: WebVOWL: Web-based Visualization of Ontologies. In: Proceedings of EKAW 2014 Satellite Events. LNAI, vol. 8982, pp. 154–158. Springer (2015)
17. LTSC: IEEE P1484.2.1/D8, Public and Private Information (PAPI) for Learners — Core Features. Tech. rep., ISO/IEC JTC1 SC36 Information Technology for Learning, Education, and Training (2002)
18. Nganji, J.T., Brayshaw, M., Tompsett, B.: Ontology–driven disability–aware e–learning personalisation with ONTODAPS. Campus-Wide Information Systems 30(1), 17–34 (2012)
19. Project, A.M.: Making Accessible Content Discoverable: A Benetech Led Proposal for Accessibility Metadata in Schema.org. `http://www.a11ymetadata.org/` (2014)

Appendix

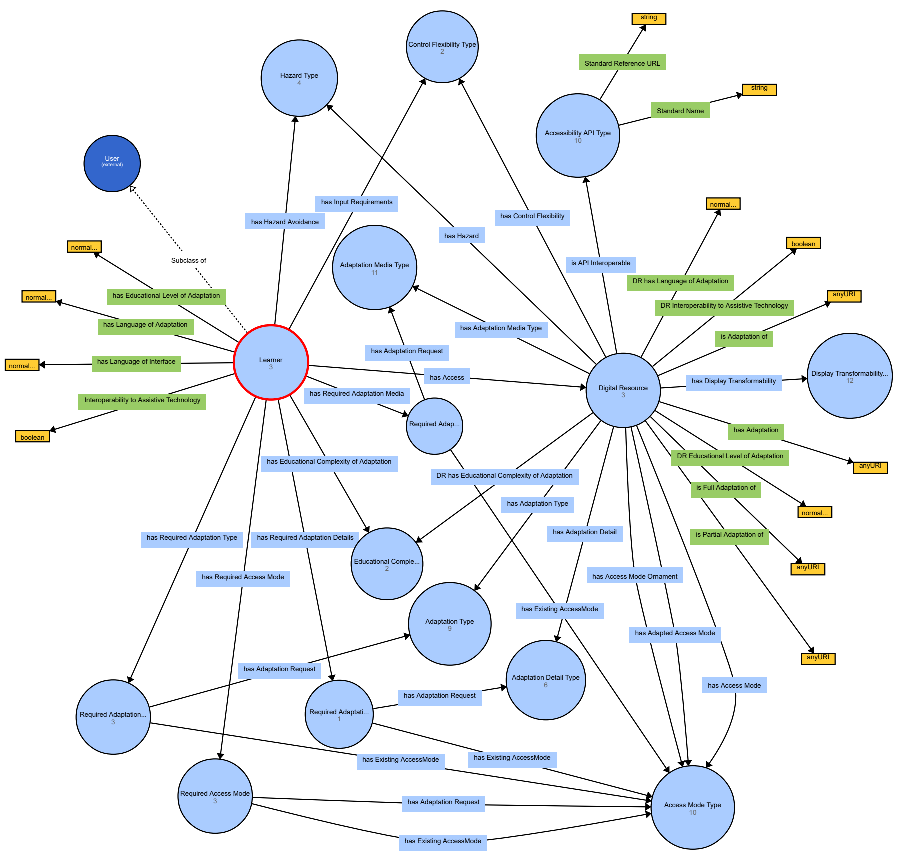

Fig. 4. AccessibleOCW ontology