Custom E-Learning Experiences: Working with Profiles for Multiple Content Sources Access and Adaptation

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It is a common belief that the problem of extracting learners’ profiles to be used for delivering custom learning experiences is a closed case. Yet, practical solutions do not completely cope with the complex issue of capturing all the features of users, especially those of heterogeneous learners, who may have special needs or characteristics (such as disabilities), or are exploiting nonstandard equipment to access services (e.g., mobile devices). For example, the standard ACCLIP (Accessibility for Learner Information Package) specification provides means for describing preferences in terms of user accessibility; yet it lacks methods to manage technical characteristics of the exploited device. Conversely, CC/PP (Composite Capability/Preferences Profile) profiles are thought to describe device capabilities, but they are unable to report on users’ characteristics. With this unsolved problem in view, we present an effective approach to profiling e-learners, which allows the extraction and adaptation of multisource didactical content for customized educational experiences. The idea behind this is to unite the strengths of ACCLIP and CC/PP protocols, while avoiding specification conflicts. Several use cases are described that show the viability of our proposal.

KEYWORDS E-learning accessibility, profiling, device capabilities, learners’ preferences, content adaptation
INTRODUCTION

E-learning has undergone a complete transformation in recent years. In the beginning, e-learning contents were distributed offline, by resorting to prerecorded digital technologies such as CD-ROMs. Ad hoc software was produced to be installed on the student's PC. Using these, learners could enjoy the very first digital lectures. Then offline testing assessments were available to allow learners to evaluate themselves, as a proof of comprehension of the didactical content (Zhang, Zhao, Zhou, & Nunamaker, 2004). While these approaches have represented an important step forward toward the personalization of e-learning experiences, some practical limitations were imposed by the need to cope with specific operating systems and hardware characteristics. From an interaction point of view, the lesson was delivered completely offline, and it was not possible to have any contact with the teacher. Finally, no customized experiences were delivered to users with special needs, since the didactical contents were presented according to a single and predefined output modality, regardless of the wide diversity of the learners' personal characteristics.

Online learning has revolutionized learning. Today learning content is delivered on the Web. A mixture of synchronous (e.g., chats) and asynchronous (e.g., e-mail, newsgroups) interactions is provided by these Web-based systems. Teachers and students are no longer separated by geographical barriers and meet in virtual didactical spaces. Despite the great opportunities offered by these new solutions, most users are excluded from these didactical online experiences. Learning content is still delivered and presented using a single output modality (Barron, Fleetwood, & Barron, 2004; Vernier & Nigay, 2001). This creates serious impediments to individuals with disabilities who are not able to access the specific media type employed to play the lecture, e.g., the lecture is based on a video and the user is blind. Moreover, employing a single output modality for e-learning content may cause problems for those users who wish to enjoy the lecture and have nonstandard equipment, e.g., handheld devices. Here, the problem is that the didactical content is encoded as a rich media presentation while the mobile device has limited computational capabilities, limited codec support, and limited network bandwidth.

Today making learning content accessible to all learners has become a major concern for most e-learning content providers (Bouras & Nani, 2004; Hricko, 2002; Savidis & Stephanidis, 2005; Seale, 2004). The typical solution is that of exploiting multiple content sources for the didactical material so as to guarantee different output modalities, depending on the user preferences (Paulsen, 2002; Salomoni, Mirri, Ferretti, & Rocetti, 2008). For instance, if a user is deaf, audio content is not utilized while visual and textual information, such as captions or annotations, should be preferred. For blind users, instead, visual contents are useless; thus, audio flows are employed, along with
textual data, which can be easily managed by assistive technologies such as screen readers and Braille displays. Finally, mobile users equipped with handheld devices, and connected through a low bandwidth network, need to receive low-quality video lectures, that better fit the device’s screen size and consume less bandwidth during the content delivery.

Managing users and device profiles is mandatory, as these allow describing personal preferences and limitations by resorting to standard languages and protocols (CC/PP, 2007; IMS ACCMD, 2002; IMS ACCLIP, 2002). The idea is that when a profile is available, effective content customization strategies can be employed with great success. Among others, the ACCLIP and CC/PP protocols emerge as candidates for profiling users and devices respectively. The IMS ACCLIP specification allows drawing up a user profile with a list of all the specific user preferences in terms of accessibility constraints (IMS ACCLIP, 2002). The CC/PP protocol, instead, is a standard that provides means to technically describe devices (CC/PP, 2007).

Unfortunately, the problem here is that none of the solutions available at the moment is really effective in capturing all fundamentals of a learner profile when used in isolation. Rather, having an approach that can comprise in a single profile both the personal user characteristics and the technical details of the exploited client device would be very useful to deliver custom multimedia learning experiences to a multitude of learners with different skills and technical equipment (Laakko & Hiltunen, 2005; Lei & Georganas, 2001, Lum & Lau, 2002; Mohan, Smith, & Li, 1999; Sloman, 2002; Stergarsek, 2004).

With this in view, we have developed a practical system to profile e-learners, which meets the variety of requirements of both users and devices. Basically, the approach consists of combining the strengths of ACCLIP and CC/PP. By coupling these two standards, user needs (described using ACCLIP-derived elements) are put in a direct correspondence with system characteristics (described using CC/PP-derived elements). This way, an effective content customization can be carried out, based on the most appropriate access technology for a user with given needs and preferences.

We describe a Web-based e-learning system along with several use cases. These cases illustrate applications where we have adapted to dynamically rich media didactical contents, based on the use of our profiling mechanism (Salomoni et al., 2008).

The next section provides a background on well-known methods to profile learners and devices, and discusses their advantages and limitations. The following section describes our profiling approach, based on user preferences and needs as well as device characteristics. Then we sketch the system we developed, to adapt learning contents by means of our profiling approach, and illustrate some use cases that demonstrate the viability of the adopted solution. Finally we summarize the results of our profiling method devised by merging ACCLIP with CC/PP with a Web-based e-learning
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platform we developed to deliver custom e-learning contents. Examples from real use cases are discussed confirming the efficacy of our approach.

STANDARDIZING DIVERSITIES: A BACKGROUND

In this section, first we discuss methods to characterize devices. We outline CC/PP and User Agent Profile (UAProf) (CC/PP, 2004; OMA, 2002). Then, we review methods to profile learners, with specific attention to accessibility issues; hence, we describe the accessibility learner information package (ACCLIP) specification (IMS ACCLIP, 2002). We also survey the accessibility metadata (ACCMD) specification and single multimedia language (SMIL) (IMS ACCMD, 2002; SMIL, 2005) employed to characterize resources composing learning contents and to define alternatives for content customization.

Profiling Devices

As the diversity of devices increases, several approaches have been proposed in recent years with the aim of characterizing their features. The most prominent solutions include Composite Capabilities/Preference Profile (CC/PP) and User Agent Profile (UAProf) [CC/PP, 2004; Open Mobile Alliance (OMA), 2002]. These two proposals are based on the Resource Description Framework (RDF) and have become two different standards, recommended by the W3C and by the Open Mobile Alliance respectively (W3C, 2007; OMA, 2002). The goal of these profiles is to allow client devices to inform servers of their capabilities. Since these approaches are based on RDF, they follow the philosophy of describing devices without making any assumption about the application domain and its semantics. For the sake of interoperability, an XML-based syntax is exploited to describe devices’ characteristics as metadata.

In particular, UAProf emerges as a standard for the interaction between wireless devices and servers. UAProf defines different categories of mobile device capabilities, as described in length by Open Mobile Alliance (OMA, 2002).

As to CC/PP, this protocol defines a vocabulary that allows specifying components and attributes of devices (CC/PP, 2004). Three main components have been identified that group different characteristics of the device. Table 1 reports some of the main elements comprised within the three components of CC/PP, with a short related description.

Specifically, the Hardware Platform defines the device in terms of hardware capabilities. Hardware components can be specified in terms of, for example, display width and display height resolution, audio board presence,
images support, type of the keyboard, or even the presence of assistive hardware technologies such as Braille display.

The Software Platform, instead, specifies the device software capabilities, such as the type and version of the operating system, the presence of software assistive tools, installed audio/video codecs, and presence of SMIL players.

Finally, the Browser User Agent describes the browser user agent capabilities. Elements can be specified such as the user agent name, its version, the versions of the supported HTML, CSS, javascript, mime types and languages.

Examples exist that have utilized CC/PP and UAProf standards to profiling devices. For instance, Sun Microsystems Inc. has defined and developed a set of application programming interfaces (APIs) for processing CC/PP information, in order to enable interoperability between Web servers and the access mechanism, thus facilitating the development of device-independent Web applications (CC/PP, 2007).

Delivery context library (DELI), instead, is an open-source library, developed at HP Labs, which consists of a set of API-allowing Java servlets to determine the delivery context of a client device using CC/PP or UAProf (DELI, 2007).

Profiling Learners

Our profiling approach exploits functionalities provided by the IMS ACCLIP (IMS Accessibility Learner Profile) to profile users in terms of
Accessibility constraints (IMS ACCLIP, 2002). This specification is a part of a broader effort devised to address interoperability issues among Internet-based learner information systems, i.e., the IMS Learner Information Package (IMS LIP) specification (IMS LIP, 2002). In particular, IMS LIP defines a set of packages that can be used to import (extract) data into (from) an IMS compliant e-learning platform. ACCLIP is part of this set of packages.

ACCLIP resorts to an XML-based syntax to describe users in terms of accessibility needs. Basically, user preferences can be specified for visual/aural media, or even for device-dependent characteristics, which can be usefully exploited for tailoring learning contents (e.g., preferred/required input/output devices or preferred content alternatives).

The accessibility preferences defined in ACCLIP can be grouped into four sections. Table 2 reports all these sections, along with most important related XML tags, for each section.

Elements included in <display> describe how information should be displayed or presented to the user. For example, it is possible to define preferences related to cursor, font, and color characteristics. Moreover, it is possible to declare the need for a screen reader, and to specify more detailed preferences, such as the speech rate, pitch, and volume of the reader. Another example is the request for employing visual alerts (e.g., some pop-up message) instead of aural ones (e.g., the classic beep sound).

Elements associated with <control> define how a user prefers to control the device. For example, it is possible to define preferences related to the standard keyboard usage. In addition, it is possible to declare the need of using nontypical control mechanisms, such as an onscreen keyboard, alternative keyboard, mouse emulation, alternative pointing mechanism, or voice recognition.

Elements associated with <content> describe which enhanced, alternative, or equivalent contents are required by the learner. For example, it is possible

<table>
<thead>
<tr>
<th>Section</th>
<th>Tag</th>
<th>Preferences</th>
</tr>
</thead>
<tbody>
<tr>
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<td></td>
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</tr>
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<tr>
<td>Control</td>
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<td></td>
<td>&lt;alternativeKeyboard&gt;, &lt;mouseEmulation&gt;,</td>
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<td></td>
<td></td>
<td>&lt;alternativePointing&gt;, &lt;voiceRecognition&gt;</td>
</tr>
<tr>
<td>Content</td>
<td>&lt;content&gt;</td>
<td>&lt;alternativesToVisual&gt;, &lt;alternativesToAuditory&gt;,</td>
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<td>&lt;alternativesToText&gt;, &lt;personalStylesheet&gt;</td>
</tr>
<tr>
<td>Eligibility</td>
<td>&lt;accomodation&gt;</td>
<td>&lt;requestForAccomodations&gt;, &lt;accommodationDescription&gt;</td>
</tr>
</tbody>
</table>
to define how to present visual, textual, and auditory contents in different modalities and the necessity of personal style sheets.

Finally, elements associated with *eligibility* allow specifying accommodations/adaptations for which a learner is eligible when using a learning object. Hence, it is possible to declare the request for accommodations and the accommodation description.

An ACCLIP profile describing a learner can be used to configure a computer workstation with appropriate assistive technologies or to reconfigure a Web application for a person with a learning disability or a cognitive impairment (IMS ACCLIP, 2002). While certainly useful for describing and managing accessibility issues, one limitation of this specification is that it does not consider the actual technical characteristics of the devices exploited by learners. In other words, it is assumed that the terminal utilized by the user offers all the required features for content accessibility. Thus, according to the ACCLIP specification, there is no way to map user requirements into the real features of the exploited final device.

It is worth mentioning that IMS has also designed a specification, to be accompanied with ACCLIP, for describing contents based on the use of metadata and for defining content alternatives, in order to improve didactical materials accessibility. Such AccessForAll Meta-Data (ACCMD) specification specifies which typologies of (primary and alternative) media resources are available in a Learning Object (LO). These multisource contents can be dynamically selected and used to present a (possibly adapted) LO to any given user (IMS ACCMD, 2002). In other words, ACCLIP profiles for users and ACCMD profiles for resources can be put in correspondence to determine which typologies of media should be provided for a specific user. For example, metadata can be utilized to state that text alternatives are available for images, descriptive audio for video content, transcripts or captioning for audio tracks, visual alternatives for text, color alternatives to increase contrast, reduced alternatives for small screens, and a variety of other potential alternative formats.

Based on ACCLIP and ACCMD, efforts have been made in the direction of managing LOs, based on the idea of adapting contents and their presentation in a suitable way. Yet none of these proposals took into account the actual capabilities of the utilized device.

As an example, The Inclusive Learning Exchange (TILE) is an LO repository, developed by the Adaptive Technology Resource Centre at the University of Toronto, which implements both ACCMD and ACCLIP (Nevile, Rothberg, Cooper, Heath, & Treviranus, 2005; TILE, 2007). Using TILE, content authors are enabled to aggregate and publish LOs, and to create and appropriately label transformable aggregated lessons (codified by the TILE system using ACCMD). On the other hand, learners can define their own preferences, stored as ACCLIP profiles. Thanks to such information, TILE inspects any learner’s stated preferences and
computes the best resource configuration by transforming or reaggregating LOs.

The Web-4-All project is a collaboration among the Adaptive Technology Resource Centre, the Canadian Web Accessibility Office of Industry, and the IMS Global Learning Consortium (Nevile et al., 2005; Web-4-All, 2007). The main aim of this effort is to allow learners to automatically configure any available public terminal by using an ACCLIP-compliant learner profile, stored on a smartcard. The data stored within the smartcard allow users the freedom to switch among different workstations, which are automatically configured based on the learner preferences. Configuration preferences include details on features combined at the operating system, browser, and necessary assistive technologies. If the assistive technology requested by the learner is not available on a workstation, the program automatically tries to find a similar, alternative configuration.

We cannot conclude this discussion without mentioning another important technology that aggregates alternative media resources, captions, and annotations into a single multimedia presentation, i.e., SMIL, a markup language developed by W3C (SMIL, 2005). SMIL multimedia presentations are made up of elements such as sound, video, pictures, and text that are stored separately and then synchronized at the time of playback. SMIL allows users to turn captions and descriptions on and off via a player interface. Moreover, test attributes can be used to programmatically determine which kind of contents should be automatically activated based on the viewer’s player preferences. These important features offered by this language make SMIL one of the main building blocks of the e-learning platform we have developed for content adaptation and distribution (Salomoni et al., 2008).

DEMYSTIFYING CC/PP AND ACCLIP SPECIFICATIONS: A UNIFIED APPROACH

This section describes the profiling scheme we have designed, based on the experiences surveyed in the previous section. The basic idea behind our approach is to take into account both pieces of information, the device in use and the learner’s characteristics, respectively.

We mentioned that languages, protocols, and tools have been proposed to create users’ and devices’ profiles, separately. Unfortunately, none of them is really effective in capturing the fundamentals of a learner profile, when used in isolation. In fact, while CC/PP offers an open profiling mechanism, it defines a common vocabulary that fully describes only the device (TILE, 2007). On the other side, ACCLIP enables one to detail user preferences in terms of accessibility needs, without considering the real characteristics of the device in use (IMS ACCLIP, 2002). Hence, to completely profile learners
and devices, we coupled these two standards, i.e., our approach implements the idea of putting together the strengths of ACCLIP and CC/PP protocols, while avoiding specification conflicts.

It is important to notice that the union of elements included in an ACCLIP profile or in a CC/PP profile, when considered as a whole, covers all the possible personal characteristics of a given user together with his exploited device; the two specifications share some technical characteristics concerned with the devices. In particular, all the information related to the assistive technologies that are declared in CC/PP as hardware and software components are reported also in ACCLIP as accessibility tools, which may be (possibly) used by (nonconventional) learners.

Figure 1 shows the ACCLIP and CC/PP profiles intersection as we have implemented it. However, even if these two specifications take into consideration common elements in their profiles, these play different roles in our profiling approach. Indeed, ACCLIP-derived elements describe the user and his needs, thus identifying the requirements to fully support the learner. Instead, the CC/PP-derived elements determine specific software/hardware features' availability, since these describe the characteristics of the client device in use.

In other words, a request for a technical feature in the ACCLIP profile (e.g., the request for the use of a screen reader) corresponds to the necessity of having a specific software/hardware feature available on the terminal (e.g., the device is equipped with a screen reader). This requirement in the ACCLIP-derived elements can be easily verified by checking the CC/PP-derived elements.

As a matter of fact, cases exist where the availability of a given software/hardware tool (properly included in the CC/PP-derived elements) does not correspond to a user requirement (i.e., the request for the use of that tool is not included in the ACCLIP-derived elements). For example, an assistive technology (e.g., screen reader) can be installed on a device in use by people without disabilities (e.g., people who test accessibility applications, people who share a device with someone else with a disability).

Based on these considerations, our profiling approach works as follows. (Figure 2 sketches a simplified pseudo code of the algorithm.)
For each specific requirement, detailed as an ACCLIP-derived element, a check is performed on the CC/PP-derived elements, to assess whether the needed technical feature is actually available on the exploited device (e.g., a request for the use of a screen reader is properly installed on the device). In the positive case, the feature is exploited so as to meet the user’s needs.

Conversely, whenever some specific requirement, detailed in the ACCLIP-derived elements, does not correspond to a feature availability on the device, detailed in CC/PP-derived elements (e.g., the screen reader is not available on the device), the feature cannot be exploited. If possible, alternative solutions are utilized, e.g., media contents are transcoded into different formats supported by the prescribed device that can be enjoyed by the specific user (Salomoni et al., 2008).

Finally, those specific system features present as CC/PP-derived elements, which do not correspond to some feature requirements detailed in the correspondent ACCLIP-derived elements (e.g., presence of a screen reader, not requested by the user), are simply neglected.

THE ART OF CUSTOM E-LEARNING: SYSTEM AT WORK

The presented profiling approach has been included in content adaptation service-oriented architecture, thought to be used in Web-based educational contexts. Our system is capable of adapting dynamically rich media, multisource didactical contents, based on the necessary profiling approach, in order to meet learners’ needs and device capabilities (Salomoni et al., 2008).

The system utilizes SMIL-based multimedia presentations, packed as SCORM-compliant LOs, to manage and distribute the didactical material (SCORM, 2004; SMIL, 2005). A sketch of the whole system architecture is depicted in Figure 3.

The activity performed by our system to retrieve, adapt, and deliver customized LOs evolves through different phases, each of which is managed by a specific (distributed) software component.

Phase 1

As soon as the learner issues a request for a particular LO, the client application contacts the system by authenticating to a broking component (called

```plaintext
for each ACCLIP derived element
    finds the corresponding CC/PP derived element;
    if (CC/PP element is available)
        exploits it;
    else
        adapt the content based on the available technical features;
```

FIGURE 2 Profiling algorithm.
**FIGURE 3** System architecture.

*Media Broker*, depicted in Figure 3). This component is in charge of managing user requests and interacting with the client device. During the first connection to the system, the learner specifies his profile, structure detailed in the previous section. The profile is mapped into a unique ID. Then, during every following access to the system, the user is only asked to specify such a unique ID. This profile (or ID) is passed to another component, named *Profile Manager*.

**Phase 2**

The Profile Manager controls the user profile. Specifically, it queries a profile database to retrieve all relevant information about the user (and its exploited device). Such information is then sent back to the Media Broker, which in turn forwards this information to another *Transcoding Subsystem*.

**Phase 3**

Based on the user profile, the Transcoding Subsystem schedules and orchestrates a content adaptation strategy for rich media contents composing the LO. In particular, our system invokes and executes, for each medium composing the LO, an appropriate transcoding process, to produce a customized LO that can be fully enjoyed by each (impaired or mobile) student. Several Web services have been developed (or plugged in to our system when the transcoding feature was already available on third-party Web services) to perform adaptation processes.

In our system, we set a number of preconfigured standard profiles to simplify the definition of user preferences and device capabilities. Users can decide whether to maintain a preset profile or to modify it by creating a new
personal and customized one that is identified by a unique user ID. Moreover, to reduce the number of attributes that need to be introduced, we have integrated our profile database with a set of device-capability descriptions derived from WURFL (Wireless Universal Resource File Library), i.e., a free and open-source project that provides information about device capabilities and currently describes about 7,000 different devices, identifying about 300 device characteristics (WURFL, 2008).

**USER CASE STUDIES**

To prove the effectiveness of our profiling approach, we tested our system with dozens of different user profiles. In this article, we report on three significant ones. Such scenarios illustrate three learners requesting an LO (Harrison & Treviranus, 2003). In the following we will describe IMS ACCLIP and CC/PP profiles. For the sake of readability and to enforce compliance to existing standards, we will maintain the original XML-based format for ACCLIP-derived elements and an RDF-based format for CC/PP ones.

The considered LO is originally structured as a synchronized multimedia SMIL presentation. Figure 4 shows a screenshot of such a lecture. In particular, it is composed by the following media contents:

1. a video lecture,
2. the audio-based lecturer’s speech,
3. the lecture slides.

Moreover, two other information flows have been added and maintained synchronized with the other ones:

4. subtitles,
5. slide captions and comments.

**FIGURE 4** SMIL video lecture, courtesy of Prof. A. Amoroso (University of Bologna).
The two last additional content types have been added to the LO to ensure portability and accessibility of the encoded contents (Gasevic, Jovanovic, & Devedzic, 2004; Guenaga, Burger, & Oliver, 2004; Salomoni et al., 2008).

Whenever a nondisabled user plays out his retrieved LO on a fully equipped PC, the original SMIL presentation is presented, such as that shown in Figure 4. As to the user profile, in this case all the details about the PC configuration are reported in the CC/PP-derived elements, while no accessibility constraints are reported in the ACCLIP-derived profile elements.

Case Study 1: A Fully Equipped Learner with Deafness

We consider the case of a deaf user who gains access to the lecture by means of a fully equipped PC. A SMIL player is installed on his system. Figure 5, top-left quadrant, depicts the ACCLIP-derived elements of the user profile. Here, a set of user preferences are defined. For example, it is specified that visual alerts must be employed instead of generic audio ones (see element <visualAlert> inside <display> element in the figure).

The other three quadrants in the figure correspond to the main elements derived from the three CC/PP components, which simply define a fully equipped PC, with no specific constraints. For example, it is specified that the PC has a common screen monitor with a 1024×768 resolution (see the displayWidth, displayHeight elements in the top-right quadrant), it provides support for audio and images, and a keyboard is present. Moreover, audio codecs are installed for the rm and mp3 formats (see the sfa:audio → rdf_1, rdf_2 elements in the bottom-left quadrant), it supports rm format for video (sfa:video → rdf_1), and SMIL documents are played out by using the RealOne software (sfa:SMILplayer → rdf_1). Finally, the employed browser is Internet Explorer 6.0 (see the sfa:TerminalBrowser element and its children in the bottom-right quadrant of the figure).

Case Study 2: A Mobile Learner with Deafness

We consider the case of a deaf user who gains access to the lecture by means of a PDA. His handheld device has a small screen, reduced computational capabilities, and it does not support the SMIL technology. Figure 6, top-left quadrant, depicts the elements derived from the ACCLIP specification. Basically, a set of preferences are detailed about different input control systems, due to the use of a PDA. In particular, mouse emulation is allowed (see element <mouseEmulation> inside <control> element). In addition, the user defines a set of preferences about visual alerts instead of generic audio ones (see element <visualAlert> inside <display> element). It is worth
noticing that, as discussed in the previous sections, the part of the profile that refers to the ACCLIP-derived elements defines a set of requirements on the exploited device, but no information about the real supported formats and display dimensions (for the specific device in use) are provided. Indeed, these device-related characteristics are fully described by utilizing the CC/PP derived elements, which are reported in the other quadrants of Figure 6.

A consideration worth mentioning is that, as reported in Figure 6, bottom-left quadrant, a screen reader (i.e., Jaws) is available on the client.
FIGURE 6 Use Case 2: Clockwise from top-left: ACCLIP-derived elements, CC/PP hardware platform-derived elements, CC/PP software platform-derived elements, Browser User Agent-derived elements.

device (sfa:tool → rdf:1). Of course, this client system feature is useless (and its use would be definitively not correct) in this specific scenario, since the user is deaf. This fact is supported by the ACCLIP-derived elements, according to which no need for such an assistive technology is detailed.

As expected, our system correctly exploits this information and does not consider the presence of a screen reader as a direct request for an audio-based presentation of contents. Instead, only visual presentations of contents are exploited.
Case Study 3: A Fully Equipped Blind Learner

We now consider a blind user who gains access to the Internet with a PC equipped with a screen reader and a Braille display. A simplified portion of ACCLIP-derived elements comprised in the user profile is reported in Figure 7, top-left quadrant. Here, a set of preferences is specified, related to the use of the screen reader (see element `<screenReader>` inside `<display>` element), as well as the Braille display characteristics (see `<braille>` element,

![Screen Reader and Braille Display Preferences](image)

**FIGURE 7** Use Case 3: Clockwise from top-left: ACCLIP-derived elements, CC/PP hardware platform-derived elements, CC/PP software platform-derived elements, Browser User Agent-derived elements.
partially omitted). Obviously, all these elements are included inside the AC-CLIP element (<AccessForAll>).

The other quadrants of Figure 7 show, in clockwise order, the Hardware Platform, the Software Platform, and the Browser User Agent CC/PP-derived elements of the user profile. Here, details on hardware and software assistive technologies are provided. For instance, SMIL player is installed on the system (see the sfa: SMILPlayer element and its children in the bottom-left quadrant of the figure). The profile reports also the presence of a Braille display (sfa: brailleDisplay, top-right quadrant) and Jaws, the screen reader (see the sfa: tool → rfd_1, bottom-left quadrant of the figure).

Based on the user requirements (reported in the ACCLIP-derived elements) and on the availability of the needed software/hardware tools (reported in the CC/PP-derived elements), our system sets the use of these features during the presentation of contents. In order to properly use these technologies, alternative textual description for contents that were originally encoded as visual ones (e.g., images, videos) are utilized during the presentation.

CONCLUDING REMARKS

Profiling users and devices remains a complex issue, especially in the case of learners with special needs, who deserve customized access to e-learning platforms. Developers and e-learning providers cannot avoid this issue, if they want to offer effective and flexible e-learning experiences. Whatever the cause for the singularity of these users (e.g., disability, mobility, constraints derived from the context where they are interacting), users characteristics must be considered to customize contents and overstep all the potential barriers due to their limitations.

We have presented a practical innovative approach to customize e-learners’ experiences based on an innovative method for providing multiple content adaptation using learners and device profiles. The idea at the basis of our approach is to take into consideration both human needs as well as device characteristics, while avoiding specification conflicts.

The profiling method we have devised by merging ACCLIP with CC/PP has been included in a Web-based e-learning platform we developed to deliver custom e-learning contents. Examples coming from real user cases have been discussed, confirming the efficacy of our approach.

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