Ontological Interaction Modeling and Semantic Rule-based Reasoning for User Interface Adaptation

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Abstract: The paper aims to show how reasoning on ontology can be helpful for user interface adaptation. From a set of user characteristics and interface parameters, it is possible to deduct the most suitable and adaptable interfaces for him/her. To do so, Semantic Web Rule Language (SWRL) rules are used to derive the appropriate interface for a specific user, considering different factors related to his/her abilities, preferences, skills, etc. A use case, in handicrafts domain, is presented; different input and output interaction modalities (writing, selection, text, speech, etc) are proposed to a handcraft woman according to her sensory perception and motor skills. The modalities are structured within what we called "interaction ontology".

1 INTRODUCTION

In human-computer interaction (HCI) areas, user with disabilities needs to be effectively supported, offering him appropriate interaction methods (both input and output) in order to perform tasks. In particular, his perceptual, cognitive and physical disabilities should be considered in order to choose the best modalities for the rendering and manipulation of the interactive system. So user interfaces, which are habitually designed without taking human diversity into consideration, should be adapted to user (Jameson, 2003) (Simonin, 2007). In the last decades, people working in diverse areas of the Artificial Intelligence field have been working on adaptive systems, hence creating valuable knowledge that can be applied to the design of adaptive user interfaces for people with disabilities.

This research work presents a part of the whole project in handicraft domain in emerging countries (Algeria and Tunisia). The project aims at improving the craftswomen socio-economic level within the two countries. Indeed, this project targets to assist the craftswomen during their business activities through the use of new technologies of Information and Communication Technologies (ICT) in order to help them to make the appropriate decisions concerning their sells and their business by providing them an (easy) interface which encourages communication between different actors (providers, customers and handcraft woman).

The project targets women from poor social background exert various business such as ceramic, tapestry, traditional pastry, embroidery etc. These women are characterized by different profiles, especially may have some disabilities (physical, cognitive, etc.), making their interaction with computer system difficult. In this work, we have built an ontology which is used to adapt user interface. This ontology describes both user profile (motor and sensory capacities), and logical and physical interaction resources (modes, modalities and devises). Set of adaptation rules on the ontology allow to provide adaptive interface according to woman profile. The ICT application in handcraft domain should adapt the interface to the abilities of different women in order to improve interaction performance between women and the system and to provide a better and easier interface. The interface customizing mechanism, including (1) an auditory interface for vision-impaired women and graphical interface for women with good visual ability, (2) vocal command without having to touch the button for the women physical disability, (3) raise volume of an audio content for the women hearing impaired, etc.

Semantic technologies enabling interoperability across different platforms are highly expressive when modeling complex relationships. They support

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semantic reasoning and have the ability to reuse information from several application domains (Janev, 2011). They enable to reason about various data, that is, to draw inferences from existing knowledge about a particular area for the purposes of creating new knowledge. At the heart of semantic-based technologies is the use of ontologies. In this work the use the semantic technologies to model, represent and reason about craftswomen has been adopted for the purpose of user interface adaptation.

The remainder of this paper is organized as follows. Section 2 provides the related work as a starting point. In Section 3, we give a global view on interactive interface design and we define and explain the notion of interaction modality. We then present our interaction ontology proposal in section 4. Finally, section 5 shows the conclusions and future work.

2 RELATED WORK

Ontologies are, according to the widely accepted definition given by Gruber (Gruber, 1995), “an explicit specification of a conceptualization". In mathematical words, an ontology is a set of classes, properties connecting classes to one another, restrictions on properties and axioms (Maedche, 2002). Ontology-based modeling involves specifying a number of concepts related to a particular domain, along with any number of properties or relationships associated with those concepts. In essence, ontologies provide a “representation vocabulary”, where these domain concepts are structured in a taxonomy based on various domain aspects. Ontological models can be used by logic reasoning mechanisms to deduce high-level information from raw data and have the ability to enable the reuse of system knowledge. This is particularly important when modeling domain aspects that can be remembered and reused later (Chandrasekaran, 1999).

Semantic Web research has devoted an important effort in defining a common language for ontology modeling and reasoning with the objective to achieve semantic interoperability. The Web Ontology Language (OWL), a language based on description logic has become the recommended language by the World Wide Consortium in 2004. Semantic Web Rule Language (SWRL) is a combination of Rule Mark-up Language (known as RuleML) and OWL-DL (OWL Description Logics) and on the Rule Markup Language (RuleML) which provides both OWL-DL expressivity and rules from RuleML (Horrocks, 2010).

In the field of ontology design, efforts have been made by several research groups to facilitate ontology engineering process, employing manual, semi-automatic and automatic (Maynard, 2009) methods. Semi-automatic methods focus on the acquisition of ontologies from domain texts (Maedche, 2000).

Methontology is a methodology that is widely recognized within the ontologies engineering community, as a reference of tasks needed to build ontology (Fernandez, 1997) (Corcho, 2005). Comprehensive surveys of existing methodologies can be found in (Cristani, 2005) and (Noy, 1997). Throughout the ontology creation process, the designers may take into account a set of ontology design criteria, such as clarity, coherence and extensibility (Fluit, 2002). Specific tools like Protégé (Noy, 2001) are under rapid development and offer a wide range of functionalities, from design of classes and concepts to visualization, querying and inferencing.

In the past few years, ontology is used for modeling context knowledge. By context, we refer to any information that can be used to characterize the situation of an entity, where an entity can be a person, a place or a (physical or computational) object (Dey, 2001). Although there is a variety of context ontologies developed for different application scenarios (Hatala, 2005) (Heckmann, 2005) (Preuveneers, 2004) (Clerckx, 2007) (Razmerita, 2003) (Poveda, 2010). However, there is no widely accepted model that can be reused for modeling context knowledge in different applications. We summarize in the following the most well-known.

Razmerita et al. (Razmerita, 2003) presented work on user modeling with a generic ontology-based architecture called OntobUM.

While user modeling associated rules and ontology-based representations for realtime ubiquitous applications in an interactive museum scenario has been proposed by (Hatala, 2005), context features and situational statements for ubiquitous computing have been proposed as a General User Model Ontology (GUMO) by (Heckmann, 2005) (Heckmann, 2007).

Authors in (Preuveneers, 2004) proposed CoDAMoS ontology which defines four main core entities: user, environment, platform, and service. The challenges surrounding CoDAMoS ontology are: application adaptation, automatic code generation, code mobility, and generation of device-specific user interfaces.

(Poveda, 2010) Proposed mIO! ontology network, a context ontology in the mobile environment that aims to represent contextual knowledge about the user that can influence his interaction with mobile devices. The goal of the mIO! ontology network is to represent knowledge related to context as a whole, e.g., information on location and time, user information and its current or planned activities, as well as devices located in his surroundings. The ontology aims at solving the challenge of adapting the applications based on the user context.

In (Clerckx, 2007), interaction environment ontology has been designed with the aim of solving the challenge of multi-devices user interfaces generation. This ontology is an extension of a general context ontology used in the DynaMo-AID development process (Preuveneers, 2004), where authors describe different modalities, interaction environment (resources, devices), and the way these two concepts are related to each other. While in (Clerckx, 2007) interaction constraints related to available devices and modalities provided are considered, the present work considers interaction constraints related to user (craftswoman) and the modalities supported by each craftswoman based on her sensory and motor abilities.

In (Skillen, 2012a) (Skillen, 2012b), authors propose a method that combines ontological modeling of user profiles and context-aware adaptation techniques. The same authors in (Skillen, 2013) (Skillen, 2014) use rule-based personalization mechanisms and services technology for providing personalized Help on-Demand services to mobile users in pervasive environments. The proposed method uses an intelligent personalization service that incorporates a rule-based knowledge and a reasoning engine. Authors focus on user environment to offer services depending on context parameters (like location for ex.). In our approach user capacities (sensory and motor) and interaction resources (both physical and logical) are modeled by the mean of an *ontology*, with the purpose of the modality adaptation for users disabilities.

The scope of our work is adaptive interface design. We aim to adapt the user interface by using ontology modeling and reasoning; expressing trough a set of adaptation rules.

3 INTERACTIVE INTERFACE DESIGN

Any given interface is generally defined by the number and diversity of inputs and outputs it provides. Different configurations and designs upon which an interface is based (Karray, 2008):

1) A system based on only modality
2) A system based on multimodality

Multimodal interfaces incorporate multiple modalities (e.g., speech, gesture, writing, and others). Nigay and Coutaz (Nigay, 1993) define modality as the combination of a physical input or output device (d) and an interaction language (L), which can be formalized as a tuple <d, L>. Examples for interaction modalities on a smart-phone could be <touchscreen, gestures> or <microphone, speech>.

When designing an interactive system, one has to choose which modalities will be used, and how they will convey information. We distinguish two types of interaction: input interaction (from the user to the system) and output interaction (from the system to the user). The concept of interaction component represents the physical or logical communication mean between the user and the application. There are three types of interaction components: mode, modality and medium (Figure 1). A mode refers to the human sensory system used to perceive (visual, auditory, tactile, etc.) or to introduce (speech, gestures) given information, so that we distinguish input modes and output modes. A modality means a communication mode according to human senses and computer devices. Input modality is defined by the information structure that is perceived by the user (text, speech synthesis, vibration, etc.). Output modality is defined by the way to introduce information by the user (selection, pointing, writing, speech etc.). Finally, a medium is an organ necessary to a system or a human in order to acquire or deliver information. Input medium is an input device allowing the expression of an input modality (keyboard, mouse, microphone, etc.). Output medium is an output device allowing the expression of an output modality (screen, speaker, vibrator, etc.).

There are some relations existing between these three notions. A mode can be associated with a set of

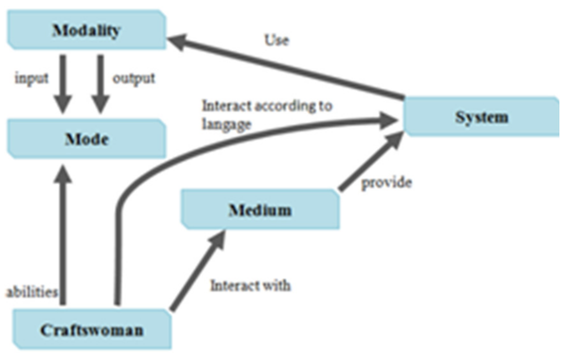

Figure 1: Overview of the interaction model.

modalities and each modality can be associated to a set of medium. For example, the "vibrator" medium allows the expression of the "vibration" modality which is perceived through the "tactile" mode. These relations are presented through the input interaction components diagram (Figure 2) and the output interaction components diagram (Figure 3).

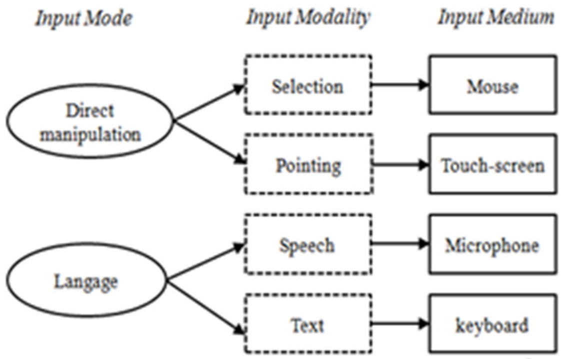

Figure 2: Input interaction components diagram.

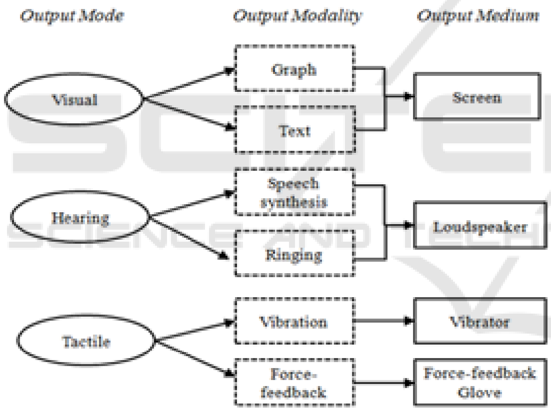

Figure 3: Output interaction components diagram.

4 PROPOSED INTERACTION ONTOLOGY

Ontology-based systems are becoming more and more popular due to the inference and reasoning capabilities that ontological knowledge representation provides. The ontology based modeling can be used for various purposes such as personalization and adaptation. In this work, we use ontology to model the interaction components and craftswoman characteristics in order to support adaptive application development. The proposed ontology is called *interaction ontology*.

Methontology (Fernandez, 1997) enables the construction of ontologies at the knowledge level. We model in the same ontology the interface parameters (mode, modality and medium) and the craftswoman profile. We focus more on the characteristics describing her abilities to use the interaction modalities. However, other user characteristics can be considered, such as skills, preferences, education level and motivation. Some ontology relevant concepts are presented in table1.

The ontology was implemented using the Protégé framework. Figure 4 represents semantic relationships between the different interaction ontology concepts.

Table 1: Interaction concepts.

Interaction concepts	Description
Craftswoman	Person who interact with the system and who is described by a profile
Input-mode	The way information is introduced (language, direct manipulation)
Output-mode	The way information is perceived (visual, hearing, tactile)
Input-modality	The way information is introduced by the user using a specific medium (speech, writing, selection, etc.)
Output-modality	The information structure as it is perceived by the user (text, graph, image, vibration, etc.)
Input-medium	Physical device to introduce information (keyboard, mouse, microphone, etc.)
Output-medium	Physical device to receive information (screen, projector, loudspeaker, vibrator)
Size	parameter "Size" of a modality (text size)
Volume	parameter "Volume" of a modality (video volume)

Object properties are defined to relate the core concept craftswoman to the concepts mode and modality, they specify modalities (input and output) that can be used by a given woman (see Figure 5):

- uses-input-mode (from Craftswoman to Input-mode): to specify the input modes
- uses-output-mode (from Craftswoman to Output-mode): to specify output modes
- uses-input-modality (from Craftswoman to Input-modality): to specify input modalities
- uses-output-modality (from Craftswoman to Output-modality): to specify output modalities

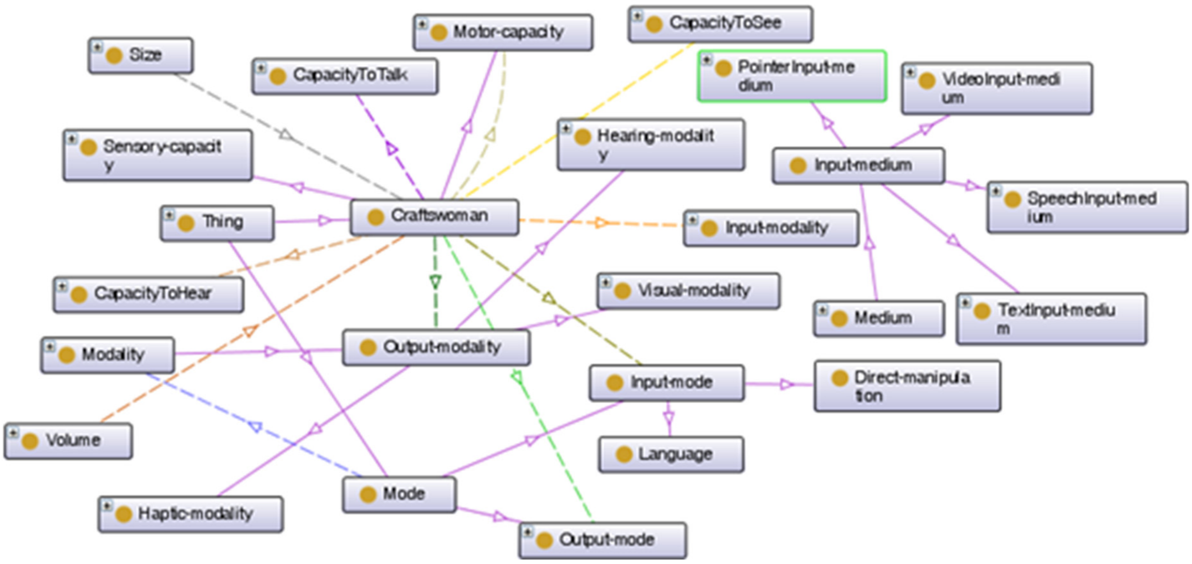

Figure 4: Relationships between different concepts of Interaction ontology.

The ontological approach for interaction modelling was motivated by the possibility of reasoning on the model. The reasoning allows checking ontology consistency. Furthermore, it helps to deduct (infer) high-level data from a set of captured raw data (low-level data).

The interaction ontology is used to adapt user interface. We describe in the following section how the user characteristics (e.g., ability to see, to talk, to move, etc.) and the interface parameters (e.g., writing, speech, text, image, etc.) are used to generate the adaptive user interface based ontology reasoned.

4.1 Reasoning on the Interaction Ontology

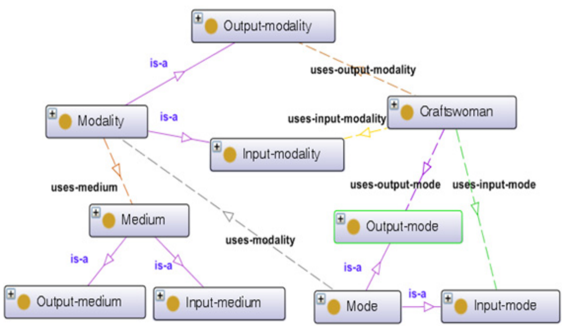

Figure 5: Object properties of interaction ontology.

Ontology based reasoning is used in our work for deriving new information based on both OWL defined concepts and properties, and adaptation rules. Based on woman's characteristics (physical abilities), interface parameters values are defined (input and output modalities). An adaptive interface is generated; is composed with these modalities for example, for introducing a new product or for displaying a list of clay providers.

The adaptation rules are defined and edited in *interaction ontology* using dedicated rule language (SWRL-Semantic Web Rule Language). There are several inference engines that allow inferring knowledge from OWL. We use Pellet (Sirin, 2007) as reasoning engine.

SWRL rules are implication rules with following syntax (Mun, 2011):

```
antecedent → consequent
```

Both antecedent and consequent are composed of a set of concepts and properties. Each adaptation rule is presented by: set of woman characteristics (antecedent) then set of interface parameters (consequent). We note that there is some relationship between woman characteristics and interface parameters. A good visual ability implies interaction mode visual possible for a given woman.

We define the following hypothesis: *any craftswoman is able to interact with the system; indeed she can use at least one input modality and one output modality*. Every woman should have some abilities enabling her to interact with the system. Nevertheless, motor or visual impairment may make impossible the use of an input or output modality. For example if a woman is visually impaired then the visual mode cannot be used. Similarly hearing or visual weakness involve the need to change some modality properties, like, increasing the audio volume or the text size. Notice that multiple modalities can be used to perform a task for a woman. In this case the redundancy is accepted, for example the combination of visual and speech modalities for presenting an information.

Physical capabilities considered are: *capacities to see*, *to hear*, *to move* and *to talk*, where:

- capacities to see and to hear, are used to derive output modalities
- capacities to move, to see and to talk, are used to derive input modalities

To measure these capabilities, we have defined four capacity levels: *Good*, *Moderate*, *Low* and *Severe*, where:

- Good and Moderate levels present no constraint for using corresponding interaction modalities; all the available modalities can be used
- Low level requires certain changes of modality properties (change the volume or the size)
- Severe level is the lowest level that requires total elimination of corresponding modality, e.g. eliminate the speech modality for a mute woman

To check our hypothesis, we have added two restrictions. The first expresses that woman's capacity level to hear and to see cannot be severe at the same time; therefore she can use at least one output modality. The second expresses that woman's capacity level to talk and move cannot be severe at the same time; therefore she can use at least one input modality (Figure 6).

```
not ((hasCapacityToHear some (capacity-to-hear value "Severe"))
 and (hasCapacityToSee some (capacity-to-see value "Severe")))
not ((hasCapacityToTalk some (capacity-to-talk value "Severe"))
 and (hasCapacityToMove some (capacity-to-move value "Severe")))
```

Figure 6: Example of restrictions edited within ontology.

Example of rule.

```
Craftswoman(?x),hasCapacityToSee(?x,
Low) -> uses-modality(?x, textModality,
size("High")
```

This rule expresses that, if a woman has a visual impairment (her capacity to see is low) then the text modality is used with increase the size.

An example of the specified SWRL rules in Table 2and Table 3. Within Table 2, the described adaptation rules allow to derive input modalities used for a specific woman. Woman without motor disabilities (i.e. her capacity to move is different to severe value) can use all the available direct-manipulation modalities (writing, selection, pointing…) (Rule 1, 2 and 3). Likewise the speech modalities (discourse) can be used with the exception mute woman (her capacity to talk is equal to severe value) (Rule 4, 5 and 6). Within Table 3, rules which are described allow to derive output modalities. Woman without visual disabilities (capacity to see is different to severe value) can use all the available visual modalities (display: text, graph, image…) (Rule 1, 2 and 3). However the modality size is increased for woman who has weak sight (Rule 3). Same rules are defined for hearing modalities; the sound modalities (speech-synthesis, ringing, bip) cannot be used for deaf women (Rules 4, 5 and 6).

After the SWRL rules are created, they can be tested and checked for inconsistencies using the reasoning tool.

Table 2: Excerpt of SWRL rules (to infer input modalities).

No.	SWRL Expression
1	Craftswoman(?x), DirectManipulation-modality(?z), hasCapacityToMove(?x, ?y), capacity-to-move(?y, "Good") -> uses-modality-input(?x, ?z)
2	Craftswoman(?x), DirectManipulation-modality(?z), hasCapacityToMove(?x, ?y), capacity-to-move(?y, "Moderate") -> uses-modality-input(?x, ?z)
3	Craftswoman(?x), DirectManipulation-modality(?z), hasCapacityToMove(?x, ?y), capacity-to-move(?y, "Low") -> uses-modality-input(?x, ?z)
4	Craftswoman(?x), Speech(?z), hasCapacityToTalk(?x, ?y), capacity-to-talk(?y, "Good") -> uses-modality-input(?x, ?z)
5	Craftswoman(?x), Speech(?z), hasCapacityToTalk(?x, ?y), capacity-to-talk(?y, "Moderate") -> uses-modality-input(?x, ?z)
6	Craftswoman(?x), Speech(?z), hasCapacityToTalk(?x, ?y), capacity-to-talk(?y, "Low") -> uses-modality-input(?x, ?z)

Table 3: Excerpt of SWRL rules used within the Ontology (for inferring the output modalities).

No.	SWRL Expression
1	Craftswoman(?x), Visual(?z), hasCapacityToSee(?x, ?y), capacity-to-see(?y, "Good") -> size(?z, "Medium"), uses-mode-output(?x, ?z)
2	Craftswoman(?x), Visual(?z), hasCapacityToSee(?x, ?y), capacity-to-see(?y, "Moderate") -> size(?z, "Medium"), uses-mode-output(?x, ?z)
3	Craftswoman (?x), Visual-modality (?z), hasCapacityToSee(?x, ?y), capacity-to-see(?y, "Low") -> use-mode-output(?x, ?z), size(?z,"High")
4	Craftswoman(?x), Hearing(?z), hasCapacityToHear(?x, ?y), capacity-to-hear(?y, "Good") -> volume(?z, "Medium"), uses-mode-output(?x, ?z)
5	Craftswoman(?x), Hearing(?z), hasCapacityToHear(?x, ?y), volume(?n, "Medium"), capacity-to-hear(?y, "Moderate") -> volume(?z, "Medium"), uses-mode-output(?x, ?z)
6	Craftswoman (?x), Hearing-modality(?z), hasCapacityToHear(?x, ?y), capacity-to-hear(?y, "Low") -> use-modality-output(?x, ?z), volume(?z,"High")

4.2 Illustrative Example

We present in the following an example of the implementation of these rules. Amel is a mute craftswoman. She suffers from a visual weakness and as a result finds it difficult to read small text. However Amel's hearing and motor abilities are good (Figure 7). Using Pellet and the associated SWRL rule-set and taking into consideration Amel's disabilities we can infer input and output modalities which Amel is able to use (yellow part in Figure 7). Indeed, Amel can use visual modalities (text, graphs ...) and the direct manipulation modalities (selection) but she cannot use the speech modality; her disability does not allow it. The size of the visual modalities (text, graph) is increased to the maximum value (high) because her visual capacity is low. Figure 8 shows an adapted interface for Amel, it allows introducing a new product using selection mode.

5 CONCLUSIONS

In the paper, we have presented a method to adapt user interface based on ontology modeling and the reasoning process. User characteristics and interface parameters are combined through adaptation rules execution to generate adaptive interface according to user profile. The proposal can be extended by considering others aspects of user (e.g. preferences, expertise, motivation, etc) and of the interface (e.g. density of information, luminosity, etc.). As future work, we plan to generalize this work and extend the ontology for taking into account other user and interface characteristics.

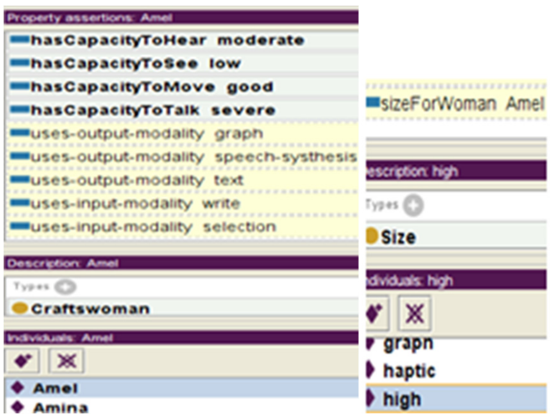

Figure 7: Reasoning on interaction ontology.

Figure 8: Example of adapted interface generation.

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