The User and Domain Models of the TERENCE Adaptive Learning System

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Abstract. TERENCE is an FP7 ICT European project that aims at developing an adaptive learning system for supporting learners and educators: the TERENCE learners are 7-8 to 11 year old children with poor reading comprehension skills; the TERENCE educators are primary-school teachers, support teachers and parents. The analyses of the context of use and requirements of the TERENCE system are based on real data. Therefore also the design of the conceptual model of the TERENCE system is based on real data. This paper describes the domain and user model of the TERENCE system, and its evidence-based design process.

1 Introduction

Developing the capabilities of children to comprehend written texts is key to their development as young adults. From the age of 7-8 until the age of 11, children develop as independent readers. Nowadays, more and more children in that age range turn out to be *poor (text) comprehenders*: they demonstrate difficulties in deep text comprehension, despite well developed low-level cognitive skills like vocabulary knowledge, e.g., see [4] for hearing poor comprehenders, and [13] for deaf poor comprehenders. TERENCE is an FP7 ICT project that aims at designing and developing the first adaptive learning system for poor comprehenders. Its reading material (in English and in Italian languages) are stories adapted to the specific requirements of poor comprehenders, and its reading interventions are interactive games centred

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around reasoning skills that foster the development of deep text comprehension, both accompanied by adequate visual aids.

This paper starts by briefly overviewing the state of the art of adaptive learning systems, and the methodology adopted for designing the TERENCE system. With the preliminaries out of the way, the paper zooms in on the conceptual model of the TERENCE system, and then delves into its main sub-models. The paper ends with a recap conclusive section.

2 Related Work on Adaptive Learning System

The ability of a learning system to tailor instruction to individual and organisational needs is a crucial issue, and lead to the development of the *adaptive learning systems* (ALSs) [3]. The conceptual model of an ALS usually includes, as sub-models, the *user model* for the users's data, the *domain model* for the learning materials' data, the *adaptation model* with rules that, given the previous models, provide the actual adaptation.

Of the aforementioned conceptual sub-models, the user model is the one that has got more attention and proof-of-concept implementations. Aside from distribution, scalability and performance aspects, the principal motivation for the development of user models is to characterise an individual user. Traditionally the main user features that are considered in ALSs include user's knowledge, background, interests, goals and preferences. User individual traits, such as personality factors, cognitive factors and learning styles, were given attention by the research community, albeit with relatively few practical uses. The KBS-Hyperbook [11] and TRAILS projects [10] based their modeling on (reasoning over) logged user actions. In the AHA! project [6], on the other hand, user actions are typically not logged but immediately translated into higher-level user model information. Various adaptive systems take into account the user's context [12], such as the user's location, platform and bandwidth [2]. In several ALSs, the user model is an overlay of the given domain ontology, which associates the users' knowledge or interests with a concept in the domain. However, few user models described in the literature provide a general representation of users in the form of an ontology, one of them being the General User Model Ontology (GUMO) [9]. For more details and examples, we refer to a survey carried out by [3].

3 The Design Process

The TERENCE system is being developed by following the user-centered design (UCD), and evidence-based design (EBD). Generally speaking, the UCD places the users at the centre of the design process, which is iteratively repeated through subsequent refinements of the requirements until attaining the usability of the system. The EBD always requires the usage of evidence-based data in such a design process.

In the first year of life, the TERENCE consortium specified the requirements of the system. The specifications are based on the state of the art as well as on the analysis of data collected mainly through: brainstorming meetings with experts;

contextual inquiries with educators and learners. In the former case, the data are purely qualitative. In the latter case, they are both qualitative and quantitative. See also [7]. The first specifications were in a semi-formal tabular format and gave us:

1. the characteristics of the users, like their reading comprehension skills or interests in books;
2. tasks, like successful reading interventions by class teachers for improving reading comprehension;
3. the environments, divided into organisational, physical and socio-cultural characteristics that may influence the usage and acceptance of the system.

Our design of the current version of the conceptual model of the TERENCE ALS is based on such semi-formal specifications, as well as on the state of the art of conceptual modeling for ALSs:

1. its domain model structures the learning material,
2. its user models specifies and structures information concerning its users, in particular, its learners,
3. its adaptation model specifies the rules correlating concepts of the domain model and the user model.

In the following, we specify the main concepts and relations of the user and domain models, which find their evidence in the semi-formal specification reported above. The adaptation model is reported in another paper [1]. The domain and user models are here represented with an Entity-Relationship (ER) diagram [5]. We opted for ERs for several reasons. First of all, ERs are easy to understand, and easy to explain to all the members of the TERENCE heterogeneous consortium. Moreover, the ERs serves as the concept scheme of the underlying databases. As in the UCD the design of interactive systems evolves cyclically, also the domain and user models of the TERENCE system needs to be updated iteratively according to the updates to the requirements, and ERs are easy to manage and update. However, ERs are only the building blocks, so to speak: they are used to create the OWL ontology of the models, as OWL enables the flexibility, interoperability and reusability of the model, besides reasoning services like consistency checking and deduction.

4 The User Model

The user model is made of three main sub-models, one for each end-user of the TERENCE system: the *learner model* for the learners of the TERENCE system, the *educator model* for the educators of the TERENCE system, namely, teachers and parents of the TERENCE learners, the *expert model* for the expert users (e.g., linguists) interacting with the TERENCE system. In the remainder, we mainly focus on the learner model, which captures information about the TERENCE learners that is relevant for the adaptation process. The structure of the TERENCE learner model consists of three main sub-models: the first for general data; the second for domain dependent data; the third for interaction data. They are described as follows.

The first sub-model represents general data about the learners such as their name, contact information, personal characteristics, and interests. The main source for this sub-model is GUMO[9].

The second sub-model of the learner model represents domain dependent data about the learner's *reading comprehension* (RC) skills. The ER for the RC skills analysis whether the problems are at the word level, sublexical level, sentence level, or entire text level. Such data and their representation are important for a competency-based classification of the learners. In particular, each learner can choose among several *avatars*, which work as a virtual representation of the learner and his/her progress. The learner chooses one of the available avatars before starting reading and playing with TERENCE. As the learner proceeds in reading and playing, he/she gains points, which allows him/her to obtain more visual attributes for his/her avatar. Such attributes are represented with the score entity in the ER. By analysing the learner's skills, the system will be able to suggest appropriate content for the learner as well as provide relevant input to the educators. The main source is the semi-formal specification of the learners' characteristics deriving from the aforementioned requirement analysis.

The third and last sub-model of the learner model includes data about the learner's interaction with the system, that is, logs about the learner's activities such as reading stories or playing games are stored in the model. By storing these data the system will be able to help the educators in keeping track of their learners' progress. Figure 1 shows the ER diagram of the learner model.

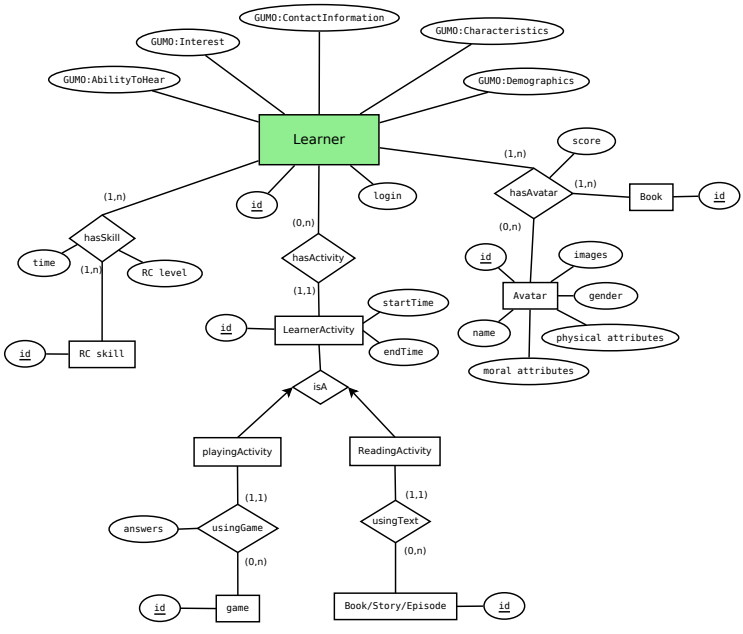

Fig. 1 The current learner model

5 The Domain Model

The TERENCE Domain Model consists of two main sub-models: the reading material model, made of the book and story models; the playing material model, currently consisting of the game model. The main source for the domain model is the semi-formal specification of the learners' tasks, namely, reading and playing, and deriving from the requirement analysis.

5.1 The Reading Material Models

Since the learners will have different backgrounds, interests and reading comprehension skills, the system will provide stories with different characteristics and difficulty levels, which depend on the RC levels specified as in the learner model. Moreover, stories are grouped into coherent narrative units, named books.Figures 3 and 3 show the ER diagrams of the story and book models, making up the reading material model. In the following we describe the main concepts of this model.

Book. The entity Book represents one of the written books that are available in the repository of the system. Each Book has the following main attributes:

- id: a unique id;
- name: the title of the Book;
- age range: the intended age range for reading the Book;
- genre: the genre of the Book's stories (e.g. fantasy, gothic, adventure, etc.);
- abstract: the main topic of the Book;
- visualMap: each Book in TERENCE will have a visual spatial map that illustrates the environments of the Book's stories. By interacting with the visual map, the learner can thus view the stories and select one of them.

Moreover, each Book has an associated set of main characters, those that recur in the Book's stories. Each character has textual and graphical descriptions.

Story. This entity represents a story of the book with main attributes:

- id: a unique id for the story;
- name: the title of the story;
- abstract: the abstract of the story.

In addition, each story, except the last, has a link to the subsequent stories.

RC (reading comprehension) Skill. Each story will be analysed using natural language processing tools such Coh-Metrix [8] (Duran, et al. 2006) in order to assess the story's difficulty level. This is expressed in terms of the RC skills and the minimum level of each such skill in order to comprehend the text, that is, the RC level.

Episode. According to the analysis of tasks mentioned in Section 3, the analysis of stories is usually conducted episode by episode, following their textual order in the story. Therefore we include Episodes as entities related to story in the ER.

Game. Each story is associated with a set of games for stimulating and assessing the reader's comprehension of the story, and described below.

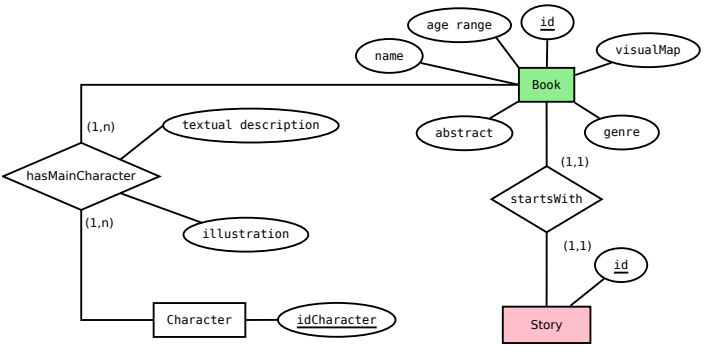

Fig. 2 The current book model

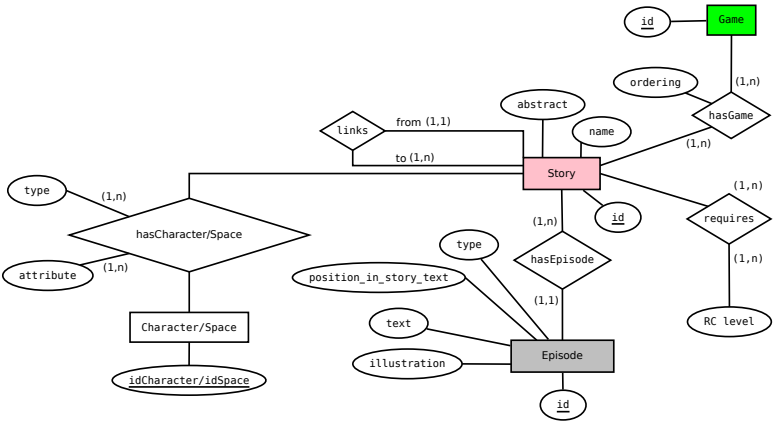

Fig. 3 The current story model

5.2 The Game Model

According to the analysis of tasks and users' characteristics sketched in Section 3, TERENCE needs to have two main types of games: smart games, relaxing games. A smart game in TERENCE consists a cognitively demanding reasoning problem concerning the story's main events, characters and their relations. Relaxing games allow the learner to have breaks from reading, and so maintain the attention alive. The ER diagram of the Game Model is shown in Figure 4, and its main entities are described as follows.

Game. The entity Game represents a game of a story with main attributes:

– id, a unique identifier;
– name, that is, the title of the Game;
– the problem (Task in the ER) that the learner has to deal with;

– the maximum number of Points a player can get for resolving the problem correctly;
– the Maximum Resolution Time, for resolving the problem;
– the Possible and Correct Resolutions of the problem.

Stimulation target. Each Game has a certain stimulation target (stimulationTarget), which is related to one or more RC (reading comprehension) skills. Each Game has also a certain difficulty level (the attribute RC level) for each of the evaluated RC skills. The difficulty level is the RC skill level required by the game.

Smart game and Relaxing game. Each Game can be either a Smart game, which stimulates reading comprehension, or a Relaxing game, which does not.

Story. Each story is associated to Games via the hasGame relation. This has the ordering attribute for setting the right alternation between Smart and Relaxing games.

Feedback. Each game may have diverse types of Feedback, depending on the learner's profile. The Feedback is given only if the Game is wrongly resolved.

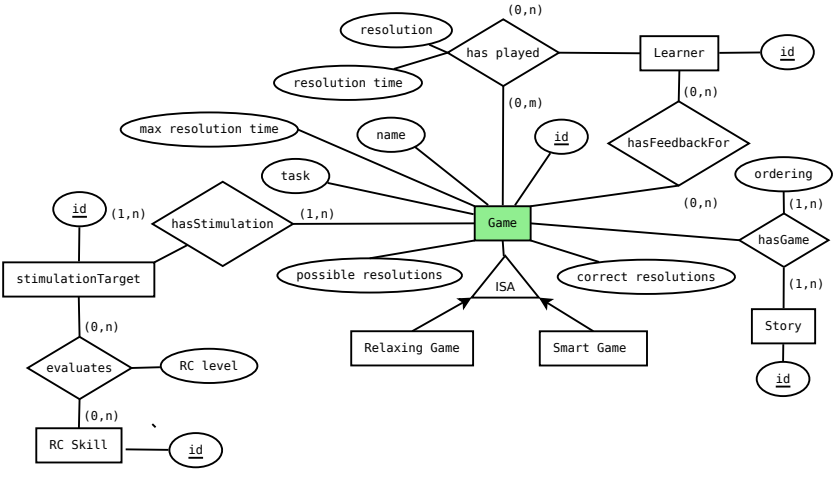

Fig. 4 The current game model

6 Conclusions

The TERENCE system is developed following the UCD and the EBD. The first phase of the project focused on the analysis of context of use and user requirements. This ended into a semi-formal specification of the characteristics of the TERENCE's users and tasks. Our design of the domain and user models of the TERENCE ALS, which is the focus on this paper, is based on such specifications. In particular, our study of the state of the art for user modeling in ALSs and the specification of the characteristics of the users allowed us to define: the learner model; the educator

model; the expert model. The analysis of the tasks allowed us to specify the domain model which structures the learning material of TERENCE, and is divided into the book, story and game sub-models. Last but not least, in the UCD, the design of interactive systems evolves cyclically. Therefore also the specification of the conceptual model of TERENCE will be updated iteratively according to the updates to the requirements.

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