Tailoring Serious Games with Adaptive Pedagogical Scenarios

A Serious Game for persons with cognitive disabilities

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Abstract—**this work addresses issues relevant to the project CLES (Cognitive and Linguistic Element Stimulation) which aims to develop a serious game for diagnosis and training of children with cognitive disabilities. In this context, our objective is to propose a system capable of generating adaptive scenarios taking into account the user's profile. A scenario here is a suite of pedagogical activities allowing the learner to achieve his/her pedagogical goal(s). The system is intended to be as generic as possible i.e. capable of being utilized with a variety serious games. Therefore, we've identified and separated different types of knowledge represented by the system namely; the *domain concepts*, the *pedagogical resources* and the *serious game resources*.**

Keywords-component; adaptive scenario, serious games, users' interaction trace, user profile, handicap

I. Introduction

This study takes place within the project CLES (Cognitive and Linguistic Element Stimulation). The objective of this project is to create an environment of Serious Games for the diagnostic and remedy of cognitively disable persons during learning activities. Our contribution in this project is the creation of an intelligent module capable of selecting the right pedagogical activities according to a learner's profile and presenting them to the user via serious games. Thus we will parameterize/tailor the serious games with learning activities. We also consider the learners' interaction traces as knowledge sources while selecting the activities.

Thus, we present in this paper a model for a system which is capable of generating dynamically adaptive pedagogical scenarios keeping into account the following properties:

- The ability to be utilized in a variety of serious games taking into account their specificities.
- The use of interaction traces as knowledge sources in the adaptation process

Serious games are defined as "a mental contest, played with a computer in accordance with specific rules, which uses entertainment to further government or corporate training, education, health, public policy, and strategic communication objectives"[1]. The idea to learn while playing games is very attractive for most of the users.

We define pedagogical scenarios [2][3] as a suite of pedagogical activities generated by the system for a learner keeping into account the learner's profile to achieve a pedagogical goal in a computer based learning environment. Here, we focus on Serious Games as computer based learning environments.

The learner's interaction traces can be defined as "a history of learner's actions collected, in real time, from his/her interaction with a computer system" [4]. These traces allow the evolution of the learner's competence to be detected and exploited by the tutoring system. The modeling of learner's traces will help us in detecting the different learner's states in while playing the game. This will enable the system to find whether or not the learner is stuck in the game and can provide the learner with some hints or aide. Furthermore, if the learner is finding the system too difficult or too easy the system can adjust the level of difficulty of the game according to the learner. Furthermore, the system can make sure that the same exercises are not repeated many times to a learner.

The problem of generating pedagogical scenarios for a learner is not new and is addressed previously by many authors like in [5][6][7][8]. These works focuses only on generating pedagogical scenarios. Therefore, they do not take into account the specificities of serious games. Consequently, they cannot be easily used with them. Furthermore, none of these systems neither model the learners' interaction traces nor use them as knowledge sources in their adaptation process.

Conversely, the idea of using serious games in education is not new and is being employed by many systems like [9][10]. However, most of the times these systems lack the notion of a pedagogical scenario. Furthermore, almost all of the systems neither model learners' interaction traces nor use them explicitly for adaptation. J-M Carron et al [11] uses the interaction traces but their system neither is usable with different games nor are their scenarios adaptive.

The remainder of this article is organized as follows; the next section will present the application's context for our work. In section III the architecture of our system will be presented. In section IV we present the organization and modeling of domain knowledge. Section V presents the working of the course generator. Section VI presents an example of the working of our system in the project CLES. This article is then concluded by presenting a brief discussion in section VII.

II. Application Context

As mentioned before, we'll be working on the project CLES with different partner laboratories. This project will provide tools (based on serious games) for the reeducation and the diagnostic of cognitively impaired persons. This project covers eight themes: perception, attention, memory, visio-spatial, logical reasoning, oral language, written language and transversal competencies.

Therefore, for every theme, this project aims to develop a suite of games that are focused on specific deficiencies while maximizing, through techniques employed in video games and their cognitive ergonomics. Based on these components, the aim of our research, in this project, consists in developing a module capable of generating personalized courses according to the challenges to be faced and the progress of each patient. This module should therefore keep in to account

- What the practitioner has prescribed for his patients
- The knowledge base of the available treatments for the pathology
- Histories of the previous exercises of the learner, stored in the form of interaction traces.
- Specificities of the serious game

This module will also be able to help the practitioner in monitoring the progress of his patients in each learning session. The global effect of CLES will be checked and validated at the end of the project when the CLES system will be completed. The module we develop has to be first validated on its theoretical properties (meta-models, models and processes).

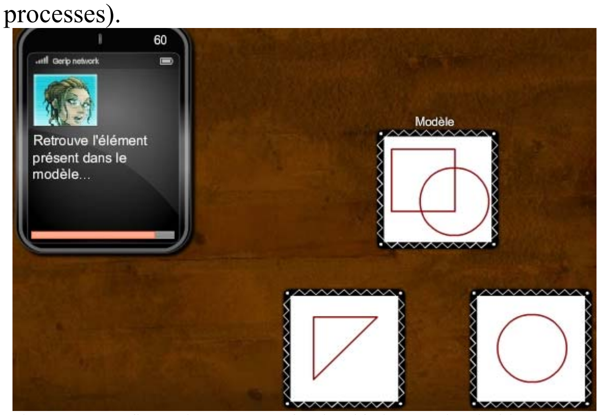

Figure 1: Configuration screen of "Identify inter-mixed objects"

The game environment is composed of a suite of games designed for each of the eight cognitive domains (mentioned earlier). Each game can be parameterized to suit the competencies of different learners. The figure 1 presents the screen shot of a game called "Identify inter-mixed objects". This game allows estimating the visual perception capacity of its learners. The learner has to identify an element, which is shown in the model, among the responses possible. The parameters of the game let the learner to adjust the number of elements in the model (in fig. 1 it is 2), the number of possible responses, the time allowed to respond, etc. Many games are presented to the learner at a time.

Our objective in this project is to select the appropriate games in proper order with their proper parameters according to the profile and needs of the learner.

III. Architechture

Our objective is to construct a system capable of generating dynamically adaptive pedagogical scenarios keeping into the learners' interaction traces and the specificities of serious games. Figure 2 shows the general architecture of this system. The process of generating pedagogical scenario is as follows. (1), the domain's expert(s) feeds the system with the domain's knowledge according to our proposed models (section IV), and the learners' profile. In each learning session, the system is fed with pedagogical goals. These goals are either selected by the learner or are predefined. (2), the system according to the selected goals and the learner's profile selects the concepts from the domain model. This selection is done by the module 'Concept Selector'. The output of this module is the 'Conceptual Scenario'. This conceptual scenario is comprised of concepts along with the competence required to achieve the pedagogical goals.

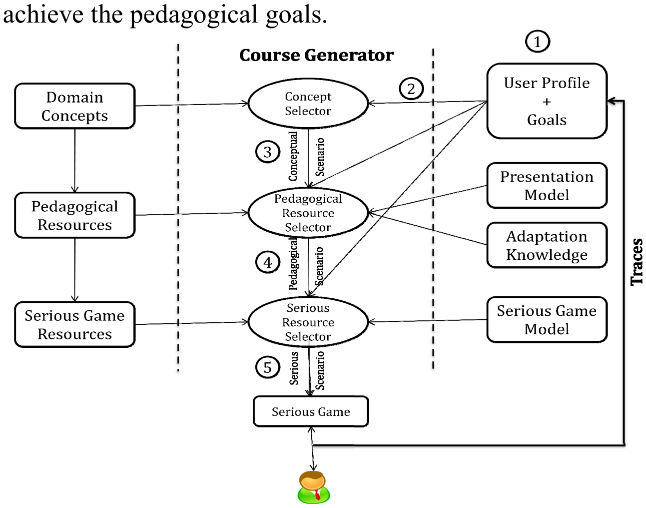

Figure 2: General architecture of our system

(3), the conceptual scenario is sent as input to the module 'Pedagogical Resource Selector'. The purpose of this module is to select for each concept in the conceptual scenario appropriate pedagogical resources. These resources are selected according to the 'Presentation Model' and the learner's profile. The purpose of the presentation model is to organize the pedagogical resources presented to the learner. This model contains two sub models namely 'scenario model' and 'test model'. The scenario model defines the structure of the scenario for e.g. starting a scenario by presenting two definitions followed by an example and an exercise. The test model describes the system's behavior on test type resources for e.g. presenting an easier test after each failure. The selection of these models can either be done by the learner or by the teacher (expert) for the learner. The structure of the scenario model can fit the form defined in [7]. Furthermore, the pedagogical resources are then adapted according to the 'Adaptation Knowledge'. The adaptation knowledge is used to set the parameters of pedagogical resources according to the learner's profile and pedagogical goals. The output of this module is a 'Pedagogical Scenario'. This scenario comprises pedagogical resources with their adapted parameters.

(4), the pedagogical scenario is sent as input to the module 'Serious Resource Selector'. This module is responsible for associating the pedagogical resources with the serious game resources. This association is done based on the 'Serious Game Model'. The 'Serious Game Model' is used to associate the type of serious game resource with the types of pedagogical resource. The output of this module is the 'Serious Scenario'. (5), sees the serious scenario provided to the serious game. The learner interacts according to the pedagogical scenario via the serious game. As a result of these interactions the learner's interaction traces are generated. These traces are stored in the learner profile. Furthermore, these traces are used to update the profile and consequently modify the pedagogical scenario according to the performance of the learner if necessary.

In the next section we present the knowledge models and their organization in our system.

IV. Domain Concepts

Since we are aiming to make our system usable for as many serious games as possible it is necessary to identify and organize different generic types of knowledge. This organization is shown in Figure 3 that represents the knowledge models in three layers.

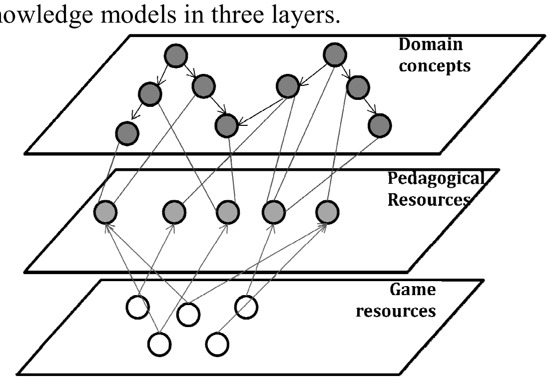

Figure 3: Different layers of resources used in our system

The first layer represents the models of 'Concepts' related to the pedagogical domain (e.g. Addition, Subtraction, Multiplication) and the concepts related to the physical and cognitive capacities of the learner (e.g. Attention, Perception). These concepts are related to each other with different relations. The second layer represents the 'Pedagogical Resources' (e.g. Exercises, definitions, examples…). Each pedagogical resource is linked with one or more domain concepts. The third layer represents serious game resources (e.g. Non-playing characters (NPC), chairs, tables, doors…). These resources are used with the pedagogical resources to be presented to the learner. The modeling of the domain concepts and relations between them is shown in the following sections.

A. Modeling

A concept is an abstract representation of an information item from the application domain [12]. In our case the concepts that we consider represent both the pedagogical domain and the cognitive capacities. We represent the domain knowledge as a tuple:

Domain Concepts (DC): <C, R >

- C : concepts of the domain
- R: relations between the concepts.

We consider the graph of DC to be a DAG (Direct Acyclic Graph) to avoid infinite paths when generating courses or scenarios [8]. We define 'C' as;

C: < id, P >

- Id : unique identifier
- P : Properties : description of the concept

The relation 'R' is defined as:

$R : < C_{From}, T, RC^{+} >$

- C_{From} : the originating concept of the relation
- T : type of relation
- RC : Relation Concepts = $<C_{To}, F, Value>$
  - $C_{To:}$ target concept of the relation, the direction of relation is from C_{From} to C_{To}
  - F: function (optional) to calculate the value of the relation. The semantics of the value may differ dependig on the type of relation
  - Value: value between the concepts of the relation. This value is used as default in the absence of function 'F'.

The values propagated are percentages. The functionality of a function F depends on the expert for e.g. a function can decide to contribute 25% of value of concept C_{To} to concept C_{From} and to contribute only if the value of the concept C_{To} is greater than 30%.

B. Types of Relations

In this section we will show some examples of the relations that we use in our system along with their modeling and an example of use. Some of the relations showed are often used in literature [8][13].

Has Parts: HP = $(x, y_1, y_2, y_3 \dots y_n)$: the concept x is composed of the sub-concepts $y_1, y_2, y_3 \dots y_n$. To learn x it is necessary to learn all the concepts $y_1, y_2, y_3 \dots y_n$. For example if there is a concept x and it has sub concepts y_1 and y_2. The concept y_1 contributes 20% to concept x and the concept y_2 contributes 50% to the knowledge of x. These concepts are modeled as follows in our model:

$R =< x, HP, RC_1, RC_2 >$

- $RC_1 = <y_1, f, 20>$
- $RC_2 = <y_2, f, 50>$

Requires: R = (x, y): to learn concept 'x' it is necessary to have sufficient knowledge of concept 'y'.

Order: O = (x, y): it is preferable to present concept 'x' before concept 'y '

Type-Of: TO = (x, y): concept 'y' is a type of concept 'x'. This relation can be considered as a Specialization relation.

Parallel: PL = (x, y): the concepts 'x' and 'y' are parallel concepts and must be studied and tested simultaneously.

Note: the semantics of the value propagated between two concepts depends on the relation type for example "**Has Parts**" relation means the contribution made by the part towards the whole. A relation like "**Requires"** means the minimum knowledge required to progress.
A concept x is called atomic if:

- $\nexists$ a concept y such that **Has Parts** (x... y)
- $\nexists$ a concept y such that **Type-Of** (x,y)

If we analyze the type of relations we have defined we can categorize these relations in two categories, namely:

- Decomposition: **Has Parts** & **Type-Of**
- Order: **Requires**, **Parallel**, **Order**

The decomposition relations are used by the system to search the domain graph for appropriate concepts given a target concept. However, the relations of the type Order helps the system to select the concepts that are useful in teaching a given concept.

The working of the Course Generator is shown next.

V. COURSE GENERATOR

As mentioned in section III, the process of pedagogical scenario generation given pedagogical goals and learner's profile is handled by three modules namely 'Concept Selector', 'Pedagogical Resource Selector' and 'Serious Resource Selector'. The general functionality of these modules is already defined in section III. In this section we'll present the textual description of the working of these algorithms

A. Concept Selector

The purpose of this module is to generate a list of domain concepts required to achieve the pedagogical goals. This generation is performed keeping into account the learner's profile. The pedagogical goals are defined as the set of target (domain) concepts along with the competence of each concept required. The generated list of domain concepts is called 'conceptual scenario' in our system.

The generation process works as follows; first for each target concept (TC) it is checked whether or not this TC is sufficiently known by the learner. If it is sufficiently known by the learner then this TC is ignored and the next TC is looked.
Then the module checks whether or not the TC has some concepts related to it. The relations checked by the module are: 'Has Parts', 'Requires', Type-Of' and 'Parallel'. If there are any concepts that are related to TC then the module calculates there appropriate required competencies. The calculation of the competencies depends on the type of relation. Then these concepts are added to the list if they are not sufficiently known by the learner.

B. Pedagogical Resource Selector

The purpose of this module is to select the appropriate resources for every concept in the 'Conceptual Scenario' given a 'Scenario Model (SM)', 'Test Model (TM)' and learner profile. This selection is outputted in the form of a "Pedagogical Scenario". This contains a list of resources associated with each concept along with their appropriate parameters.

The selection process goes as follows; firstly, the process for each target concept (TC) in the 'conceptual scenario' searches for the resources of type 'T' as described in the SM. If there is more than one pedagogical resource of type 'T' associated with the concept. Then the resource which is not already seen by the learner or not sufficiently known by the learner is added to the list. Along with the resource the process also consults the adaptation knowledge of this resource to select the parameters of it according to the learner's profile.

C. Serious Resource Selector

This module is responsible for the association of pedagogical resources in the 'Pedagogical Scenario' with the serious game resources according to the learner's profile and Serious Game Model (SGM). The result of the execution of this module is a list called 'Serious Scenario'. This list contains resulting concepts along with the serious game resources initialized with the pedagogical resources and their parameters.

The working of this module is as follows; firstly, the process for each concept and for each of the concept's selected pedagogical resources selects a serious game resource of type 'SGT' according to the type of pedagogical resource as defined in the SGM. Then the process consults the learner profile to verify whether the selected resource is appropriate for the learner. If yes then this resource is added to the list.

Our contribution in the project CLES is shown next.

VI. FIRST RESULTS

The application context has been described in the Section II. The project CLES tests many cognitive competencies of a student using a serious game. This game is an adventure game. The protagonist of this game is a character named 'Tom O'Connor'. His job is to search for a relic. In the game he is placed in different rooms. Each room contains many game objects (chairs, tables, bookshelf, lamp etc). Hidden behind some of these objects are different challenges. The learner is required to click on these objects to access the challenges. Each challenge corresponds to a game (figure 1 is a screenshot of one of the games). Then the learner is required to solve these challenges in order to advance to the next room. A screenshot of one of these rooms is shown in figure 4. In this example, the game objects are: chair, screen and table.

The figure 5 presents an example for knowledge modeling of *Perception* theme. The modeling is divided into three layers; the first layer represents the domain concepts. The second represents the pedagogical resources attached to the concepts (such as Long-Vue presented in Section II). The third layer represents the game objects like chairs, tables, bookshelf, lamp etc.

Figure 4: Level screen of the game

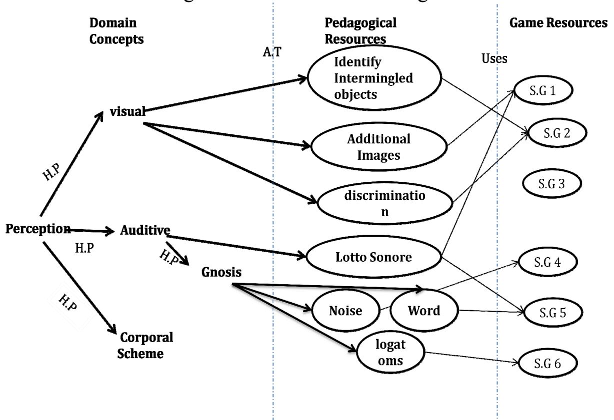

Figure 5: Modeling of the concept 'Perception' in three layers

In the context of the project the prototype of the game is in the final stages of development. The games being developed are flash-based games and will be accessed via web. At our end the development of the course generator is completed. The models that we've developed are validated and tested with the project. To test the performance of the course generator several simulations have been ran. The results obtained are as expected thus encouraging. Experimentation with real learners will be conducted once the prototype is completed and deployed.

VII. Conclusion and Future Works

In this paper we presented the working of a system capable of generating dynamically adaptive pedagogical scenarios. This generation keeps into account the learner' profile and uses the interaction traces as knowledge sources. Furthermore, the specificities of serious games are also kept into account. This helps in tailoring the Serious Games according to the learner. The practical application of this system in the Project CLES is also discussed.

The workability of the system has only been tested via simulation. More tests with real audiences in real environment will be conducted once the games are fully deployed and are made open to public. On the functional side of the system we are yet to fully integrate the learners' interaction traces in the system i.e. to use them effectively as knowledge sources in the adaptation process. The other functionality we are currently working on is the ability to dynamically adapting the scenarios in real-time if and when necessary. This adaptation is done according to the performance of the learner. The learner is constantly monitored during his/her interaction with the game and when necessary the system will intervene with appropriate modifications. These modifications can take the form of, reducing the difficulty of the proposed exercises, giving hints or tips to the learner where s/he Seems stuck, modifying the scenario itself etc.

Acknowledgment

A part of this work has been supported by the project ITHACA.

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