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80Days: Melding Adaptive Educational Technology and Adaptive and Interactive Storytelling in Digital Educational Games

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Abstract. The present paper introduces the 80Days project, an interdisciplinary European research project endeavoring after pushing the state-of-the-art in digital educational games. The main objectives of the project are enabling curriculum-related education with competitive computer games, realizing non-invasive and educationally meaningful support of the learner, and combining adaptive tutoring with interactive digital storytelling. 80Days' solution to those challenges is an ontology-based linkage between so-called knowledge spaces and atomic narrative elements. On this basis, an intelligent adaptation of storyline, story pace, and game play to the learning progress and the preferences of the learner can be achieved.

Keywords: Adaptivity, Personalization, Interactive Storytelling, Educational Games, Computer Games

1 Introduction

Computer games have become an incredibly successful part of today's entertainment landscape. With increasing time children and adolescents spend on computer games, the idea of utilizing their motivational and educational potential is getting increasingly popular and fascinating. Today's computer games not only have a tremendous motivational potential, computer games enable realizing elementary and essential pedagogical and didactical principles in a very natural way [1]. Computer games, for instance, provide an emotionally and semantically appealing and meaningful context for learning, rich and immersive possibilities for visualizing contents, or the possibility for self-directed, active learning. In short, computer games do have the potential to make knowledge and skills attractive, important, and meaningful.

From today's perspective, the realization of that vision is still in its infancy [2]. Serious products have not entered the market yet; this is especially true for games that focus on older children and adolescents. The European research project 80Days – inspired by Jules Verne's novel "Around the world in eighty days" – aims at

developing the necessary psycho-pedagogical and technological foundations for successful digital educational games (DEGs) - successful in terms of educational effectiveness as well as financial turnovers. Basically, the project's endeavors include melding curriculum-related subject matter with the fun and excitement of an attractive and compelling computer game. In this context, the intrinsic motivational potential of computer games is the key to learning success in the sense of voluntary and maybe hidden learning activities.

The basis for 80Days' mission is an intelligent technology that allows an adaptation to individual learners, their prior knowledge, abilities, and preferences; even more, a technology that allows a so important but so fragile dynamic balance between challenge and ability. Only such learner will have optimal motivation to play and therefore to learn, that is perfectly challenged, neither overburdened by too difficult gaming and learning activities nor bored by too simple ones. In 80Days, this kind of adaptation is realized by providing the learner with adequate psycho-pedagogical interventions (e.g., hints or feedbacks) but also by the adaptation of the entire gaming context and ambience (e.g., the level of difficulty, the mood, the pace, or even the entire storyline). At the same time, this approach shall contribute to the chances of educational games on the market: the envisioned intelligent personalization can reduce the immense development costs of state-of-the-art computer games by realizing different game scenarios and even entirely different games on the basis of a single pool of (expensive) game assets (e.g., 3D objects).

The very nature of the 80Days project is melding adaptive educational technology with interactive and adaptive storytelling. In the rich context of DEGs with their large degrees of freedom, the individualization of the learning experiences as well as the adaptation to the individual aims, needs, abilities, and prerequisites of learners requires an in-depth understanding of the learners and their behavior within a DEG. Another challenge is not destroying the flow of the gaming experience by educational guidance and knowledge assessment procedures. To meet these requirements, cognitively sound models of a learner's behavior within virtual learning environments are essential. Moreover, while traditional approaches to adaptive educational technologies primarily focus on knowledge and learning progress, digital games constrain the consideration of aspects such as individual preferences (e.g., visual styles or gaming genre), individual motivation, collaboration, or (problem solving) behavior. Existing, primarily competence-based, cognitive models for adaptive educational technologies must be merged with theories of (achievement) motivation and models of interactive and adaptive storytelling in order to establish a comprehensive theoretical framework for combining learning and gaming.

As already mentioned, a weak spot of utilizing digital games for educational purposes is the high level of development costs, in terms of assets production and didactic design. The overall costs for developing DEGs, however, must be justified by educational efficacy, by an appropriate balance between gaming and learning, and - most importantly - by the market for specific educational game genres. The reduction of development costs is a crucial factor for publishers of educational material and game developers in so far as the market for games with specific educational aims can be considered to be significantly smaller than the global market for recreational or commercial games. Therefore, a technological as well as psycho-pedagogical framework must be established that enables to reduce the costs and shorten the

development lifecycle. Essentially, this shall be accomplished by providing generic frameworks and models for adaptive interventions, interactive and adaptive storytelling, the (re-)use of one base game to create multiple games, and the integration of existing learning resources. 80Days mission is to develop a methodological framework that allows either publishers, educators, or learners to choose from different classified game genres and styles as well as from different learning-related factors (e.g., the learning goals or preferences) in order to realize tailored learning experiences based on an existing pool of learning objects and game assets as well as external resources. Making development more effective also includes theoretically and empirically sound evaluation and validation methods.

2 Adaptive, Interactive Competence Development

Using “intelligent” machines for educational purposes can be traced back to 1926 when Sidney Pressey [3] tried to build a machine that presented multiple choice questions, their answers, and immediate feedback. Current efforts in providing intelligent and adaptive educational technologies were leveraged by Benjamin Bloom in 1984 [4] who stated that students who received one-to-one tutoring performed on average as well as the top two percent of those receiving classroom instructions. Ever since psychologists, educationists, and technicians attempted to develop technology that is able to take the role of a private teacher and to intelligently provide individual learners with suitable tutoring. In the context of educational games, concepts of adaptivity on macro and micro levels, which are tailored to learning environments with large degrees of freedom, were introduced [5] [6]. Macro adaptivity refers to traditional techniques of adaptation such as adaptive presentation and adaptive navigation on the level of learning objects (or *learning situations* in a DEG). Generally, macro adaptive interventions are based on a fixed learner model (e.g., traits) or adaptation model (e.g., pedagogical implications) and on typical (knowledge) assessments (via test items). Micro adaptive interventions, on the other hand, are non-invasive (meaning that an overall narrative is not compromised) and affect the presentation of a specific learning object or learning situation.

The cognitive background of these types of adaptation is *Competence-based Knowledge Space Theory* (CbKST) [7], a cognitive framework, extending the originally behavioral *Knowledge Space Theory* [8], where a knowledge domain is characterized by a set of problems and prerequisite relations among them, establishing a *knowledge space*. The basic idea of CbKST is to separate observable performance and underlying latent skills or competencies (e.g., [9]). The relationships between the skills and the learning tasks are established by interpretation and representation functions. By associating skills with the tasks of a domain, a knowledge structure on the set of problems is induced. Recently, this theoretical framework has been elaborated by integrating an ontological approach including conceptual structures, didactic strategies, and by connecting the competence approach with problem solving models in order to interpret a learner’s behavior in various learning and assessment situations [6].

3 Adaptive, Interactive Storytelling

The second core element of 80Days is tailoring the game's storyline and story pacing to individual learners. Digital storytelling means utilizing digital media to generate rich and immersive stories. Adaptivity indicates the system's ability to automatically adapt the story to the needs of the audience; interactivity indicates functionalities to enable the audience to affect the story according to their individual interests.

Early story generation systems relied on non-dramatic models of narrative. In the spirit of Brenda Laurel's vision of interactive drama [10] and [11] implemented the first story generation systems. The most effective drama models developed for feature films by several authors (e.g., [12] or [13]) have since become global professional standards. Very few drama models developed for screenwriting have yet been integrated in story generation systems. In a DEG, adaptive and interactive digital storytelling basically serves two essential purposes:

First, it strongly supports a personalized learning experience by adapting the game's story to individual preferences and by providing the possibility of explorative learning processes. Additionally, it enables the learner to actively interfere with the game and its narrative. Such individual preferences in style and emotional quality are considered to be a crucial factor for facilitating learning and retaining motivation to play and learn. For that purpose, a specific authoring environment for DEGs has to be conceptualized, supporting the configuration of adapted story pacing, accounting for the integration of varied didactical drafts [14].

Second, interactive and adaptive storytelling serves the re-usability of learning material by enabling the realization of different stories and entirely different games (even for different learning domains) based on more or less the same pool of atomic story units, patterns, and structures as well as learning and gaming concepts, elements, and objects.

The challenge of creating dynamic yet plausible adaptive narratives is not trivial and requires arduous manual editing of branching narratives. Experimental systems such as *Façade* [15] or *Virtual Human* [14] exemplify the challenges of creating adaptive narratives. Therefore, 80Days generates a theoretical basis for generic yet engaging, immersive, and plausible storytelling in DEGs. More importantly, 80Days merges this theoretical basis with cognitive and motivational/emotional aspects of dynamic learning processes.

There are different projects and initiatives targeting either at (interactive) storytelling issues as 'instrument' for virtual environments, training, and simulation or at educational games in general. However, both approaches did not converge yet and integrated solutions combining both interactive storytelling and gaming for learning and training purposes are lacking entirely.

The main challenge is settled in the 'narrative paradox': The conflict between narration (linear approach, dramaturgy, and plot) and interactivity (interaction, user participation, game approach). Chris Crawford [15, 16] and others argued that this link can never be made. Michael Mateas and Andrew Stern [17], in turn, provided a first 'almost' working interactive storytelling system.

The question is how to transpose such experimental approaches of interactive and adaptive storytelling to educational settings and educational games. From an application oriented point of view it is very exciting to combine the different

disciplines, expectations, or typical workflows and analyze arising requirements and constraints for storytelling and game-based learning scenarios. 80Days aims at applied research covering basic theoretical work (definition of a theoretical framework or formats) as well as domain-specific developments (methods, concepts, authoring tools, story editor, etc.) and exploitation (story editor or format).

4 Game Paths: A Link between Story and Knowledge

A crucial aspect of adaptive, interactive storytelling in an adaptive DEG is to find an appropriate storyline on the basis of a pool of given scenes/game-based narrative learning objects. The key challenge in this context is to find a suitable and fair balance between the initially created story and ‘exceptions’ caused by user interactions (unforeseen or at least not intended by the author) or educationally inspired adaptations. Examples for such exceptions are wrong paths (not following the instructions of a virtual guide), skipped stations (passing artifacts without interacting), or too long/short interactions with artifacts (causing problems with external and internal time constraints). Moreover, the red thread through the story and therefore through the game must be in line with the learner’s learning progress and goals. To accomplish this linkage, finding educationally meaningful, yet immersive and exciting storylines, formalisms and rules are required. The following are the core constraints for rule building:

- *External constraints*
Constraints by the game design, learning progress, learning goal, or prior knowledge of the learner
- *Dramaturgic aspects and story models*
Aspects including the characteristics and heuristics of story models and narrative structures. For example, plot points should be set at specific times, introductions/explanations shouldn’t take too much time, the story climax shouldn’t be acquired too early, and so on.
- *Importance of content and individual story elements*
As far as individual story elements (such as scenes or specific dialogues or content) are attributed by the author with an indicator for importance, higher weighted elements should be preferred. For instance, an author might classify the importance of specific dialogue fragments of a chat station as ‘very high’ because it provides the answer to a leading question or ‘essential knowledge’, which the pupils should take out of a museum visit. Contrary, background information about the artist of a painting might be classified as ‘interesting’ and should only be selected/visualized to the user as far as there is enough time for it.

With respect to the last point and the importance of story elements from an educational and pedagogical viewpoint, [18] introduced a three level concept with a content level storing the learning units (learning objects = story objects), a learning level (where the learning objects and units are classified and assigned to didactic learning phases), and a story level (integrating the learning units into a story with plot points and an arc of suspense). On this basis it is easy to attribute individual

(narrative) learning objects as well as a set of objects belonging to a didactic learning phase with an indicator of importance. Similar to traditional learning systems and courseware, learning elements/units are important for specific user groups and are skipped (to speed up a story) for other more advanced and experienced learners. In contrast, additional learning units might be integrated in the course in order to ‘keep fast learners busy’ or provide further background information about a topic.

An overview of well-known story models and its applications in interactive storytelling systems and storytelling-based edutainment provide [14] and [18]. In conclusion, most story models and dramaturgic approaches, especially in the area of scriptwriting, are more or less derived from the classical three-act structure of Aristotle providing an arc model with ‘exposition’, ‘rising action to climax’ and ‘denouement’. 80Days combines this story and learning by linking competence spaces with story plots (Figure 1), which generates game paths, possible and meaningful paths through the game accounting for story model, learning objectives, and pedagogical interventions. From a technical perspective, this linkage grounds on an ontological approach, which was developed in the context of DEG [5], extending it by story elements and by a mapping of competences / knowledge and story. Similar to

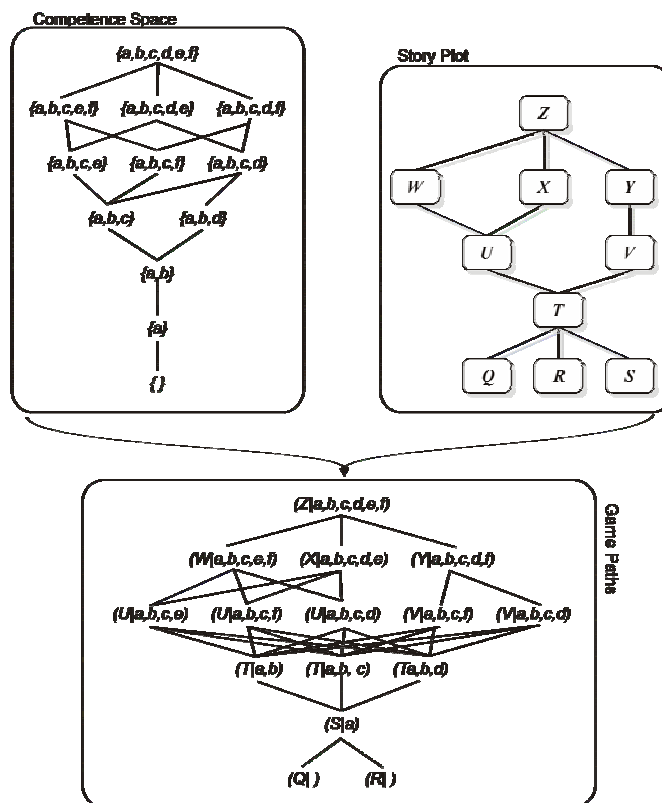


Fig. 1. Deriving game paths by merging competence spaces and story plots.

the competence-performance separation introduced in CbKST, we realize a competence-performance-story separation based on mathematical interpretation and representation functions. Therefore, from competence spaces and story plot we can derive a “game space, the set of admissible and meaningful paths through story and game.

5 Summary and Outlook

This paper introduced the 80Days project and its enthusiastic attempt to meld aspects of DEGs, adaptive tutoring, and interactive digital storytelling. - We have outlined a conceptual approach on a general level and specified new ideas in the context of story sequencing and story pacing, on a theoretical as well as technical perspective. However, the project is at an early stage and future research and development must develop, refine, and implement the current ideas. Particularly, the mapping between game elements, story elements, and educational elements on a formal basis of interpretation and representation functions must be worked out in detail. In the context of 80Days, the outlined approach is integrated as a narration engine, establishing a pendant to an adaptive engine, which is responsible for monitoring learning progress and for providing suitable psycho-pedagogical interventions, and the game engine.

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