Applications

Automatic feedback generation in scenario-based e-learning with an application to the healthcare sector

Paola Beltrami,[b] Pierluigi Crescenzi,[a] Giacomo Gensini,[b] Alessandro Innocenti,[b] Paolo Lippi[b] e Nicoletta Saccone[a]

[a] Dip. di Sistemi e Informatica, Università di Firenze
[b] SAGO – Firenze

{piluc, saccone}@dsi.unifi.it;
{a.innocenti, g.gensini, p.beltrami, p.lippi}@sago.fi.it

Abstract

The aim of this paper is to propose a scenario-based course model inspired by the «game-book» paradigm in which the learner has the opportunity to choose his/her own adventure. In particular, our aim is to develop a model that provides a mechanism for automatically generating semantically rich feedback to the learner during and at the end of the learning process. To this aim, the system individualizes and analyzes the learner's personal learning paths, so that immediate feedback is given according to the choices taken. The feedback algorithm gives indications to the learner about the points in which a presumably incorrect behaviour has been followed. In particular, feedback is provided through an «indicator of quality» which is based on the topology of the graph induced by the scenario-based environment.
We applied our model to the healthcare sector, which is experiencing a phase of considerable growth. In particular, we considered the problem of the waiting lists in Radiology. The course is composed of several scenarios that describe the situation at the current time, the resources available and the performable choices (examples of resources available are the number of surgeons and the quantity of available financial resources, while the choices are mainly related to the number and the level of instruction of surgeons and to the status of the technology). The course implementation is basically complete and a preliminary experimentation will be executed in the near future.

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1. Introduction

The use of internet and computers has grown at a rapid rate, and it has produced a radical change in the educational and informational services. A direct consequence of this development has been a different way to learn, underlining the importance of self-learning. So the meeting of technology and education has produced e-learning, which has the advantage that it can be used at any time, making use of free time, but lacks the learning effectiveness of the traditional method. In a classroom there is interaction between students and teachers and also between students and students. In this context the teacher provides motivation to the students, adapts his teaching to the formative needs of everyone, introduces new subjects and uses questions as a means to understand if the concepts or the «problem solving» techniques have been learnt. In other words, teachers produce feedback: indeed, any message generated in response to a learner's action helps the learner to identify errors and to become aware of misconceptions.

Even though e-learning has potentially the ability to provide immediate feedback to individual responses, so far there has been a lack of effective feedback in the electronic learning environments since almost all feedbacks are related to question-answer situations (Mory, 2003). To overcome this drawback the blended learning has been introduced, this combines online learning activities with formative tools like virtual classroom, teaching and tutoring online, forum and so on. Unfortunately these tools introduce delays, are time consuming and can't always take place: hence, also this method loses part of its effectiveness.

In our research we intend to circumvent these limitations by realizing an interactive learning environment in which a learner reads, learns concepts, tries to solve problems, gets feedback on solutions, and uses feedback to make progress. Our environment is based on the constructivist theory which states that, in order to acquire knowledge, the course has to be composed of two parts: a theoretical one in which the student learns concepts, and a working one in which the student makes exercises. Our scenario-based learning course starts from the «game book» concept and produces «intelligent» and immediate feedback during the learning process.

2. Scenario-based e-learning

We developed our scenario-based model having in mind «game books». A game book is an interactive book and represents the union between the narration of a story and the freedom of action/selection that a player has in a role-playing game. Game books are sometimes known as «choose your own adventures»: the player starts reading it as an ordinary book, but at the end of each page both options and choices are given (i.e., decision points). The player's decisions will influence

the course of the adventure and determine the destiny of the reader who is the protagonist.

Most game books have multiple possible endings, at least one of which is a «win» with most or all of the rest being «losses». Some game books also require the reader to keep track of the main character's resources or status, upon which certain branches of the story may be dependant.

The scenarios of our scenario-based model are similar to the pages of a game book in which the learner – i.e. the protagonist - is prompted to choose between one of several possible courses of action, and to turn to the appropriate scenario. As in a game book, the learner decides the sequence of actions to solve problems and may or may not arrive at the prefixed goal.

We have designed and implemented a «scenario-based model» as a learning tool for several reasons:

- the scenarios put the users in a situation or context, expose them to issues, challenges and dilemmas, and ask them to apply knowledge and practice skills relevant to the situation;
- a scenario represents a real job situation in which the user is asked to make a decision before going on. It is not important to give the «right answers», but it is relevant to have, for instance, «a coherent strategy» and a right behaviour (Naidu, Oliver & Koronios, 1999);
- the scenario serves to motivate learners and gives them the opportunity to «learn by doing» in a complex area;
- a (real life) problem is explicitly used to make learners «to identify and search for the knowledge that they need to obtain in order to approach the problem» (Davis & Harden, 1999).

The last issue, i.e. «searching for knowledge», is a relevant aspect that our learning tool can enhance and this scenario model aims to promote both self-instructed and collaborative activities. We believe that every learning path, to be successful, requires interaction, discussion and active collaboration between peers and/or with teachers, experts, and mentors. This is why we consider a scenario like the one described in this paper as «one of the elements» to be used in an on-line «community-oriented» environment like, for instance, Moodle could be.

We have to consider that the scenario approach generally follows a performance improvement imperative. The focus could be on improved outcomes rather than the acquisition of knowledge and skills. The learner is asked to make some behavioural changes. A central principle of this approach is that changed performance is a function of the immediate and tangible «rewards» received for successful behaviour. A sophisticated chain of psychological events occurs from the initial phases of learning about a subject to the internalization of habitual behaviour required for successful interaction in a learning scenario. Testing learner performance in a

scenario is obtained by assessing outcome measures and performance behaviours through indicators of successful results and consistent behaviours. According to the model there may be one or more success paths and one or more failure paths determined by good or bad choices. After having described the scenario and the particular decision situation, learners have a set of choices. It's at the decision nodes that the learner's behavioural path is determined and learner's performance it is assessed.

3. The relevance of feedback

Feedback has an important role in increasing the level of motivation of the students and in keeping them motivated and involved at the same level throughout the entire process of learning, as well as in stimulating the interaction between students. Feedback has been incorporated in many theories of learning, from the early views of behaviourism (Skinner, 1958), to cognitivism (Gagné, 1985; Kulhavy & Wager, 1993) and through more recent models of constructivism (Jonassen, 1999; Mayer, 1999; Willis, 2000). Because of its significance in the past, feedback still pervades the literature and instructional models as an important aspect of instruction.

In the context of instruction, the term «feedback» can be used to describe any communication or procedure given to inform a learner of the accuracy of a response, usually to an instructional question (Carter, 1984; Cohen, 1985; Kulhavy, 1977; Sales, 1993). According to Gagné, this type of feedback represents one of the events of instruction and usually follows some kind of practice task. More in general, feedback allows the comparison of the current performance with a standard set of performances. In technology-assisted instruction, feedback is the information presented to the learner after any input that might include not only answer correctness, but also precision, timeliness, learning guidance, motivational messages, lesson sequence advisement, critical comparisons, and learning focus (Hoska, 1993; Sales, 1993). Briefly, it is any message or display that the computer presents to the learner after a response (Wager & Wager, 1985). The purpose of feedback is not only to confirm or change a student's knowledge as represented by answers to practice or test questions but also to obtain variances in behaviour as a result of self-regulation and student engagement. Research literature identified several common areas to be studied that determine the different types of feedback. These areas include: type of information content, amount of information, and feedback complexity (Dempsey, Driscoll & Swindell, 1993; Kulhavy & Stock, 1989); timing of feedback, that is, immediate versus delayed feedback (Dempsey, Driscoll & Swindell,1993; Kulhavy, 1977; Kulik & Kulik, 1988); type and analysis of errors (Peeck & Tillema, 1979; Phye, 1979); type of learning outcomes being studied (Smith & Ragan,1993); and various motivational functions that feedback might provide.

Regarding this last area, feedback can be used to help the motivational level of students, and psychologists have constructed basic theories of motivation to explain it in the learning process. Some of these theories, that tend to focus on behavioural reinforcement and performance, are those based on goals and goal discrepancy feedback, those based on self-efficacy and task expectancy, the attribution theory and the ARCS (attention, relevance, confidence, and satisfaction) model of motivation (for a comprehensive survey of these theories see Mory, 2003).

Finally, a wide range of potential uses of feedback, previously not considered, appeared with the new learning environments such as simulations, scenario-based environments, interactive microworlds, gaming environments, and so on: first of all the ability to provide rapid information from and to learners. Of course, these environments enable us to provide more complex and complete feedback compared with those provided at each step of Skinner's programmed instruction.

The advances and growth in Web-based instruction have certainly changed the types of feedback mechanisms that are being actively used by students. As asserted by Bischoff (2000), the role of feedback in on-line teaching is critical for students' success in the on-line environment.[1]

4. The course model description

Our aim is to develop a Scenario-Based Learning Course model (in short, SBLC model) that, on the one hand allows learners to acquire knowledge by means of a learning tool, and on the other hand allows authors to «build» the courses.

The learning tool provides a mechanism for automatically generating generic, domain and target independent, semantically rich feedback to the learner during and at the end of the learning process. In our course, the learner takes decisions that determine a sequence of activities whose result may or may not lead to the prefixed target.

The course individualizes and analyzes the learner's personal learning paths and immediate feedback is given on the bases of the choices taken. On the other hand, the author of the course defines the set of choices the learner can make with the corresponding preconditions and state transformations, the resources that the learner has at his disposal, the indicators that show the current state of learning, the initial state (i.e. the values of the resources and indicators at the beginning), and the set of targets.

Of course, the author's task is the most complex one because he has to identify the elements that compose the course: it is common knowledge that the organization of an online course is more difficult than a traditional course.

[1] Feedback in on-line environments should have the following qualities: multidimensional, nonevaluative, supportive, student controlled, timely, and specific (Schwart and White, 2000).

4.1 The mathematical model

The basic notions used in order to formally define the model behind our SBLC are those of resource and indicator, system state, page and scenario.

Any course based on our approach must include a set of *resources* and a set of *indicators:* for each resource r (respectively, indicator i), V_r (respectively, V_i) denotes the set of possible values of r (respectively, i). Let R and I be the sets of resources and of indicators, respectively. A *state* of the course is a function s with domain the union of R and I, such that, for each resource r and for each indicator i, $s(r)$ belongs to V_r and $s(i)$ belongs to V_i.

A *page* p is formed by the following two components:

- a *description* d_p which can be any combination of textual and hypermedial information;
- a set C_p of *choices*, where each choice c in C_p is specified by a *text* t_c, a *pre-condition* π_c which is a function that associates to any state s a Boolean value true or false, a *state function* σ_c which is a function that maps states into states, and a *target page.*

A scenario is formed by a state s and by a page p. Given a scenario $S=(s, p)$, for any choice c in p such that $\pi_c(s)$ is true, the successor of S corresponding to c is the scenario $S_c=(s', p')$, where $s'=\sigma_c(s)$ and p' is the target page of c.

Any course includes an *initial* scenario I, that is, an initial state and an initial page. By starting from I, the player will navigate from a scenario to another one according to the choices that will be made at each page. In particular, if the player is in the scenario $S=(s,p)$ and selects the choice c in p, then the player will be moved to the successor of S according to c.

Finally, the system includes a set F of *final* scenarios: the goal of the player is to reach any element of F.

4.2 The feedback indicator

In general, any course built according to the above described model will allow the player to navigate from the initial scenario to a final scenario in several different ways.

Moreover, it is not even sure that the player will reach a final scenario. For this reason, we now propose a measure of quality of the player's behaviour which can be used in order to provide the player with an immediate feedback concerning the correctness of the performed navigation.

A *path* from S_1 to S_k is a sequence $S_1=(s_1,p_1),\ldots,S_k=(s_k,p_k)$ of scenarios such that, for any i between 2 and k, there is a choice c_{i-1} in p_{i-1} for which S_i is the successor of S_{i-1} according to c_{i-1}. The value k is said to be the *length* of the path from S_1 to S_k.

The *quality q(S)* of a scenario S is equal to the minimum length of a path from S to a final scenario: clearly, more than one such path can exist, but this does not change the quality of S.

A possible *move* $m=(S_1,S_2)$ of a player is any pair of scenarios such that there is a path of length 2 from S_1 to S_2 (in other words, there is choice c in the page of S_1 for which S_2 is the successor of S_1 according to c). The *quality of a move* $m=(S_1,S_2)$ is defined as $q(S_1)/q(S_2)$.

It should be clear that the quality of a move is always a number less than or equal to 1. Indeed, if the move is consistent with a minimum length path towards a final scenario, then the quality is 1, otherwise the quality of S_2 must be greater than the quality of S_1 and, hence, the quality of the move is less than 1.

For each navigation by a player, that is, for each sequence $m_1,\ldots,m_h$ of moves, the system then keeps trace of the quality of each move m_i: this function is equal to 1 for every «correct» move (that is, for every move consistent with a current minimum length path towards a final scenario) and it is less than 1 for every other move.

At any moment or at the end of the navigation, the system can consult the quality of the performed moves and, hence, can eventually identify critical steps performed by the player (see figure 1): how the system is assumed to deal with these critical steps depends on the application and it is beyond the scope of our model. In the next section, instead, we will show how the model can be used in order to develop a specific scenario-based learning environment.

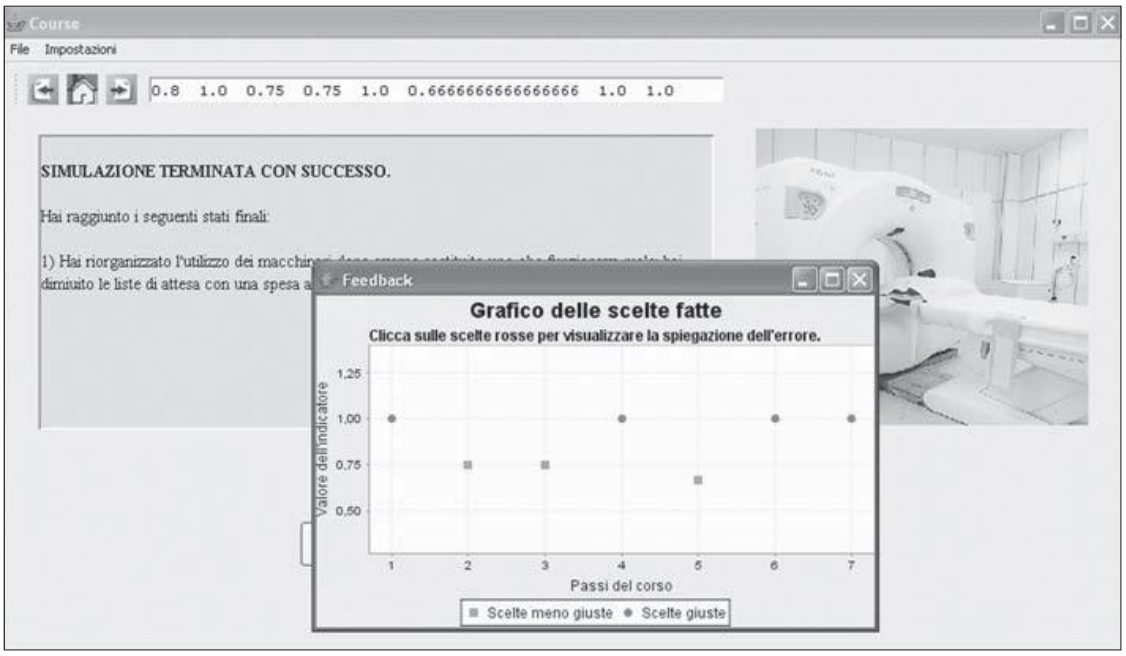

Figure 1 An example of feedback generation.

5. An application example

TBT (Technology Based Training) in the health sector is experiencing a phase of considerable growth also in Italy, especially owing to the introduction of the national plan of Continuous Education in Medicine, that sees in on-line activities one of the main tools of education for the health professions. In this scenario, we have decided to design and realize a «learning tool» to be used in the health sector. This tool will be able to offer both interactivity elements for the motivational and androgogic components, and immediate possibility of verification/self-assessment in addition to supporting the applicability of learned concepts to real contexts represented by the scenario itself.

The specific area of health management is a sphere in which this typology of learning tool can find an optimal placement. As an example, we consider the problem of the waiting lists in Radiology.

5.1 Course description

The course application was inspired by two main events. The first was a traditional training course on the Balanced Score Card and its application in Radiology, realized by Sago (Florence) in February 2005 in collaboration with some radiological medical associations; the second event was the increasing interest of the Italian Health Office in reducing the waiting lists for health services. As is well known, Balanced Score Card (BSC) is a method recently introduced by Kaplan & Norton (1996) to pursue strategic decisions, which applies a system of balanced indicators, whose results support management (either in health or in a factory) to reach the target.

Reducing the waiting list in Radiology is a strategic target that can be reached, for example, by operating on human resources, their productivity and education or, still for example, by implementing technological equipment after a correct evaluation of its productivity. Following each path (human resources or equipment), time and money or other resources are consumed and the original budget is reduced.

Different results might be reached at the end or during the path: the manager could decide to change his approach on final or intermediate results (feedback) and to follow a different approach to reach the goal. The proposed model supports this decisional approach and permits integrating traditional training with a didactic instrument which shows, at the end, the results of learner decisions.

The problem of the waiting list reduction for radiological services has been simplified for didactic purposes.

Practically speaking, a set of possible choices has been identified in order to reach the target — waiting list reduction in Radiology — with different times and costs.

The final state (i.e. the reached target), even if partial, is measured by a system of balanced indicators. These indicators are grouped in four conceptual dimensions: the economical and financial dimension, the client dimension, the internal process dimension, and the knowledge and learning dimension. The proposed solutions operate mainly in the internal process area also if education and knowledge are considered in decisions.

Different possibilities do not exclude one each over reciprocally: it is possible to change the type of intervention or to combine different kinds of intervention.

In the described course, the learner can choose between two options: he can face the waiting list cut by operating on human resources (radiologist, technicians, nurses) or by evaluating the available equipment.

For simplicity and for didactic purposes, within the first choice, no distinction has been made among different professional figures although costs are really different for radiologist rather than technicians.

Within the second path, that is evaluating equipment, no distinction has been made among different methods or instruments: if waiting lists, for example, stress CT (Computerized Tomography) rather than MR (Magnetic Resonance), only the CT line (or MR one) should be considered, or both if necessary, applying different sets of control indicators, producing different decisional paths and, as it is well known in the radiological world, «burning» different amounts of economic resources.

If the decision to modify or shorten radiological waiting lists starts with the human resources approach, the «decision man» can face the problem by operating on two different decision lines: if knowledge level is considered a possible cause of generating or supporting radiological waiting lists, he will decide to evaluate or to integrate the educational level of human resources who work in radiological service; alternatively, the numerical adequacy or the productivity of health operators can cause waiting list lengthening: the system also permits one to follow this decisional path.

Before deciding to acquire new resources, an evaluation of the resource productivity is done. In particular, in order to evaluate the radiologist's productivity, an indicator officially provided by a recent study of SIRM (Società Italiana di Radiologia Medica) and SNR (Sindacato Nazionale dell'Area Radiologica) has been used in the course.

Resource integration, both human and technological, may require human education: the path on human resources numerical adequacy joins and carries on the human resources education path, although the initial budget has, at this decision moment, a different consistency if compared with the one which the learner had if he started from human resource education.

Obviously, in reality, the learner has at his disposal many more possibilities than the ones that the course permits: if a context and more complex intermedi-

ate choices had been considered, there would have been an explosion of nodes and final states.

If the learner decides to follow the «equipment» path, the same level of complexity in choices implications comes out: this path has been simplified for didactic purposes. When a final state has been reached, the learner can verify the final amount of the available budget; he can also compare his decisions with the best ones (in terms of costs and/or efficiency) the teacher included in the course.

Certainly the teacher has to choose of many values of reference or to test which have to be associated to decisional nodes. The greater the increase in the number of available decisions, the more difficult bit becomes in finding values for results evaluation.

6. Conclusion

The role of feedback is crucial in education, and it is an accepted psychological principle; the awareness of results during the learning affects the motivation and efficiency of the student. Besides, a scenario-based model thrusts the learner into a realistic scenario in which he has to take decisions. Our aim is to improve the effectiveness of learning, providing feedback that allows learners to adjust behavior and improve performance.

In particular, in the paper we have proposed a scenario-based learning course model that allows us to give learners a semantically rich feedback, and we have applied this model to an example application in the health sector, that is, the waiting lists in Radiology. The described example could have been substituted with any other one, in which a decisional process with different possible choices is required in order to reach a fixed goal.

We intend to develop a SBLC that gives the learner this kind of feedback at every step during performance, so that the learner has the possibility to reflect on his choices. The first step towards this objective will be to produce a SBLC, integrated with automatic feedback generation, related to the health sector example described in the paper, and to test its effectiveness within a real course on this topic.

Finally, it is our intention to analyze other feedback indicators, beyond the one introduced in this paper: one interesting possibility would be a «clustering indicator», inspired by the research done in the area of the World Wide Web mining, which concerns, among others, with the identification of navigational patterns.

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