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# Intelligent Gaming-Simulations and Their Evaluation

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**Abstract**

Gaming-simulations provide learning through game activities in artificial environments in which students can experience the consequences of their actions without taking real-world risks. However, as an educational tool a gaming-simulation follows the concept of discovery learning and, therefore, does not necessarily pursue any direct educational goal. A way to overcome this weakness is to equip the gaming-simulation with an intelligent tutoring facility. These intelligent gaming-simulations have become increasingly popular teaching environments. Although it is generally believed that intelligent gaming-simulations promise a great potential for instruction, little work has been done on the development of an appropriate evaluation method to assess their tutoring abilities. This paper gives an introduction to intelligent gaming-simulations for education. It then proposes an evaluation approach for the assessment of the tutoring abilities of an intelligent gaming-simulation. This evaluation approach addresses intelligent gaming-simulations from two main perspectives. Whilst internal evaluation examines how the architecture of the intelligent gaming-simulation gives rise to a particular system behaviour, external evaluation is concerned with the educational impact of the system behaviour on the student.

**Keywords**

Gaming-simulation, intelligent tutoring, evaluation

## 1 INTRODUCTION

A gaming-simulation is a sequential decision-making exercise with the basic function of providing an artificial but realistic environment in which players experience the consequences of their decisions through immediate response. The use of gaming-simulation in education is in the increase (Lane, 1995). Gaming-simulations promote interest and motivation and communicate and develop knowledge and skills by putting

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players into situations in which they must articulate positions, arguments or facts they have previously learned.

A major problem that has frequently been mentioned with gaming-simulations is the lack of sufficient conceptual ability of the player to exploit the gaming-simulation in order to gain best insight into the procedures involved (Angelides and Paul, 1993). The original version of the Metal Box Business Simulation Game (1978), for example, aims to teach managerial skills to students through experience during game play. However, the game lacks any adaptability to the student since the students are merely provided with a business environment in which they have to organize the game play themselves. Intelligent tutoring systems, however, offer individualized player guidance and support within the learning environment. In order to overcome their weaknesses an increasing number of recent gaming-simulations have therefore been developed incorporating an intelligent tutoring facility (Siemer, 1995).

The arrival of these intelligent gaming-simulations coincides with the need for an assessment of their usefulness. The evaluation of intelligent gaming-simulations influences interest in, and support for, future research and development, and it directs opinions about the usefulness of intelligent gaming-simulations for the purpose of education. In a future where gaming-simulations may be widely available in schools, evaluations will shape how and what people learn. These facts call for well developed and appropriate evaluation techniques (Winne, 1993).

This paper proposes an evaluation method for the examination of intelligent tutoring within gaming-simulations. The paper starts with a short illustration on how intelligent tutoring systems provide for intelligent tutoring. It then continues to develop an evaluation method for the assessment of intelligent gaming-simulations following evaluation recommendation from the field of intelligent tutoring systems.

## 2 GAMING-SIMULATIONS AND INTELLIGENT TUTORING

The major incentive for the incorporation of an intelligent tutoring facility into a gaming-simulation is to make the teaching process more adaptable to the individual player. Intelligent tutoring systems provide helpful guidance and adaptation to the player by exploring and understanding the individual player (Kaplan and Rock, 1995). For this purpose an intelligent tutoring system makes use of its *domain model*, an explicit representation of the knowledge of the topic to be taught. At the same time, an intelligent tutoring system is equipped with teaching expertise which is contained in its *tutoring model*. Furthermore, an intelligent tutoring system collects feedback from the user during the course of interaction and analyzes this feedback against a wide range of predefined student behaviours. The resulting information about the user's knowledge state is stored in the *student model* and is used to tailor the instruction according to the needs of the student. These characteristics of intelligent tutoring systems have been used in gaming-simulations to monitor the players and to provide individual feedback on their behaviour and performance and thereby foster learning.

INTUITION, the implementation of the Metal Box Business Simulation Game, is an example for such an intelligent gaming-simulation (Siemer, 1995). The integration of the intelligent tutoring facility involved the extension of the gaming-simulation environment by the three standard intelligent tutoring knowledge sources. Additional domain knowledge allows INTUITION to use alternative explanations of concepts, e.g. in form of an example or an analogy. The integration of tutoring knowledge enables INTUITION to use teaching strategies which allow the system to follow a clear and attainable educational learning goal for each player, to manage market resources and to control the decision making processes accordingly. Eventually, INTUITION incorporates a student model for each player. The student model provides the basis on which the system can make decisions, such as further distribution of resources and role re-assignment. Additionally, the student model contains the necessary information for error diagnosis and remediation.

## 3 EVALUATING INTELLIGENT GAMING-SIMULATIONS

The purpose of this section is to propose an evaluation method for intelligent gaming-simulations. Since the intelligent tutoring facility of intelligent gaming-simulations is based on the architecture of an intelligent tutoring system we can borrow ideas from this field.

The evaluation methods that have been used for intelligent tutoring systems to date have emerged from evaluation methods proposed by researchers from various academic backgrounds, such as computer science, education and psychology (Mark and Greer, 1993). Researchers currently decide on a particular evaluation method according to their interests and concerns. However, the research interests and concerns can be divided into two generic categories which are manifested in the use of either *external* or *internal* evaluation methods which can directly be related to the evaluation of intelligent gaming-simulations (Littman and Soloway, 1988).

Internal evaluation addresses the question: *What is the relationship between the architecture of the intelligent tutoring facility and the behaviour of the intelligent gaming-simulation?* External evaluation addresses the question: *What is the educational impact of an intelligent gaming-simulation on the player?* The answers the two resulting classes of evaluation provide to these two questions illustrate how the design and implementation of the system lead to the system's behaviour and how this behaviour may effect the player.

### *3.1 Internal evaluation*

The purpose of internal evaluation is to provide a clear picture of the architecture of the intelligent tutoring facility and to determine how this architecture provides for the system's behaviour. To clarify the relationship between the three main components of the intelligent tutoring facility and the behaviour of a gaming-simulation, an intelligent gaming-simulation can be characterized in terms of answers to the following three key questions:

- *What does the intelligent tutoring facility know?* This question is addressed by an analysis of the system's domain, student and tutoring knowledge in respect to what the intelligent gaming-simulation can possibly do based on the knowledge it is able to provide.
- *How does the intelligent tutoring facility do what it does?* This question is answered by analyzing the intelligent gaming-simulation to determine how its processes generate the system's observed behaviour.
- *What should the intelligent gaming-simulation do?* This question is addressed by an examination of the overall capabilities of the system's teaching processes.

According to Littman and Soloway (1988) these three questions are addressed by performing *knowledge level analysis, program process analysis and tutorial domain analysis*:

Knowledge level analysis provides useful information about whether the intelligent tutoring facility has sufficient and appropriate knowledge about the domain, the student and tutoring in order to meet the requirements that were set for it. It is not concerned with how the system uses or manipulates this knowledge to provide for student guidance. Accordingly, knowledge level analysis has to address issues, such as the scope of the system's domain, student and tutoring knowledge and whether the knowledge representation is appropriate.

Program process analysis examines whether the intelligent tutoring facility does what it does in the right way. Program process analysis looks at how a system uses and manipulates its intelligent knowledge for the purpose of game play. Program process analysis may consequently investigate the expertise, i.e. the way domain knowledge is used and manipulated, the diagnostics, i.e. procedures used by the system to analyze the input of the student to maintain the student model, and the didactics, i.e. the way teaching goals are determined and teaching strategies are used to guide the game. Eventually, program process analysis may assess the control structure which coordinates the interaction between the system's three knowledge models.

Tutorial domain analysis determines any lack of tutorial abilities in any of the three standard knowledge components of the intelligent tutoring facility. These tutorial capabilities are generally specified at the outset of the system implementation stage. However, tutorial domain analysis during the implementation process may change the system requirements, with the result that part or all of the three knowledge models may require alteration or extension.

The result of these three analyses intend to provide a picture of whether and how all three knowledge models provided by the intelligent tutoring facility within a gaming-simulation provide for the system's desirable behaviour. Consequently, these analyses involve a thorough investigation of the behaviour of the intelligent gaming-simulation under evaluation. In order to carry out such an investigation it is necessary to define what exactly constitutes the behaviour that an intelligent gaming-simulation should display. A popular representation of such desirable intelligent behavioural properties is

a set of evaluation questions. Since the details of the desirable behaviour depend on the gaming domain of the gaming-simulation under evaluation, the establishment of the specific evaluation questions is generally left to the judgment of the evaluator (Mark and Greer, 1993).

In addition to an examination of the relationship between the architecture of an intelligent gaming-simulation and its behaviour, a complete evaluation also requires the examination of the impact of the system's behaviour on the student: The intelligent gaming-simulation has to be evaluated externally by the users themselves before it is put into operation.

*3.2 External evaluation*

External evaluation examines how the intelligent gaming-simulation affects the player and how it helps the player to improve his knowledge and skills (Mark and Greer, 1993). External evaluation, therefore, aims at an overall conclusion or estimate about the system, such as the more fundamental needs concerning the system's usefulness to the player, like its ability to

- foster learning, which is generally referred to as *learning achievement*, and to
- motivate and satisfy the student, described as the *learning affect*.

- Learning achievement

Learning achievement as an overall impact of an intelligent gaming-simulation includes aspects such as the acquisition and the understanding of, and the performance with, the player's knowledge. The dominant approach to assess learning achievement of students with earlier tutoring systems, such as computer aided instruction systems, has been through determining whether students correctly responded to test questions. However, with the emergence of intelligent tutoring systems and intelligent gaming-simulations came the request to assess the reasons why students give correct and incorrect answers and make correct and incorrect moves within a game by determining how well the system teaches users the knowledge and skills that support the mental processes required to solve certain problems or make particular decisions.

Littman and Soloway (1988) first proposed the use of student modelling techniques to assess how well the intelligent tutoring system teaches problem solving knowledge in the domain. They suggested the use of student modelling techniques to construct a range of problems that the student should be able to solve. These problems can then be used to test the student. The success rate of the student is a measure for the student's learning achievement. A correct student problem solution indicates that the underlying knowledge has been taught successfully by the system.

Therefore, the evaluation of early tutoring systems which focused on correct and incorrect answers is different from the evaluation of intelligent gaming-simulations which assess the reasons why players make correct and incorrect decisions or moves. In the external evaluation of the intelligent gaming-simulation the criterion is not how many of the players' answers are correct but how well the game teaches underlying fine-grained skills that support the player's problem solving processes within the game.

• Learning affect

The affect of game play is concerned with aspects such as attitudes and emotions caused by the intelligent gaming-simulation. Motivation in the context of learning can be viewed as an indication of the student's willingness to be active and involved in the learning process and is therefore recognized as an important factor of learning. Various ways of assessing the motivating impact of systems have been suggested. Motivation is often assessed by asking the player to simply rate his agreement with specific issues, such as attitudes and activities. Comparisons of time spent on task-related and task-unrelated material during a game are another indicator for the motivation of the player. Also the drop-out rate, i.e. the overall time spent playing a game, indicates the level of interest of the player.

Measuring motivation provides an indication for how players feel about a particular system. The extent of motivation in return may provide information about the learning achievement since such motivation contributes towards the actual learning achievement discussed in the previous section. At the same time the motivation of players working with a particular system suggests whether the Simulation-Game will be accepted and used.

Whilst the assessment of learning achievement may also be supported by the student model of an intelligent gaming-simulation the assessment of motivation generally restricts itself to experimental evaluations with students (Mark and Greer, 1993). Experimental research enables researchers to examine whether the implementation of a system has been successful in the sense that it is accepted by the players.

## 4 CONCLUSION

In order to provide greater adaptability to the player more recently developed gaming-simulations have been equipped with an intelligent tutoring facility. Whilst these intelligent gaming-simulations have become increasingly widespread teaching environments little work has been done on the development of an appropriate evaluation method.

This paper has proposed an evaluation method to examine the tutoring abilities of intelligent gaming-simulations. This evaluation method consists of two major assessments. Whilst internal evaluation assesses the inner workings of an intelligent gaming-simulation, external evaluation assesses the impact the intelligent gaming-simulation may have on players. The result of this two part evaluation will reveal the educational worth and value of intelligent gaming-simulations, i.e. their strengths and shortcomings, and may thereby influence interest in, and support for, future research and development.

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## 6 BIOGRAPHY

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