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Integrating Stereotype User Models for Adaptive Scenarios in Game Playing within Immersive Virtual Environments

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***Abstract*—Stereotypes constitute a widely used technique for creating user models. This paper explores the potential of stereotype-based models in virtual environments in order to enhance user engagement and learning outcomes. The focus is on an application, named Beekeeper World, which employs adaptive scenarios that respond to user actions. These scenarios, referred to as stereotype user models, represent predefined behavior patterns that Beekeeper World uses to respond to specific user actions. In the game context, these stereotypes are triggered by particular player interactions involving the ecological dynamics of bees and spiders. The first one challenges the player when s/he fails to protect a bee by strengthening the enemy spider. The second stereotype is a way of helping the player by pausing the spiders' spawning when s/he cannot defend the bees. These stereotypes can be instrumental in creating predictable, consistent behavior in Beekeeper World. They provide a framework for the system to respond to various user inputs in a consistent manner. This consistency can be crucial in maintaining the desired user engagement, as it ensures that the system's responses align with the user's expectations based on their previous interactions. Furthermore, these stereotypes can contribute to the complexity and challenge of the game, as they require the player to understand and adapt to these patterns in order to succeed, thereby promoting strategic thinking and problem-solving skills.**

Keywords*— *Intelligent Virtual Environments, Stereotype User Models, User Engagement, Adaptive Scenarios, Virtual games, Adaptivity

I. Introduction

In the last ten years, there has been a surge in research on technology-assisted methods in interactive applications. One critical development is the rise of intelligent virtual environments designed to promote enhanced user engagement and learning outcomes, particularly in the gaming universe. These environments offer an innovative approach to immersive, interactive experiences accessible to users globally. Unlike traditional video games, intelligent virtual environments cater to diverse users with varying knowledge backgrounds, skill levels, and learning needs. Developers and researchers can construct intelligent virtual environments that respect and adapt to the unique personal characteristics of each user by providing a tailored, immersive gaming experience that facilitates effective learning. These environments, powered by artificial intelligence (AI), provide a dynamic platform where users can interact with the system in various ways, leading to diverse outcomes based on their actions.

A vital aspect of these environments is using adaptive scenarios, which respond dynamically to every user action in a predefined manner. This concept is the stereotype user models. The stereotypes describe the performance type of the users, and the models represent a form of AI behavior that is predictable and consistent. This consistency is crucial in maintaining user engagement, as it ensures that the system's dynamic responses are reliable and meaningful based on users' interactions [1]. In the realm of educational games, these adaptive models can play a significant role in enhancing the learning experience. These games can provide a challenging yet engaging environment that promotes strategic thinking and problem-solving skills. This is obtained by the measured adjustment to the game's difficulty, as it dramatically impacts the player [2].

In this paper, in the context of "Beekeeper World", a stereotype-based model is manifested in the form of adaptive scenarios that respond to specific player behaviors. More specifically, two stereotype models have been used. The first one is triggered when the player fails to safeguard the bee. In that case, the killer spider is getting stronger and bigger, forcing the player to a challenge. The second one activates when the player struggles to protect the bees. In this situation, the production of new spiders is halted until the player eliminates some of them. These adaptive scenarios create a dynamic gaming environment that not only engages the players but also challenges them to think strategically about how they will manage their primary resources, honey, and money in order to upgrade themselves and respond to these tasks. At the same time, they have to protect the bees from hundreds of untamable spiders.

After evaluation, it is shown that using stereotype user models has significant implications for learning outcomes because they ensure that the game's difficulty is balanced so that the users do not struggle but learn simultaneously. Games can achieve their goal by creating an adaptive to the players' skills environment, whether for providing fun or fostering meaningful learning opportunities [3, 4].

II. Related Work

Elaine Rich was one of the first [5] to suggest the use of stereotypes in user modeling. Rich developed the GRUNDY system, a system that understands each user and offers personalized experiences. Two parts define a stereotype: (a) the stereotype's description based on common features and (b) the pre-conditions a user must meet to be assigned to it [6].

Research investigating the efficacy of stereotype-based models in mobile user personalization has also been conducted, demonstrating significant potential in enhancing the overall user experience through tailored recommendations [7, 8]

Another example of a stereotype-based model is AC-ware Tutor, an adaptive e-learning system that adapts the learning process to the student's knowledge level. It uses Bloom's taxonomy to define knowledge stereotypes. Then it uses these stereotypes to select dynamically and sequence courseware elements and generate tests and questions [9].

A combination of stereotype-based models has also been evaluated, more specifically, a model for student personalization that combines the Visual, Auditory, Reading/Writing, and Kinesthetic learning style model and the Herrmann Brain Dominance Instrument [10].

Several additional related studies underscore the prevalent use of user stereotypes. Relevant studies encompass diverse domains such as community-based applications [11], problem-solving environments [12], Enterprise Information Systems [13], and recommender systems. Notably, user stereotypes have been adopted in creating recommender systems for movies and series, further highlighting the breadth and potential of tailored user experiences across a myriad of contexts [14, 15].

In adaptive gaming experiences, whether the stereotype-based model is used or not, the focus has traditionally been on individual player experiences [16–19]. However, in this paper, a novel approach has been developed and studied that expands this perspective to consider one or even multiple players simultaneously. This innovative method utilizes stereotype-based modeling to dynamically adjust the game's difficulty level based on the players' skills. In that way, the player, instead of struggling for the win, can now understand the educational content embedded within the game. However, this method does not solely rely on stereotype-based modeling. There are also fixed adjustments proven to, even more, improve the players' experience.

III. Application Overview

Beekeeper World is an interactive game created to familiarize students with beekeeping (Fig. 1). It is emphasized, especially in the difficulty of keeping a hive safe from external threats. The game's virtual environment is an island surrounded by a vast sea. At each start of the game, the environment's configuration is different from any previous instance because every world uses a unique combination of thousands of variables to create its singularity. The game's environment features four types of flowers, each containing a random amount of nectar to be collected. This diversity enriches the game environment while emphasizing the importance of symbiosis between bees, flora, and their shared ecosystem. The game supports multiple players in the same session. It promotes collaboration and strategic thinking as participants help each other in their shared mission to protect the bee sanctuary from the relentless attack of spiders.

Presented as robot guards, participants ensure the integrity of the bees and their hive by neutralizing the threatening spiders and maintaining a harmonious balance in the game's ecosystem. Bees play a vital role in the game, as they are crucial to the cyclical rhythm and economy of the virtual ecosystem. They diligently collect nectar from the flowers and transport it to their hive. This hive serves as the hub of resource management, where honey production occurs. The interrelated roles of the players, the bees, the hive, and the spiders give this game a dynamic and exciting character. In addition, the participants deepen the economic aspect of the game through the marketing of honey. The resulting revenue can be used to increase their skills, enhancing their flexibility and strength.

The game ends ingloriously if the maximum hive capacity or the number of total bees in the world reaches zero. Conversely, if the hive is full of nectar or there is no more nectar available for collection, and all the bees enter the hive, the game ends with a victory for the players. By the end of the game, players must have achieved as high a score as possible, regardless of how the game ends.

Fig. 1. Spiders Attacking

IV. Enhanced User Engagement Using AI-Stereotypes

Beekeeper World has a dynamic and adaptive environment for enhanced user engagement. Each player's behavior can be adapted for a more personalized experience by applying stereotype user models to the application. This captivating interplay between AI and user interactions forms the heart of the game dynamics, adding a layer of complexity and immersion only found in advanced virtual worlds. The two primary stereotypes identified are intrinsically linked to player action or inaction, changing the game environment, and offering an ongoing challenge requiring players to adapt their strategies continuously throughout each game session (Fig. 2).

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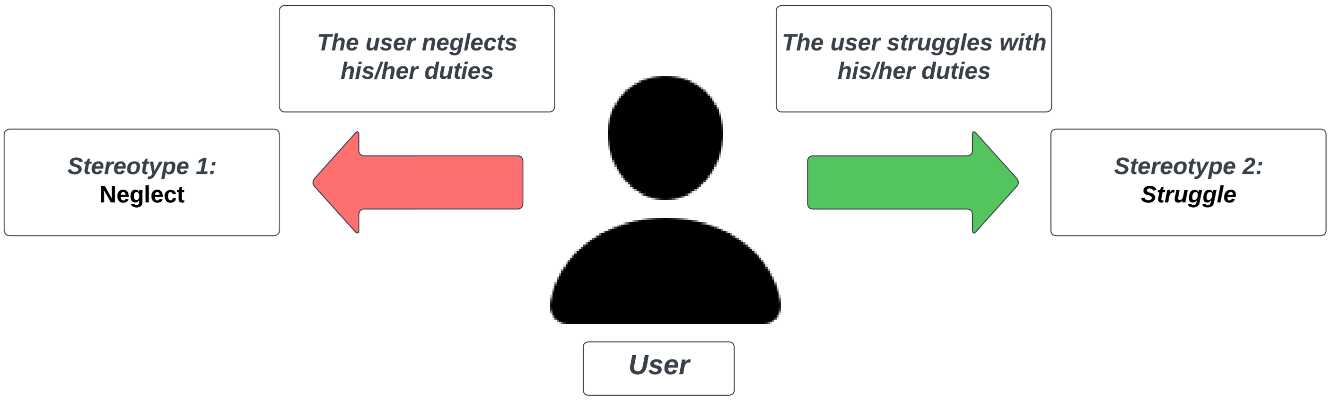

Fig. 2. The two Stereotype-based models used in Beekeeper World

A. *First stereotype user model "Neglect"*

The first stereotype-based model in the application represents the game's responsive dynamics, particularly when players neglect their duties. The strategic AI incorporated into this model is highly adaptable and continuously learns from players' actions in order to evolve the game's dynamics accordingly. More specifically, when the player fails to protect a bee, it has the result that the spider is getting bigger and stronger, making the game more challenging. This is done to passively force the player to follow the task needed to be done, namely, protect the bees and the beehive from the fierce spiders. This enhancement to the spiders is not punitive but rather a strategic shift in the gameplay, designed to stimulate players' interest and encourage them to reevaluate their actions within the virtual environment. This shift also serves as a subtle educational tool, highlighting the importance of ecosystem conservation, thereby enriching the gaming experience.

B. *Second stereotype user model "Struggle"*

The second stereotype-based model in Beekeeper World activates when players struggle to neutralize spiders efficiently. This trigger stems from the game's intuitive understanding of player performance, achieved through real-time tracking and analysis of player effectiveness against complications. To elaborate further, when the player encounters significant difficulty in eliminating the spiders, the result is that their unstoppable proliferation temporarily halts. This response underscores the game's commitment to a balanced challenge, capping difficulty to prevent overwhelming players while setting a concrete target that players must hit to trigger the break. This halting of spider spawning is not just a pause in gameplay but a crucial tool for maintaining the game's learning experience. It helps players understand the game's logic and the consequences of their actions. It also encourages them to enhance their efficiency in managing the spider threat, urging for the evolution of their gameplay. Furthermore, it provides a breather for struggling players as a motivational factor in the ongoing cycle of challenges.

Incorporating stereotype user models in Beekeeper World is a potent intersection of advanced technology and immersive gameplay. The strategic responses, balanced challenges, and constant adaptation required not only to add depth to the game but also to make it uniquely personalized. This interactive virtual environment is not simply a reactive field but a living ecosystem where the consequences of player action or inaction are tangible. The distinct game dynamics educate and engage players, pushing them to evaluate their strategies and evolve.

The game's mechanism effectively becomes an invisible tutor and an unforgiving opponent, cleverly maintaining balance and regulating difficulty. As a result, it cultivates a cycle of challenges that continually motivate and reward players, promoting engagement and a profound sense of investment in the game's world. By doing so, Beekeeper World offers an exciting glimpse into the future of educational gaming, where AI enriches the narrative and the environment responds organically to player decisions.

V. Enhanced User Engagement Using Static Mechanisms

In addition to the stereotype-based models, Beekeeper World utilizes some static mechanisms to enhance user engagement and create a more realistic gaming experience. Unlike stereotypes, these mechanics are not based on player behavior but serve as intrinsic elements of the game's mechanisms. They add a layer of challenge and immersion for players, making the virtual world more captivating and unpredictable.

A. *Adaptive Spider Spawn*

One non-AI stereotype in Beekeeper World is the adaptive spider spawn. This mechanism introduces a characteristic where the spider population dynamically scales with the player count. As more players join the game, spider spawning increases proportionally, creating a more challenging environment for everyone involved. This encourages collaboration and competition among players, as they must collectively work together and strategize against the growing spider threat. The adaptive spider spawn adds an exciting and social dimension to the gameplay, fostering a sense of shared experience and engagement within the virtual world.

TABLE I. DEMOGRAPHICS

Measure	Item	Frequency	Percentage (%)
Sample Size		30	100
Gender	Male	24	80
	Female	6	20
Age	18-21	18	60
	22-25	12	40
Motivation	All students were interested in Unity Applications.		

B. Time-Based Spider Spawn

Another nonadaptive stereotype in Beekeeper World is the time-based spider spawn. This mechanic revolves around the progressive spawning of spiders in waves after the initial spider spawn. Once the game begins, the first wave of spiders appears after one minute, giving players time to orient themselves and adjust to the randomly generated environment, as it is a new map that has never been experienced before. After the initial spawn, subsequent waves of spiders intrude at regular intervals of 40 seconds, creating a sense of rhythm and escalating the challenge. Each wave brings a new surge of spiders, requiring players to adapt their strategies and react swiftly to defend against the increasing threat. This progression of spider waves adds an element of anticipation and urgency, keeping players engaged and continuously on their toes throughout the gameplay experience. By gradually introducing enemy waves, Beekeeper World creates an adaptive and evolving adventure that demands strategic thinking, quick decision-making, and effective resource management.

The Stereotype-user models respond to player interactions, while the static mechanisms introduce mechanics independent of player behavior. Together, they form a comprehensive system that keeps players engaged, motivated, and invested in the game world. Beekeeper World provides a sight to the future of gaming, where the synergy between advanced technology and innovative game mechanics takes user engagement to new standards.

VI. EVALUATION

To evaluate the research objectives and understand the effectiveness of stereotype user models in an enhanced user adventure with strategic decisions and personalization in the Beekeeper World game, we conducted an empirical study where 30 undergraduate students from the Department of Informatics and Computer Engineering at the University of West Attica were involved at a survey. The students (Table I) were instructed to play the game and then provide feedback on the game experience without previous knowledge of the game's goals. The feedback was captured through a structured questionnaire with questions based on a Likert scale, ranging from "strongly disagree" to "strongly agree." Pie charts were used to visualize the participants' feedback.

This research will address the following research questions:

1. *On a scale of 1 to 5, how successfully do you believe Beekeeper World used stereotyped user models to create a more engaging and challenging gaming experience?*
2. *On a scale of 1 to 5, how effectively do you believe Beekeeper World used stereotyped user models to stimulate your strategic thinking?*
3. *On a scale of 1 to 5, how successfully do you believe Beekeeper World used stereotyped user models to create a more personalized gaming experience for you?*
4. *On a scale of 1 to 5, how successfully do you believe Beekeeper World used stereotyped user models to enhance your learning outcomes as an educational game?*

A. Engaging and Challenging Gaming Experience

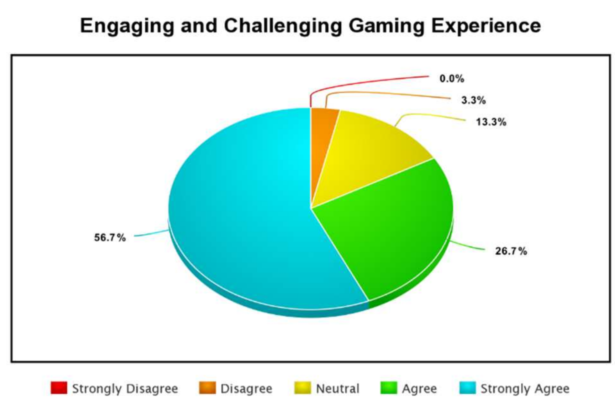

Fig. 3. Engaging and Challenging Gaming Experience Chart

Most students (n=25) agreed that stereotype user models create a more engaging and challenging gaming experience (Fig. 3), some (n=4) were neutral, and just one disagreed with the statement. In general, they appreciated the game's dynamic nature, including strategic AI responses and balancing challenges. Many students found that the spiders' adaptation to the players' behavior maintained constant difficulty and engagement, leading to a more compelling gaming experience.

B. Stimulate Strategic Thinking

Fig. 4. Stimulate Strategic Thinking Chart

Stereotype user models also successfully promoted creative thinking among the participants (Fig. 4). The vast majority of them (n=28) agreed with the efficiency of stereotype-based models in strategic thinking. At the same time, 2 of them were neutral, and no answer of disagreement was recorded. The challenges presented in the game, such as maintaining the hive's integrity and managing the spider threat while keeping the balance in the economic side of the game, necessitated the development of strategic approaches and quick decision-making. Additionally, the adaptive spider spawn and time-based spider spawn mechanisms kept the players on their toes and fostered a high level of strategic engagement.

C. Personalized Gaming Experience

Fig. 5. Personalized Gaming Experience Chart

The personalization of the gaming experience was another highlight identified by the participants (Fig. 5). The game's stereotype user models adapted to the player's actions and strategies, which not only presented a unique challenge for each player but also made the game more immersive and interactive. The majority of the participants (n=26) agreed about the successfulness of personalization using stereotype-based models, two were neutral, and two disagreed with the statement.

D. Enhancing Learning Outcomes

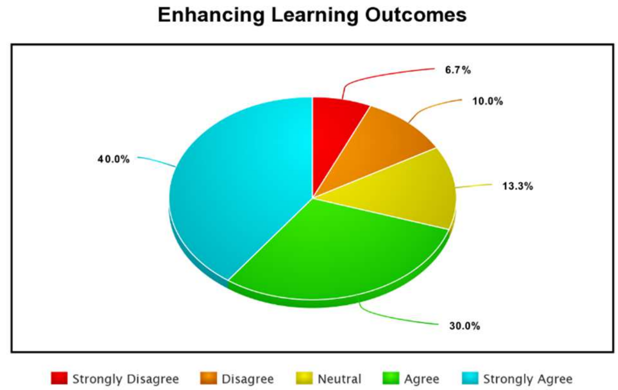

Fig. 6. Enhancing Learning Outcomes Chart

All in all, the players found Beekeeper World a powerful educational tool (Fig. 6). The adaptive AI behavior created dynamic learning environments, offering players infinite scenarios to apply and improve their understanding and skills. In this case, 21 of the students agreed with the statement about the enhanced learning outcomes of the game, 2 of them were neutral, while 2 of them disagreed.

Based on the survey results, it can be ascertained that stereotype-based models in Beekeeper World successfully achieved the research objectives, creating a more engaging and challenging gaming experience, promoting strategic thinking and problem-solving skills, and providing a more personalized experience for each and every user. This supports using stereotype user models as a potent tool for enhancing user engagement and interactive learning in gaming environments.

I. Conclusion and Future Work

The use of stereotype-user models in Beekeeper World is an effective way to enhance user engagement, strategic thinking, and personalized gaming experiences while also keeping educational expectations high. The interactive and dynamic nature of the game, made possible by these models, encourages the participants to remain focused while continually adapting their strategies to manage the changing virtual environment. The feedback collected through the survey reaffirms the effectiveness of this approach, showing a positive response to the attractive and tailored challenges presented by the game.

Blending intrinsic gameplay elements with AI responses to player behavior has successfully generated a more immersive and challenging virtual environment. Still, the further addition of static mechanics, such as the adaptive and time-based spider spawn mechanisms, also contributes to the enriched game logic.

Building on the successes and lessons from the development and implementation of Beekeeper World, future work should explore the potential for further integrating AI technology into gameplay and game design. This could include researching more sophisticated stereotype user models that can learn from player behavior over multiple game sessions, increasing personalization and challenge over time.

Further research could also explore the benefits of interactive and educational games, where these strategies help capture student attention with experiential learning.

Finally, it would be beneficial to expand the sample size and diversity of the evaluation phase in future studies. It collects feedback from a broader range of players, possibly across different age groups, skill levels, and cultural backgrounds. That would help refine the approach and ensure it can be as accessible and effective as possible for a broad audience.

Through these advancements, the gaming industry can continue to push boundaries and offer players increasingly immersive, challenging, and rewarding educational adventures. The potent intersection of AI and tutoring gaming opens up an exciting frontier for exploration and innovation.

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