

Game Design and Player Metrics for Player Modeling in Adaptive Educational Games

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Introduction

As data-driven information technology becomes more prevalent, its potential use on game-centered learning systems becomes increasingly evident. By monitoring learners' progress based on a series of observable metrics, adaptive learning environments can make inferences about individual learner's needs and preferences and adjust accordingly to support the learner. Online educational organizations such as Kahn Academy, Code.org, and Codecademy have shown promising results of mixing traditional education with online learning environments, but also run the risk of trading educational merit for entertainment (Kumar, 2014).

Recent educational games have started to incorporate adaptive technologies to facilitate learning. For example, *Plant RPG* (Hwang, et al., 2013), a game to teach natural science in elementary schools, experimented with adapting its presentation of learning missions in accordance to a player's alignment with the sequential/global component of Felder-Silverman's learning style model (Felder & Spurlin, 2005). Depending on how students scored on a pre-test survey measuring their sequential/global inclination, the game presents its missions either as a sequence of unlockable, linear quests or an overview of multiple quests available at any given time. Another example is the Crystal Island project (Mcquiggan et al., 2008), an educational game that explores how to modify story sequence of the based on how the learner progresses in solving the game's biological puzzles.

Adaptive educational games are still in an early stage of development when monitoring "fine-grained student needs and interests" (Magerko, Heeter, & Medler, 2010). Much about how to design and develop adaptive learning games is largely not well-understood. In this paper, we present our approach for designing *game mechanics* and *player metrics* toward player modeling, necessary steps toward adaptive educational games. Through our on-going Avian project, we demonstrate how we design gameplay activities to support learners of different player types and design player metrics to capture their behavior patterns for player modeling. We believe that the approach behind our game design can be applied in other adaptive educational games that uses player modeling. We also discuss our future plans to player modeling and the evaluation of our approach.

Theoretical Framework

Player type and play style have been two main means of representing players and their in-game behaviors in the game-centered learning community. Play style is the "actual play behavior enacted while playing a specific game" (Magerko, Heeter, & Medler, 2010). As play style is directly tied to players' observable in-game behaviors, it is relatively straightforward to measure (Magerko, Heeter, & Medler, 2010; Heeter, et. al, 2009; Foster, 2009). However, a player may adopt different play styles in the same game, for instance, based on how confident he or she is about achieving her goals at a given moment. Beyond player choices, the design of games themselves limits available options to players: control and expression in games are confined by their genre -- their underlying design patterns -- and thus can only support a certain set of actions and strategies. Such limitations by game design decisions therefore constrain the possible play styles a player may engage in. The variability of play style of a single learner makes it challenging to construct and maintain a stable player model.

By contrast, player types are traits or underlying characteristics of a player (Magerko, Heeter, & Medler, 2010; Foster, 2009). Research has shown how player types influence the way players interact with and learn from video games (Foster, 2011; Magerko, Heeter, & Medler, 2010). Although player types cannot be observed directly, it has been suggested that one way to construct a player type is through the combination of observable player behavior and the motivations that drive them (Bartle, 2004; Foster, 2011; Heeter, et al., 2011).

In our project, we aim to model player types based on a player's in-game activities and their motivation. In particular we use Foster's framework of player type (2012), which combines research on achievement goal theory (Ames, 1992; Elliot & McGregor, 2001) with player styles (Foster, 2009). This work builds on the research of Heeter, et. al. (2009), seeking to clarify play styles and learning in educational games. Built on the Achievement Goal Theory (AGT) framework, Foster (2009; 2011) divides player types into two general categories of *Explorers* and *Goal-Seekers*. Explorers investigate and analyze the inner-workings of game features while Goal-Seekers

are primarily focused on achieving the goals of the game. When applied to educational games, this means that explorers are inclined to experience a wider range of in-game content while goal-seekers will tend to focus on content necessary for winning. Based on how much players value game objectives, knowledge attainment, and social interaction, there are two subtypes within each division that reflect valences seen in AGT. Explorers can be Localized – becoming an expert in a single subject with a willingness to help others – or Comprehensive – experts of a broad range of game material who are less willing to socialize. Goal-Seekers can be Competitors – players who focus on winning the game and enjoy socializing to the point of sabotage – or Achievers – players who are interested in completing the game as fast as possible without the desire for socializing.

Avian: Research and Design

Avian is an educational game that aims to teach basic ornithology through virtual bird watching activities, e.g., photography and bird identification on two virtual islands. Players are asked to catalog bird specimens, fill in their personal field guides (Figure 1 Left) and report their findings to kiosks (Figure 1 Right). To win the game, a player has to correctly submit photographs of the requested bird species to all four kiosks.

In addition to promoting an engaging learning experience on ornithology, a main goal of Avian is to provide an environment to collect data for modeling the player types defined by Foster (2011). It is our assumption that the more learners of the four different player types behave differently in Avian, the more likely we can build an accurate player model of player type. Therefore Avian needs to support learners of different player types by providing different game activities that attract each of the four player types.

Gameplay Design for Player Types

Gameplay activities in Avian can be broadly grouped into four categories: island navigation, photography, field guide usage, and kiosk usage. As shown in (Figure 2), elements of each category are designed to appeal to specific groups of learners based on their player type.



Figure 1: In-Game Screenshots (Left: Field Guide Bird Catalogue, Right: Kiosk and Leaderboard)

	Goal-Seeker		Explorer			Goal-Seeker		Explorer	
	Competitors	Achievers	Localized	Comprehensive		Competitors	Achievers	Localized	Comprehensive
Island Navigation					Field Guide Usage				
Find New Kiosks	✓	✓	□	□	General Info	✓	✓	✓	✓
Find New Areas	□	□	✓	✓	Local Validation	□	□	✓	✓
Photography					Complete Guide				
Kiosk & Guide	✓	✓	✓	✓	Complete Guide	□	✓	✓	✓
Upload to Gallery	□	□	✓	✓	Kiosk Usage				
					Online Scoring	✓	□	□	□
					Complete Kiosks	✓	✓	□	✓
					Local Scoring	✓	✓	□	□

Figure 2: In-Game Activities for Player Types

Island Navigation. Basic mechanics of Avian involve the navigation and exploration of the virtual islands in the first-person perspective. In order to differentiate the two main player types, we include clear indications of the goal. For example, since winning the game requires the player to find all four kiosks, trail paths are marked on the ground which lead players from one kiosk to the next. The locations of all kiosks are clearly marked in a map. For explorers, since we know that they are less driven by winning the game, Avian allows players to wander off the trail paths and discover new areas with other payoffs such as scenery and rare birds. To potentially further differentiate the behavior of the two player types, we include a second island that does not have any kiosk and hence is unnecessary to win the game.

Photography. Players are able to take pictures of birds and scenery as they navigate the islands. These photos can be uploaded to an unranked online gallery for sharing, or submitted to a kiosk and/or the field guide (details below). Photography in Avian is purposely unrestricted. Although a green indicator shows when the camera is pointing at a bird, players can take a picture at any time about any subject. These pictures, birds or otherwise, can then be uploaded to the online gallery should the player choose to do so. The online gallery displays photo submissions of all the users. Each photo shows the player who took it, but doesn't present any information about score or evaluation. Since there is no formal competition between the photos, the gallery is designed to share experiences, birds, and scenery that players find interesting. These qualities are representative of explorer inclinations.

Field Guide Usage. The field guide consists of a bird catalog, index, and help section. The bird catalog (Figure 1 Left) includes a series of birds, each of which contains the name of the bird species, descriptions, and a picture slot where the player can submit a photo of that species (only correct photos will be accepted.) In addition, the index section displays user information and the help section contains explanation about how to play the game. These elements provide general information to all players.

Uploading the correct photos to the bird catalog does not affect player's scores or allow them to win the game. Instead, it provides feedback for the quality of the photo based on the bird's species, its facing angle, distance from the player, and its captured action (e.g., perching). As a form of local (i.e., single-player) validation, the bird catalog is designed for explorers as an uncompetitive alternative to kiosks (discussed below). Finally, the ability to complete the guide is designed to attract explorers and the achiever type under goal-seekers.

Kiosk Usage. Each kiosk contains the task of finding a particular species of bird, which the game places near the kiosk. The player can submit the photo to the kiosk and get scored on the quality of their photo. The score is computed based on the same criteria as the feedback from the bird catalog except the kiosks provide a numeric overall value.

The scoreboard provides a list of the highest scoring players for the goal bird at any given kiosk. The online scoring feature of the kiosk is designed for competitors, who are motivated to compete with other players of the game. It is our hypothesis that competitors will make multiple submissions per kiosk to maximize their score, while achievers will make as few submissions as possible to win the game quickly. As discussed above, winning the game requires completing the tasks at all four kiosks. It is designed for all player types except localized explorers.

Player Metrics Collection

Our game records data to generate a series of metrics that capture how each player interacts with the game and eventually to build a model of play style patterns. While modeling player types is premature, our research draws relationships between play styles and achievement goal motivation through aggregated player metrics. More specifically, we currently collect the following groups of data. 1) Time spent on different types of activities, such as menu usage (help pages, bird catalog), navigation, photography, and total time spent in Avian. 2) Trail variance, such as percentage of time spent on the trail paths, how often the player deviate from them, how far from the starting position does the player go in average, and whether the players ventures to a second island via the use of a bridge. 3) Photo content, such as what percentage of photos taken contain birds, and among them, how much variance is present among the birds. 4) Gallery uploads, that is, how many and what kind of photos players upload to the gallery. 5) High scores, that is, how often players submit photos to kiosks along with the score, timestamp and what species of bird was submitted.

In order to identify trends and patterns in our data and to evaluate our current player metrics, we developed tools to visualize user activities. Fig. 3 is an example displaying of multiple players' navigation traces and the locations where they used their camera to take photos (see Figure 3). Heatmap is another visualization technique we implemented as it shows where players focus attention (and where they ignore). They show aggregate player behaviors and may prove useful not only in seeing possible patterns relevant to research, but also to potential flaws in game design that can be improved upon in future iterations.

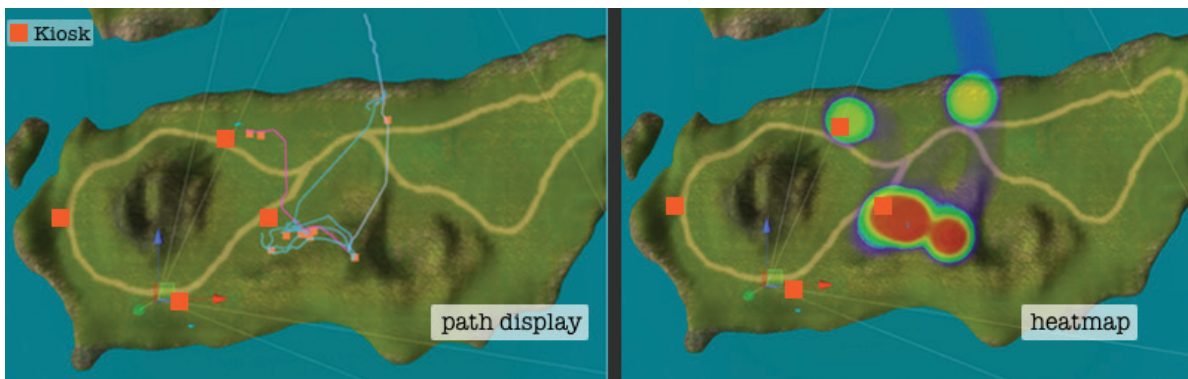


Figure 3: Visualizing Player Paths in Avian (Left: Path Visualization, Right: Heatmap)

Future Direction

As part of our future work, we plan to conduct a study to collect data on how different players interact with the game. We will use this data to analyze player behavior. Specifically, we are interested both in performing two types of analysis. First, we will use machine learning clustering methods such as k-means (MacQueen, et. al, 1967) to investigate whether meaningful clusters of players emerge and whether they are correlated with any aspect of interest to our study. Second, we are interested on using this data to validate our game design hypothesis regarding the different activities (Fig. 2) in our game.

To validate our player modeling results, we have designed an instrument based on the Achievement Goal Questionnaire (Elliot & McGregor, 2001) – a 12-item achievement goal orientation instrument ($r=.800$) – to measure players' self-reported goal orientation. Results of the automated player modeling techniques will be compared with the results of the AGQ.

Conclusion

In conclusion, we presented our approach to game design and player modeling in adaptive educational games. Through an on-going educational game called Avian, we have shown how we designed Avian's game mechanics in order to allow learners of different player types to engage in different gameplay activities. We also present

the player metrics Avian collects. We believe that the approach behind our game design can be applied in other adaptive educational games that uses player modeling. Our next step is to collect player data through a study and evaluate the effectiveness of our player metrics for player modeling.

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