Eye-Tracking for User Attention Evaluation in Adaptive Serious Games

Alexander Streicher[1], Sebastian Leidig[1], and Wolfgang Roller[1]

Fraunhofer IOSB, Karlsruhe, Germany
firstname.lastname@iosb.fraunhofer.de

Abstract. The Ideal Path Score (IPS) developed in this work is able to improve adaptivity of serious games by more accurately estimating performance and need for help based on players' interactions and eye movements. The automatic personalization of adaptive e-learning systems supports effective learning for users with varying levels of knowledge and skills. Particularly in games, indicators informing adaptivity, like attention and performance of the player, should be assessed non-invasively to avoid interrupting the player's flow experience and to keep up the immersion. Passive sensors like eye tracking can solve this challenge. This paper presents the concept of the IPS and its integration in an adaptive serious game for image interpretation training. The realized IPS-adaptive game assesses performance and attention of players based on eye movements and interactions with the game.

Keywords: adaptive games· eye tracking · ideal path · serious games

1 Introduction

The problem statement in this paper deals with the question of when an adaptive serious game needs to adapt, e.g, when to automatically personalize or customize the learning experience, and how to effectively assess user progress. The correct timing is important to match the players' needs [5]. Digital game based learning needs to constantly motivate the users and sustain a constant flow experience to achieve an effective learning outcome [1]. This flow, a balance of challenges and skills, can keep the learner self-motivated and is an important aspect of effective serious gaming. Adaptive serious games for learning try to personalize the gaming and learning experience to keep the user in the flow channel and to maximize to learning outcome. Effective adaptivity is based upon sound user or learner models which contain all the necessary information to adaptively guide the learner. The user models can include information on the users' abilities, which can be measured either implicitly or explicitly. However, in serious gaming each intervention by an explicit measurement, e.g., via user questionnaires, could have negative impacts on the users' flow experience. Hence, implicit measurements try to estimate the users' current learning progresses or cognitive states. For effective adaptivity, ideally the adaptive interventions would be guided by a measure of the users' progress. One possibility to measure the users' progress is to look at the

purposefulness or goal-orientedness of their actions. A user working efficiently towards the goal obviously does not need further assistance, whereas a user who is lost or moving in a wrong direction should be adaptively assisted. An approach to measure such a goal-orientedness is the definition of a metric to measure the distance between an ideal path and the users' observed action [3]. The scientific research question is, if there is a correlation between gaze, ideal path and attention. We are asking, when the users follow the ideal path do their gazes also follow that path, and can the attention level be inferred (estimated) from that. We contribute the concept and work-in-progress of the *Ideal Path Model* (IPM) and the *Ideal Path Score* (IPS) for its application for attention level detection with eye tracking.

2 Ideal Path Score for Adaptivity

The IPS can improve adaptivity of serious games by more accurately estimating performance and need for help based on players' interactions and supported by eye movements. The IPS is especially helpful in combination with gaze or eye tracking. Eye tracking can give insights on the cognitive states of the users by tracking their visual attention. A typical example would be that attention is turned to the first area of interest, moving the fovea to this point. Once the movement is complete, the feature is inspected with higher attention before moving to the next area of interest [2]. This gaze data can make an adaptive system more robust, i.e., a high correlation between gaze direction and pointing coordinates (mouse clicks or touch events) could indicate a high user attention level. To evaluate the attention level in regard to a goal-orientedness the Ideal Path Model as a reference model has been developed.

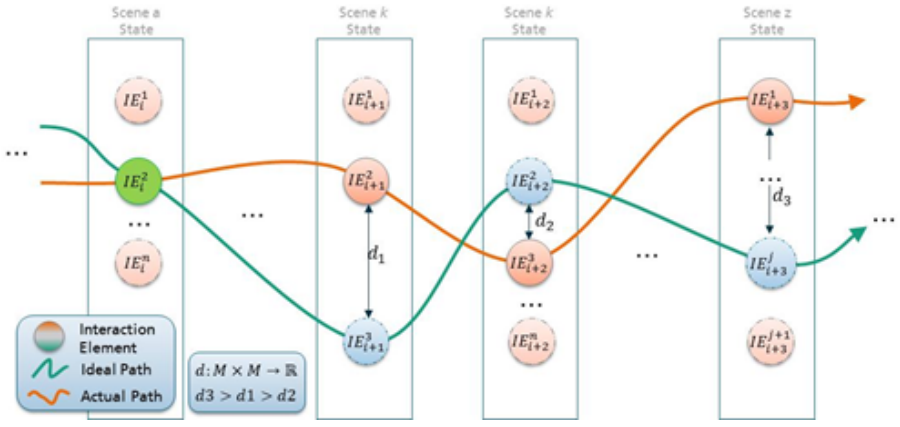

Fig. 1. Ideal Path Model with scene states, interaction elements and distances.

2.1 Ideal Path Model

The IPM describes all necessary steps to reach the game's goals without any unnecessary detours. In essence it is a sequence of episodes and interactions in a virtual environment that most directly leads to the next goal [3]. For example, in an adventure game, the ideal path would be the optimal walk-through, i.e., the optimal sequence of interactions from the game start to the game ending. The building blocks of the IPM are (figure 1): (1) scene manifestations which capture the current state of a scene; (2) interaction elements which are all game elements a player can interact with; (3) an ideal path through the sequence of all scene manifestations and interaction elements; (4) the actual path which reflects the actual sequence one player has taken. A scene can have multiple manifestations for each possible interaction a user can undertake. The IPM can be built manually or automatically by recording the steps an optimal player would undertake. The recording of both the ideal path and all actual paths can be implemented using the *Experience API* (xAPI) data format.

2.2 Ideal Path Score

The IPS supports the computation of user progress. The score is normalized to $[-1; 1]$ to be invariant of varying game genres or different users. A value of $IPS = 1$ means a perfect game move (congruent with the ideal path); a value of $IPS = 0$ is a game move without significant progress; and $IPS = -1$ is a degrading game move (negative progress), e.g., moving in the utter opposite direction. For games with continuous movements IPS could be in $\{x | x \in R, -1 <= x <= 1\}$. While the Ideal Path Model is generic and can be modeled game independent, the IPS and its metric are typically game specific. For example, for step-by-step games this could be a string similarity distance; or for a 3D shooter-type game the metric could be a distance between waypoints. For our game, a 2.5D seek-and-find game, the metric is the euclidean distance between optimal and actual direction.

3 Application

The seek and find game *SaFIRa* [4] has been extended with an eye tracking plugin and the IPS (figure 2). The game itself is implemented with the game engine Unity. The adaptivity for SaFIRa has been realized with the E-Learning A.I. (ELAI) adaptivity framework [4]. The ELAI's interpretation engine and heuristic adaptivity score computation (a weighted linear equation formula with so called Didactic Factors) has been extended by the IPS as a new factor. The concept has been successfully implemented. Preliminary evaluation results indicate an improvement of the adaptive behavior.

4 Summary

The presented *Ideal Path Model* and its linked *Ideal Path Score* (IPS) enable attention-driven adaptivity for serious games. The IPS can be used for more

Fig. 2. Eye-tracking and the *Ideal Path Score* applied to adaptivity for a serious game.

precise estimations of players' performance and their need for adaptive assistance. It targets the problem statement of when an adaptive system should engage. This is of particular importance in games where interrupting the players' flow experience should be avoided to keep up the immersion. The realized IPS-adaptive game assesses performance and attention of players based on eye movements and interactions with the game. In future work an evaluation will target multiple hypotheses, including e.g., correlation between measured attention or goal-orientedness and related subjective answers of study participants; or influence of eye tracking on IPS evaluation and on adaptivity.

Acknowledgments

The underlying project to this article is funded by the Federal Office of Bundeswehr Equipment, Information Technology and In-Service Support under promotional references. The authors are responsible for the content of this article.

References

1. Chen, J.: Flow in Games (and Everything else). Communications of the ACM **50**(4), 31–34 (apr 2007), http://doi.acm.org/10.1145/1232743.1232769
2. Duchowski, A.: Eye tracking methodology: Theory and practice. Eye Tracking Methodology: Theory and Practice pp. 1–328 (2007)
3. Streicher, A., Roller, W.: Towards an Interoperable Adaptive Tutoring Agent for Simulations and Serious Games. In: International Conference on Theory and Practice in Modern Computing, MCCSIS 2015. pp. 194–197. IADIS Press (2015)
4. Streicher, A., Roller, W.: Interoperable Adaptivity and Learning Analytics for Serious Games in Image Interpretation. In: EC-TEL 2017, pp. 598–601. Springer (2017)
5. Streicher, A., Smeddinck, J.D.: Personalized and Adaptive Serious Games. In: Entertainment Computing and Serious Games, chap. 14, pp. 332–377. Springer (2016)