Continuous and Unobtrusive Capture of User-Player Behaviour and Experience to Assess and Inform Game Design and Development

Tim Marsh
Integrated Media Systems Center
University of Southern California
Los Angeles, CA 90089-0781, USA
marsht@usc.edu

Kiyoung Yang
Computer Science Department
University of Southern California
Los Angeles, CA 90089-0781, USA
kiyoungy@usc.edu

Shamus P. Smith
Department of Computer Science
Durham University
Durham DH1 3LE, United Kingdom
shamus.smith@durham.ac.uk

Cyrus Shahabi
Integrated Media Systems Center
& Computer Science Department
University of Southern California
Los Angeles, CA 90089-0781, USA
shahabi@usc.edu

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Abstract
We describe a continuous and unobtrusive approach to capture data amassed from user-player interactions with virtual or game environments. Central to this is a tool called ISIS (Immersidata analySIS) to query and identify data of interest and to index events within video recordings of game sessions. Analysis of the associated data and video clips help us to understand user-players' behaviour and experience to assess and inform the design and development of games. ISIS supports six queries to identify: actions and activities, breaks in interaction caused by reflection or ineffective and problematic design, navigation problems caused by user disorientation, and events or tasks that are the most difficult to perform in a game. In the development of an educational serious game, we provide examples of how our approach has helped to inform redesign to make improvements to the game.

Keywords
Experience capture, serious games, game development, tool support, immersidata.

ACM Classification Keywords
H.1.2 [**Models and Principles**]: [User/Machine Systems *Human information processing*]; H.5.2 [**Information Interfaces and Presentation**]: [User Interfaces *User-centered design*]

Introduction

User-player activities or behaviour within game environments provides fun and experience. An appropriate or stimulating experience encourages user-players in *staying there* [5] behaviour as the user engages with game activities. Conversely, inappropriate or un-stimulating experience from ineffective or problematic design can compromise the *staying there* experience.

The capture and interpretation of user-players' behaviour and experience can inform design and development approaches supporting the game experience [5]. Current methods to capture and assess fun and game experience are limited. Typically methods disrupt the user-player and hence disrupt their experience, while others are retrospectively administered following game play. Hence, it is difficult to link fun and experience to tasks, activities or design. In addition user-players may not reflect accurately on their entire game experience. For example, methods requiring the user to perform operations - e.g. verbalize [15] or reposition a slider [2] - to indicate their experiences that are additional to operating input devices necessitate users to divide their attention between the virtual/game experience and the methods used to capture and assess experience. This may interrupt the virtual experience and its assessment. The limitations of retrospective techniques such as questionnaires are well reported, for example in capturing user experience such as presence [14], voyeuristic, visceral and vicarious [4] and empathy between user-players and characters [7, 9]. The capture of physiological data [11] and similarly, fMRI brain scans and EEG brain waves overcome some of the aforementioned problems but raises the question of whether or not the probes and sensors attached to a user are disruptive, encumbering or obtrusive.

In this paper a continuous and unobtrusive method is presented to seamlessly capture data generated from interchanges between a user-player and a three-dimensional virtual or game environment. We refer to this data as *immersidata* [13] and have developed an application called ISIS (Immersidata analySIS) to expedite the consultation and summarization of immersidata to help understand user-players' behaviour and experience. ISIS queries immersidata to identify and index events within video clips for analysis. This paper focuses on the capture and assessment of user behaviour and experience in digital games[1], and more specifically, on the transfer of knowledge to user-players[2] in game environments. In particular we explore experiential learning or the learning experience, and games exhibiting learning as their primary purpose. Such games are referred to as social impact games or *serious games* - games for non-entertainment purposes, thus distinguishing them from computer or video games developed primarily for entertainment purposes. However learning and entertainment are not necessarily mutually exclusive in serious games and

[1] Digital games refers to computer, video or serious games.

[2] User-player in serious games is synonymous with student.

therefore development tools and techniques should be able to address both. While assessment of user-player experience in serious games provides a means to validate learning and design, there is negligible research literature on the pedagogical value of serious games and moreover, a dearth of available tools and techniques. The current version of ISIS supports six queries for analyzing user-player behaviour and experience, to assess and inform design to make improvements to games. The six queries identify: actions and activities [5], breaks in activities and experience caused by contemplation/reflection or ineffective and problematic design [10], navigation problems caused by user disorientation [17], and events or tasks that are the most difficult to perform in a game [18].

Serious game environment

In the Integrated Media Systems Center (IMSC) at the University of Southern California (USC), a serious game has been designed and implemented (see [8]). The games' objective is to help students learn the physiology of human organs. It consists of three activities or missions: Training, Nature Pumps and Control Systems. The Training mission familiarizes users with the fundamentals of the game, instructing them on how to move within the game and how to interact with the environment. The Nature Pumps mission helps students learn the processes of digestion and absorption of nutrients, and the Control Systems mission teaches students the roles of glucagon and insulin in maintaining blood glucose levels.

Game Immersidata Collection

In virtual reality and digital games users are immersed in activities with characters and objects within places depicted virtually. As mentioned, we refer to the data generated from user interchanges in these environments under the all-embracing term *immersidata* [13]. Immersidata can be considered as several continuous data streams (CDS) generated from interactions, events and sensors, etc. The amount of immersidata that is required to be captured to represent user behaviour and experience in virtual environments is considerably large.

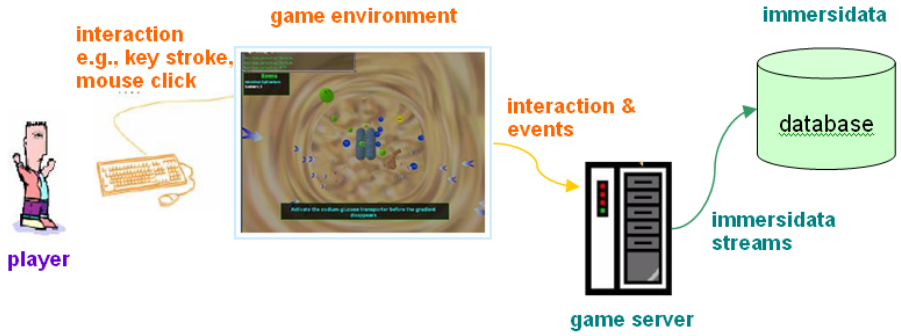


Figure 1. Game immersidata collection.

The third and the fourth rows of the table indicate that the user-player made a mistake by placing the intestines into the panel that describes the muscles.

The fifth and the sixth rows of the table indicate that the user-player made another mistake by placing the lungs into the panel that describes the muscles.

Table 1. A snapshot of the event stream.

EVENTTYPE	OBJECTNAME	X	Y	Z	RX	RY	RZ	ANGLE	TIMESTAMP
pick	liver	302.826	293.232	225.45	0	0	1	.487397	1794750
place	liver	302.826	293.232	225.45	0	0	1	1.41507	1797406
pick	intestines	305.154	293.45	225.431	0	0	-1	1.0532	1807417
place	muscles	305.154	293.45	225.431	0	0	1	2.59662	1809241
pick	lungs	305.154	293.45	225.431	0	0	-1	1.06403	1812053
place	muscles	305.154	293.45	225.431	0	0	1	2.59106	1813977
pick	muscles	305.154	293.45	225.431	0	0	-1	.698755	1816303

Hence, this creates the difficulty of how to efficiently store and retrieve the immersidata. To help in this, Shahabi [13] proposed the Immersidata Management System (AIMS) with database support. An overview of the game immersidata collection environment can be seen in figure 1.

In laboratory-based studies, a video camera captures the user-player while playing the game together with a monitor displaying the user-player in the game. While the user-player attempts to fulfil the game's tasks, the user-players position in the game and the events generated from their interaction within the game are continuously collected. Table 1 provides a typical fragment of an event stream. X, Y and Z represent the position of the user-player within the game. RX, RY, RZ and ANGLE represent the direction that the user-player is facing in the game. The final column shows the timestamp in milliseconds. We also collect the position of the user-player within the game environment 3 times a second. This consists of a timestamp, positional and angular coordinates as described, and EYEX, EYEY and EYEZ to represent the direction in which the user-player is looking in the game. While the 3Hz sampling rate has also been used in [18], this is not a limitation of ISIS as the sampling rate can be increased according to the requirements of the application under evaluation.

In addition to the immersidata, we also collected demographic data (e.g., gender, age, games experience) taken from pre-study questionnaires.

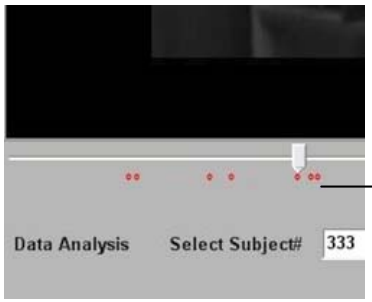
ISIS: Immersidata analysis

ISIS is a graphical user interface (GUI) that indexes the results from queries of immersidata with video clips of user-player's gaming sessions (see figure 2). Identified events can then be observed to help understand user-player's behaviour and experience. Hence, instead of manually linking video with immersidata and then sequentially analyzing recorded video material, ISIS utilizes the immersidata linked to video to expedite the process of analysis. ISIS's user interface consists of several frames. In the upper left window, video clips of user-players during study session are displayed. Pointers or indexes to immersidata retrieved from the database are placed on the track bar under the display screen. The bottom left window allows the selection of a user-player, a query and associated parameters.

The right window consists of three frames: user-player profile, statistics and questionnaire. The user-player profile frame displays demographic information such as computer and game competency. In the statistics frame, the statistics across all the user-players such as comparison between male and female (e.g. task

completion times) are represented. Finally, the questionnaire frame provides comparisons of content questionnaire results taken before and after game play.

Indexes are red markers on the track bar under the display screen.



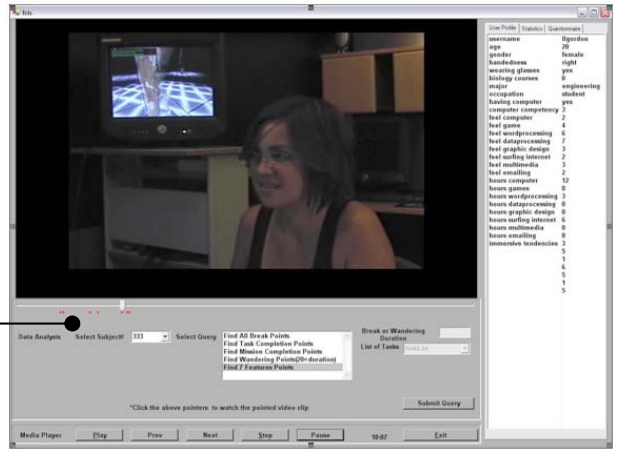


Figure 2. ISIS: illustrating indexing of results from queried immersidata with video clips of a user-player's gaming sessions.

Six queries for analyzing user-player behaviour have been implemented. Although the current work is applied to an educational game, it is anticipated that these queries can generalize to other serious games and across different game genres that are primarily for entertainment purposes.

Activity or Mission Completion Points
This query identifies the moment when a user-player completes the final task(s) associated with a particular activity or mission. As well providing the overall completion time of activities, it provides a frame for the tasks and sub-tasks (i.e. events) associated with an activity.

Task Completion Points
This indicates the points when a user-player finishes each task and the duration of each task. Evaluators and developers can choose which task completion points they want to retrieve from the database and from analysis of video clips, learn which behaviours and strategies a user-player employed to fulfil a particular task and reason about the kinds of experience they have been through.

Break Points
A break is defined to be the moment when the user-player does not make any movement and no events occur for a specific period of time. Break is a very important concept in game assessment and development because it provides clues to causes of what interrupts the user-players while they are playing the game. In serious games for learning, the cause of breaks can be either that the user-player is appropriately contemplating the educational content of the game or there is a design problem. The implementation of a break query in ISIS provides evaluators and game developers with an efficient way to select break points and analyze video clips associated with break points to determine the cause of break. For example, Figure 3 illustrates the point at which a user-player in a study session stopped playing the game because she was not sure what to do next after correctly placing all of the organs. This suggests a lack of instruction after finishing the first task and further analysis confirmed this to be the case.

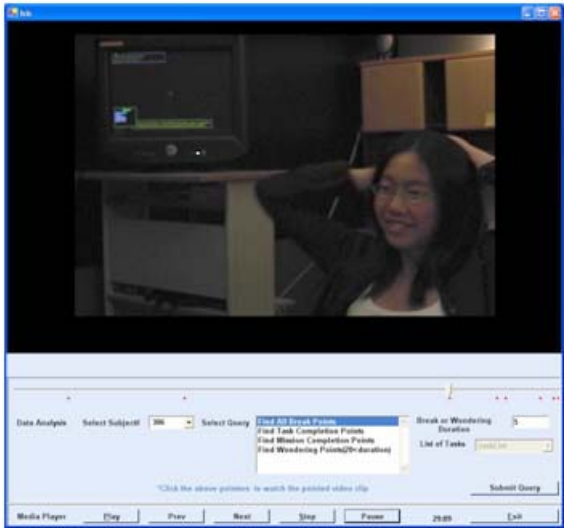


Figure 3. Break example captured using ISIS: - the user doesn't know what to do next.

Wandering Points

A similar query to breaks is wandering points that identifies the period when the user-player is moving but does not make any events (e.g. selection of objects) for a specific period of time. Evaluators can use this query to analyze user-player behaviour to identify any difficulty user-players may have encountered and developers can use this query to identify design problems. In study sessions, one user-player was identified as roaming around for quite some time and said that she was "not sure what to do next". Following further analysis of the circumstances surrounding this and then comparing this with the behaviour of other user-players using ISIS, we were able to reason that the problem was not with design as we had first suspected but a lack of experience on behalf of the user.

Table 2. The seven critical events/features that identify novice from non-novice user-players for task one of the Control Systems activity/mission.

Event Name
place_pancreas
place_muscles
pick_muscles
pick_pancreas
enter_body_room
pick_liver
pick_stomach

Critical Events

This query identifies user-players performing events that have been classified as the most difficult to fulfil in a task. Building on earlier work [18], the classification of events is an important procedure that uniquely characterizes a game through critical events performed in tasks of activities. For example, the red markers on the track bar in Figure 2 illustrate the indexing of the completion points of seven most difficult or critical events for task one of the Control Systems mission as listed in Table 2. As well as quantitative measures such as, time to fulfil events and number of errors made as shown in Table 1, analysis of the behaviours and strategies that a user-player employed to fulfil a particular event provides an indication of user-players' level of competence and learning ability in game play and also, an indication of fun and experience they have from playing the game.

Navigation
Problems associated with navigation are attributable to many causes. These including the lack of navigation cues to guide users [1], problems when the whole display screen is reduced to one colour whilst navigating too close to or through virtual objects [3], the cognitive load that is placed on the user [16] and the restricted field of view seen through the display screen [12]. Any one or a combination of these may result in user disorientation, potentially interrupting game play and negatively effecting the inducement of experience as reflected by *staying there* [5].

A query has been developed to identify environment collisions from the immersidata. It is not assumed that every time a user-player collides with an environment object that they are disorientated but that disorientation is more likely to happen in such a situation [17]. Evaluators can use this query to analyze user behaviour for signs of disorientation. Such instances can be further examined to determine the user's spatial awareness. Colliding with objects and any resulting disorientation can reduce the user's ability to construct spatial knowledge of the environment. The query can help in identifying sections of the video and game data to be reviewed to determine if the user is actually disorientated.

Conclusion and future work

In this paper we described how interchanges between a user-player and an educational serious game environment are seamlessly captured and stored in a database as immersidata. In order to capture the behaviour of students in the real world environment we also videotaped the game play. An application called ISIS has been developed. ISIS supports queries to an immersidata database to retrieve data of interest and marks or indexes this data with video clips to help evaluators, educators and developers to understand user-player's behaviour and experience. The gathering of immersidata and the ISIS tool provide powerful support for the evaluation of game and virtual environments. Patterns of user behaviour can be quantitatively identified for further qualitative analysis. The wealth of data collected by the system allows user sessions to be rerun and studied as necessary. In addition user behaviour and experience can be unobtrusively analysed by a number of complementary techniques including in-game performance and user verbalisations, facial expressions and other body language.

We are planning to extend this research to add more functionality to ISIS so that it can identify the game design problems that interfere with subjects in game experience. Recognizing the repeated actions of subjects would be useful for this purpose. In addition as video recording is potentially intrusive to some users, we plan to use a virtual replay of events rather than video so that queried immersidata of interest is indexed to a user-player's point-of-view in the game. Finally, work is already underway to capture and link with design and game events the foundational elements of experience: the voyeuristic, the visceral and vicariousness [6].

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