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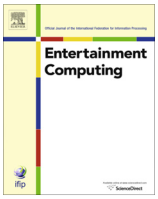

Temporal multimodal data synchronisation for the analysis of a game driving task using EEG ☆

Aparajithan Sivanathan *, Theodore Lim, Sandy Louchart, James Ritchie

Heriot-Watt University, Edinburgh EH14 4AS, United Kingdom

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ABSTRACT

Multimodal data channels such as bio-physiological signals are increasingly used in game-play studies to better understand players' behaviours and their motivations. It is however difficult to perform any sort of conclusive analysis solely based on bio-physiological signals due to the complex nature of epistemic, semiotic and ergotic activities surrounding in-game activities and the artefacts facilitating player immersion. Thus a combined analysis of multiple data streams including in-game data and bio-physiological signals is indispensable to produce contextualised information from which a deep analysis of game mechanics and their effects can be performed.

Precise synchronisation in capturing multiple streams is required to generate valid inter-stream correlations and meaningful information. Typically there are no automatic mechanisms built in the game architecture or in commercial data logging systems for multimodal data synchronisation and data fusion. This paper presents a novel and generic technique based on inducing identifiable signature pulses in data channels to accurately synchronise multiple temporal data streams. This technique is applied and its capabilities are exhibited using a driving game simulation as an exemplar. In this example, driver's in-game behavioural data is synchronised and correlated with their temporal brain activity. The concept of simplex method borrowed from linear programming is used to correlate between the driving patterns and brain activity in this initial study is provided so as to allow studying/investigating user behaviour in relation to learning of the driving track.

1. Introduction

Computer games are increasingly being used as a medium to study user affect in psychology and behavioural studies. To study a particular phenomenon, such as learning, perception or emotion, often the arbitrariness of real world activities makes for a difficult experimental setup to gather, track and analyse the provenance of data. Temporal data from human bio-signals e.g. Electroencephalogram (EEG), Electromyogram (EMG), Electrooculography (EOG), Galvanic skin response (GSR), etc. are often used to study the human behaviour with the reduced attitudinal and demographical influences. Unfortunately, such data are prone to noise and thresholding, weakening the correlations where evidence of temporal influences upon the multi-dimensional and subsetting operations during in-game activities to produce contextually meaningful information. Having well thought out and implemented game play mechanics would provide a context and immersive experience, by reflecting the temporal phenomena.

Contemporary Serious Games (SGs) are often represented through complex environments in which users are led to interact with many game-related elements and information. While SGs generally focus on a set of specific and recognisable purposeful activities (core mechanics) oriented towards specific learning outcomes, they also integrate a number of smaller, shorter, activities designed to engage players on different levels (secondary mechanics) and generate a state of flow for the player. Logging game play is a common practice in order to study a player's in-game behaviour and monitor the efficiency of specific game elements. Behavioural knowledge gained through this approach could be used to assess the contribution of individual game mechanics (core or secondary) in supporting player engagement and learning. However, gathering and analysis of user behaviour is a multivariate process which requires more information than the mere logging of game context and player activity.

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* Corresponding author. Tel.: +44 0 131 451 4435.

E-mail addresses: a.sivanathan@hw.ac.uk (A. Sivanathan), t.lim@hw.ac.uk (T. Lim), s.louchart@hw.ac.uk (S. Louchart), j.m.ritchie@hw.ac.uk (J. Ritchie).

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1.1. Synchronous logging of in game temporal data

The data captured in a game session can be classified as context independent and context dependent data [1]. Context independent data is normally external to the game, such as EEG, eye tracking, screen capture, etc., while context dependent data relates to the internal elements of the game such as score, lap time, driving speed, interaction with a game asset or character. Apart from enabling insights into the actual internal affective state of the player [2], context dependent and context independent data permits a more holistic understanding of the combined and interactive user-game system. Consequently, accurate synchronisation of multimodal data streams is critical to avoid parameter skews for analysis. Analysing task based operations (e.g. Event Related Potentials) require precise time measurements where the chronological ordering of events is crucial [3]. For example, if one wants to analyse P300 or N400 components in EEG signal, temporal alignment tolerance of the synchronisation should be in millisecond range rather than in seconds [4].

To date configured solutions for multimodal data capture are ad-hoc solutions [5–10] and cannot serve as a holistic system. Almost every solution for multimodal data capture is interfaced with specific hardware or software tools from various vendors. Because of the ad-hoc interfaces, they are depended particularly to one or a family of data capture tools. Therefore it becomes obligatory to use multiple customised data logging solutions to satisfy different application scenarios. Assorted tools run on independent platforms, for instance different hardware or assorted software even if they run on the same hardware. In addition to the game logging, multiple data capture devices (e.g. EEG Capture Device, Eye Tracker, and Video Capture Device) also work as detached components in a data logging environment. Devices running on independent hardware or software platforms will naturally run asynchronously. Data captured from these isolated components are required to be synchronised by some means because data streams originating from these components must be temporally aligned to decipher the meaningful information. The temporal alignment can influence the information extracted in such a way that significant information of an activity is detected, undetected, or falsely detected. For instance, eye tracking data stream should be adequately aligned with the data stream from the in-game context in order to recognise what in the dynamic screen of the game could have caused the change in the eye data.

1.2. Driving task and game elements

A study using a driving game play was used in this paper to quantify driver performance and skills so as to gain a better understanding of a driver's ability. The intention was to ascertain whether cognitive and motor skills from a driving game transferred to real world driving. The hypothesis that characteristics such as confidence, skills, capacity of learning, etc. in a gaming environment reflect similar skill sets for real-world driving, particularly since these activities align with requirements for Formula (F1) Student driver selection [11].

In this particular study, it is anticipated that learning is achieved via the repetition of the same game activities and a trial and error approach towards task completion. Drivers were asked to drive around the racing track against the clock. Driver abilities vary greatly depending on their real and simulated driving experience (i.e. driving games) and their knowledge of motorsports. The study therefore focused on the learning process rather than performance. The aim is to determine how accurately temporal data can be captured and fused to help document driver performance in the areas of braking point, corner entry, negotiating an apex and corner exit, prior to track days and race-driving tuition.

1.3. Game-driving task and psychophysiological analysis

Correlating driving performance and psychophysiological data, specifically monitoring the brain activity (using EEG) can potentially reveal the relationship between driving behaviour and the cognitive state of the driver [12–17]. However, the research in the area of distinguishing the above described skillsets from psychophysiological signals is not explicit. Neurometric studies and experiments for brain-based/driven applications are performed in tightly controlled environments (i.e., movement restrictions). It also limits the actual intended task and therefore not always feasible to perform the actual behavioural measurement during the recorded task [18]. A game-driving or real-world driving is essentially a mixture of various visceral and sensorial activities from which the driver has to respond [16,17,19]. The brain activity at an instance of driving corresponds to all these activities invariably.

The conventional practice of neurometric analysis is to ringfence the study and hence reducing the number of parameters that can affect the experiment. Other activities are recognised as artefacts and the signals relating to these activities are considered as 'noise' in the signals. It might be neither possible to split the driving task into smaller key activities, nor reject other activities as artefacts in driving. Consider the task of negotiating a corner at speed, it involves hand-eye coordination and is associated to the driver's confidence level. If a study has been performed to associate the confidence level using the affect state of the driver measured using EEG, separating the movements or visuals processing from task might breakdown the purpose of the study.

Although the action-chain (i.e., epistemic, semiotic and ergotic) relationships [20–22] of driving can be broken down into individual elements, the context of behaviour and cognitive organisation cohesion is more than the sum of its parts. The alternative approach is to extract patterns from combined modalities, car-related parameters (e.g., steering activity, pedal depressing, speed of driving, position on the track, etc.) along with neurometrics (mainly, EEG).

Consequently, a synchronised data capture of driving telemetry and psychophysiological data is critical for the combined analysis and for finding correlations. Since the outcome of the analysis is highly dependent on the synchronisation of independent data streams, a proven mechanism was required for the data capture and to verify the temporal alignment between data streams. This necessitates re-scrutiny on assumptions made about data capture tools and the whole data stream pathway.

1.4. Paper contributions

The paper introduced the compelling need for the synchronised multimodal data capture in the Section 1. Issues related to EEG analysis in a game environment, specifically for driving were addressed in Section 1.3. Section 2 provides a background on issues related to the time synchronisation in data logging and standard strategies used to tackle the synchronisation problem are briefly reviewed here. As a solution to the synchronisation problem, Section 3 presents a novel and generic technique to temporally synchronise diverse multimodal data streams. Section 4 introduces the experimental task, a game-driving scenario as a case study. This section explains the data logging setup in detail with relevant data capture devices, also technically revealing potential flaws related to the temporal synchronisation of data streams. A driving game is used as an example scenario; however, the issues are generally encountered in many other gaming domains. Finally the accuracy and granularity of the synchronisation are critiqued by referring to the collected data.

Section 5 demonstrates how temporal synchronisation can be utilised to correlate the brain activity and the events related to driving. Simplex correlations [23] between EEG data and driving