A NeuroIS Platform for Lab Experiments

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Problem Identification and Motivation

NeuroIS research necessitates the collection of high quality empirical data (Dimoka et al. 2012). In particular, research in this domain necessitates the collection of psychophysiological and neuroimaging data synchronized to a subject's current context. Here, context refers to the environment and the behavior of the observed subject, e.g., decisions during an auction, answers on a questionnaire, or the time to complete a control task. Due to the controlled environment, many researchers use lab experiments to conduct their studies and collect the above described data (Falk & Heckman 2009).

Software used in these lab experiments, either third-party or customized software, often suffers from a number of limitations, such as (i) a limited set of functionalities, both for the user interface and the experimental structure, (ii) data collection and storage being spread over several different tools, which results in data synchronization problems and time consuming post-experiment data cleaning, (iii) being limited in subject size or possibilities in subject interaction, (iv) requiring to learn new or proprietary programming languages in addition to heavy programming effort, (v) no extensibility to handling emerging and changing software and hardware, e.g., new operating systems or new bio sensor technology, (vi) missing flexibility to handle requirements of experimental economists, IS researchers, or to meet future requirements, such as integrating physiological data to research technostress (Riedl et al. 2012).

Objectives of the Solution

Following a design science approach (Peffers et al. 2008), we next define broad objectives of a possible solution to address the problems stated above.

- Facilitating the creation of lab experiments by reducing development time and cycles
- Facilitating individual & group interactions in a controlled lab setting
- Integrating measurements of bio sensors and logging of physiological data specific to subject events
- Ease of event logging and data storage, enabling experiments to scale in time and subject size
- Meeting emerging technical requirements in the field of IS research and experimental economics

Design and Development

To address these objectives, we herewith present a Java™-based platform, which provides functionalities necessary to run NeuroIS lab experiments while, at the same time, offering flexibility to adapt to experiment specific requirements. The platform implementation is inspired by Smith's (1982) definition of an experimental system. In combination with the integration of bio sensors, the platform can be used in many research disciplines, which seek to apply a NeuroIS approach, e.g., design science (vom Brocke et al. 2013), biofeedback (Jercic et al. 2012), consumer research (Koller et al. 2012), and educational software (Chintalapati et al. 2010). The platform's support for experiments with multiple and simultaneously interacting subjects, for group or market experiments, offers numerous possibilities for NeuroIS research.

The platform's software architecture is divided into two parts (see Figure 1): a built-in part (*core components*) and a customizable part (*experimental design* and *bio sensors*). The *core components*, which are provided by the platform, form the robust foundation. They handle, for instance, client-server communication, database logging with client and server timestamps on millisecond precision, and the management of experimental sessions, i.e., all the required building blocks essential to almost all lab experiments. Also provided by the *core components* is an internal database, which makes the use of a dedicated database server optional.

On top of the *core components*, the customizable parts are implemented by the researcher. Both customizable parts, the *experimental design* and *bio sensors*, are based on the idea of modules, i.e., they are developed independently and added to the *core component* as needed. First, the *experimental design* which defines the actual experiment. Here, the researcher implements all elements and "rules" of the experiment, e.g., the experimental procedure, the matching of subjects and groups, and the options for subjects to interact. The *experimental design* also defines the visualization of the experiment, i.e., the user interfaces, which are shown to the subjects. Since there are no restrictions to what Java™ elements can be integrated into the design of the user interfaces, all elements can be included from simple elements, such as images and videos, to more complex elements, such as dynamic real-time charts and the integration of websites through a built-in web browser element.

The second part, which is implemented by the researcher, is the *bio sensors*. This optional part is used to integrate support for various bio sensors into the platform. To facilitate the integration, the platform provides a general framework for handling bio sensors, which can be adapted by the researcher when integrating support for his or her specific bio sensor. This general bio sensors framework provides functionalities for a centralized control in order to manage and operate all connected bio sensors simultaneously—especially useful in experiments with multiple subjects. These provided functionalities include starting and stopping data recordings, defining storage strategies, and monitoring the bio sensors' connection and overall data quality. As a result, using bio sensors in lab experiments becomes less time consuming, since bio sensors do not have to be setup or monitored individually. In addition, the recorded data is available instantaneously within the platform and can therefore be included into the experimental design itself, e.g., by using physiological data to create a real-time biofeedback element in the user interface.

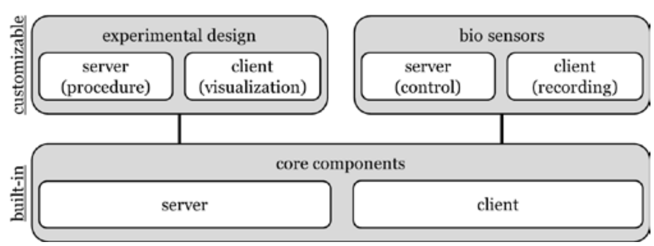

Figure 1. Basic platform architecture

Demonstration

Next, as part of the demonstration, and to observe how well the developed artefacts solve the above mentioned problems better, we present two use cases that were implemented using the proposed platform. Use case (1) implements a single-subject auction experiment, whereas use case (2) implements a multi-subject auction experiment. Both experiments were conducted with different sets of bio sensors.

Use case 1: Measuring interplay of emotions and workload in auctions.

This use case is an auction experiment on 54 subjects wherein subjects' brain activity was recorded using a 32-channel electroencephalograph (EEG) along with their electrocardiogram (ECG) and skin conductance (SC) data. The platform enabled the interaction between each subject and 2 computer opponents in different auction types and conditions, namely ascending and descending auctions. The aim of the experiment was to understand how the IS constructs (arousal and workload) are influenced by the auction types and conditions, and how they in turn impact subjects' bidding behavior. By means of the platform, events of interest (such as information events, placing of bids, outcome, and regret information) were logged directly to the database along with client and server timestamps. Synchronously, triggers were added from the Java™ interface of the platform to the EEG data through suitable Java™ wrappers to perform system-level calls, and transmit the event trigger via parallel port, along with the timestamp information. In parallel, heart rate and skin conductance data were transmitted over Bluetooth, and stored on the local client.

Use case 2: Investigating the influence of auction fever on bidding behavior in auctions.

The second use case was conducted with a total of 216 subjects where ECG, SC, and plethysmography data were recorded. During this experiment, nine subjects at a time competed in groups of three in multiple ascending auctions. For each auction, groups were automatically re-matched to achieve a perfect stranger matching. Before the experiment started, all subjects had to successfully complete a questionnaire on the experiment's instructions in order to ensure that they understood the upcoming events. Using the platform's built-in questionnaire capabilities, the experiment was set to wait for all subjects to complete the questionnaire and only then continue with the actual experiment. Next, subjects could choose an individual name and picture, which later was used in the experiment to show subjects their current competitors in the user interface. By choosing and implementing a between-subjects design, the experiment had a 2x2 full-factorial treatment structure. Using the platform's session manager, the sequence of treatments was set, such that all treatments were conducted equally often and that they were properly distributed over time to avoid, for example, time-of-day biases. The recorded events of interest were similar to those of use case (1), e.g., the placing of bids and the auction outcome, in addition to the simultaneously recorded bio sensor data. Due to the high amount of data produced by the bio sensors during an auction, the data was first stored on each local client and then was moved automatically to a central storage location after all auctions were completed.

Evaluation

The initial evaluation of the presented platform shows that the experiments in both use cases were programmed with ease, conducted successfully, and enabled easy data handling post-experiment—hence, indicating the potential of this NeuroIS platform.

Also, the platform meets the previously defined objectives. Creating an experiment is less time consuming, since the necessary basic building blocks are already provided, and the well-known and widely available programming language Java™ is used for implementations. Researchers therefore can focus their attention on the design and calibration of their experiments, rather than spending time and effort on re-developing generic and existing software solutions, e.g., client-server communication. This provided client-server communication in particular allows researchers to create experiments where subjects can not only act individually, but also interact in group or market experiments with no additional overhead in the implementation. In combination with the integrated bio sensor functionalities, the platform facilitates measuring and logging of physiological data as well as context data of the conducted experiment. All this results in less effort spent for the collections, cleaning, and preparation of data, which reduces data errors and provides more time for the statistical analyses of interest. At the same time, since the platform is an open-source software project, any researcher can adapt the platform to meet new emerging requirements in his or her respected domain of research.

Additional evaluation was provided by presenting the platform to members of various departments at the Karlsruhe Institute of Technology (KIT). Thereby, valuable feedback was provided and incorporated into the implementation of the platform. As a consequence, two upcoming studies now use the platform to implement their experiments, one study in the area of telecommunication markets and one in the area of risk management.

Communication

The platform will be distributed as a pre-compiled version for instant use, where the application can be started either as a client or as a server, as well as a version including a ready-to-use development workspace for easy access to own implementations. The source code will be available as a version controlled repository, which can be downloaded, modified, and used to include community feedback, such as bug-fixes and new features. As examples, three implemented sample experiments will be provided. In addition, tutorials will be made available in the form of sample sensor setups, documentation of the architecture explaining core concepts, and documentation of source code where necessary. Technical support will be provided through commonly used tools, such as issue trackers and forum discussions. Finally, the importance of the artifact, its usefulness and originality, as well as several aspects of the design and architecture will be communicated through scholarly research publications.

Contribution

The presented platform serves as a stable prototype to implement experiments involving physiological measurements and strategic interactions. Following an iterative design science process, the next steps are to examine the existing requirements critically and redefine new ones, where necessary. Based on these, the available features will have to be further developed, incorporating feedback from NeuroIS researchers, and cater to the needs of a broader community of researchers to use the platform for their studies.

Finally, the presented software platform facilitates the conduction of NeuroIS lab experiments, which hopefully inspires researcher to employ NeuroIS experiments.

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