Synchronized Communication and Coordinated Views: Qualitative Data Discovery for Team Game User Studies

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Abstract
We present a tool for qualitative data discovery that aids researchers in analyzing synchronized log data with audio collected from multiple computers. The tool was originally developed for team games in which the goal of play is to exercise coordination skills. In team coordination games, players cooperate toward a shared objective by communicating effectively and synchronizing their game world actions. To evaluate such games, researchers observe communication between players synchronized with their actions in-game, discovering instances of team coordination. Coordination is a composite of communication and in-game action; thus it is essential to observe both in context. The tool enables simultaneous observation from each player's viewpoint, synchronized with communication using log files and time-stamped audio. Viewpoints and voice tracks can be selectively soloed and muted, enabling researchers to focus attention. The application can be expanded to support logs and audio from other user studies.

Keywords
Qualitative data discovery, data synchronization, research tools.

ACM Classification Keywords
H5.2. Information interfaces and presentation: User Interfaces: Evaluation/methodology.

Introduction

Discovering informative qualitative data from user studies is difficult. This problem is compounded when multiple participants are interacting. The data is a composite both of vocal utterances and interaction through the application. Understanding situated contexts requires examination and comparison of multiple sources of data for each participant. We need tools that synchronize the resulting data streams, and allow manipulation of coordinated views.

Based on our user studies with a game for teaching team coordination, we present the Coordinated Log + Audio Playback System (CLAPS) that synchronizes audio tracks from each participant with the view from each participant's perspective in the application. In the case of team coordination games, this approach enables discovery of events where team members are working together effectively. Such observation is performed holistically, unlike prior log playback mechanisms [1]. CLAPS uses data feeds that are, by necessity, recorded on separate machines and merged offline, making it impossible to use elegant analog recording for synchronized data capture [6]. The data files supported by the application are XML for log data and WAV files for digital audio; the application can easily be expanded to support other types of studies that provide XML logs and WAV audio files.

This paper explains our motivation for designing CLAPS and the design of the team coordination game for which we originally designed the application. We briefly describe the types of data collected from user studies. We then provide an explanation of the design of the application, and a case study from our data analysis, validating the design. We conclude by considering future work.

Motivation

One goal of this research is to engage participants' team coordination skills by requiring that they work together and share information in ways that reflect team coordination in practice [8]. One telling sign of improved team coordination skills is the emergence of *implicit coordination*, where team members work together with little or no communication [5]. Implicit coordination is advantageous in practice because it reduces the amount of communication within the team, conserving resources. One way of discovering implicit coordination is through qualitative instances where team members are productively working together with minimal communication.

We originally conducted analysis of our user studies by manually loading the audio into an audio playback application and listening to players' audio tracks. However, the analysis is weakened by the lack of context. There are occasions in which the players' conversations are situated in context, such that an accurate meaning cannot be inferred without seeing the game states associated with an audio exchange. While this is possible with an earlier tool that only played back the game log (without audio), the cognitive load is formidable. It requires calculating an offset time into the game from the audio playback position, loading the

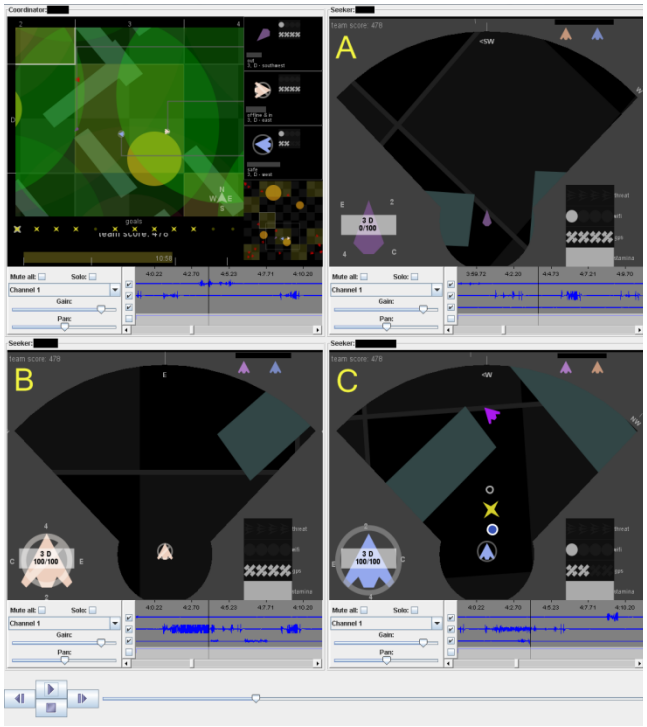

Figure 1. CLAPS interface. The split screen shows the coordinator's interface (upper left), and the interfaces of the three seekers in the game. Log playback controls are at the bottom, with audio controls for each player under their view. Player names have been blacked out to protect their identities and letters added to the seeker interfaces to identify them.

separate application, and finding the desired position within the log. Continuous comparison is not possible with this method.

We found that maintaining a mental model of the game state while listening to the audio was cumbersome, distracting from the communication of the players. By developing this tool, we aim to reduce the cognitive load for the researcher so that s/he is able to analyze study data more thoroughly, without the overhead of forming a mental model of the in-game situation from only the audio.

In the present research, participants play a game in which information is divided up between team members, requiring participants to communicate and work together to succeed. Some team members, *seekers*, move avatars in a game world, searching for goals and avoiding threats; these players have a detailed local view. Some goals require multiple seekers to come together to collect them, encouraging them to synchronize their actions. Another team member, the *coordinator*, observes the game world globally with reduced detail, and communicates with the other players. This research aims to build a location-aware game, in which players are moving around outdoors and communicating (either face-to-face while co-located or using radio when distributed). In its current form, the game is played at computer terminals, and experimental conditions have players co-located or distributed (altering their communication modalities).

Data Collection

Due to the distributed nature of play, recording all data centrally using analog methods for synchronization would be cumbersome. In future, location-aware versions of the game, seekers will be distributed throughout a real-world environment with wirelessly networked mobile game clients, making central recording impossible. It is thus necessary to record data on individual computers, and re-construct a coherent, synchronized record of user study events.

Each game state frame is recorded on the game server in an XML file at 10Hz. Program objects (the state of the game) are translated to and from XML using the `ecologylab.xml` information binding framework [3]. The game state consists of the location and heading of each seeker's avatar, as well as the condition and location of every object in the game world. As the game is transitioned into a location-aware version, mobile clients in the field may temporarily be disconnected from the game server; thus, game state will also be recorded on individual clients, ensuring a complete log. All game state frames are marked with an ordinal frame index that is counted on the server.

Multi-track audio is recorded for each participant using a wireless headset and a Pure Data patch [7] at 8000Hz. One track records every utterance from the player, another records all of the radio sounds the player hears, and a third records all of the game sound

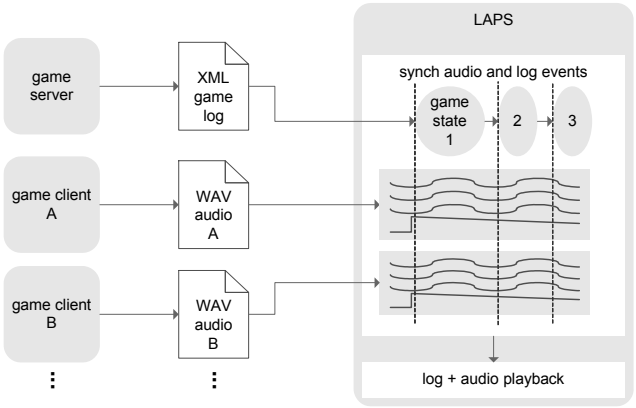

Figure 2. Flow of data from user study application (team game) through CLAPS.

effects. A fourth track, the synch track, records a sample value corresponding to the current game frame index, in a manner similar to using SMPTE timecode for synchronizing video and audio frames [2].

Using the synch track and the game frame index from the server log, it is possible to reconstruct the synchronized audio and game perspective of each player.

Coordinated Log + Audio Playback Design

Our highest priority in the development of CLAPS was the ability to view the log playback synchronized with audio records, and provide an interface that makes it easy for researchers to discover qualitative data events within the data from user studies.

Using the audio synch track and game information in the log, we find the point in each record at which gameplay begins (**Figure 2**). This point serves as an offset into the record, and is used as a reference to compute elapsed time within the record. Once this has been determined, we let the audio play at the rate given by the audio format and check periodically against the offset time into the log in order to update the current game state display to a time that matches the position in the audio. The audio record is used in this manner to preserve the quality of the sound, which is the data source with the highest sample rate.

The split screen interface shows the view for each player, as well as controls for the audio for that player (**Figure 1**). We provide the option of focusing on only one view by making it full screen (**Figure 3**, **Figure 4**). This significantly reduces the visual complexity of the interface and allows the researcher to focus on a single player. Playback controls at the bottom allow the researcher to randomly access both audio and game state with a playback scrub bar, as well as play, pause, step-forward, and step-back buttons.

Audio Interface

We present the researcher with an interface to the audio records for each player. This interface includes a zoomable waveform representation of the participant's three audio channels (personal voice, radio, and game sound effects). This allows the researcher to verify the origins of individual utterances, as distinguishing them can be difficult while listening to several different audio sources. The waveform also enables the researcher to anticipate upcoming audio activity.

The audio interface allows the researcher to solo or mute all audio for each player, mute specific channels, and control the balance and pan for each individual channel. The researcher is then able to configure audio playback in any manner s/he chooses. This allows the

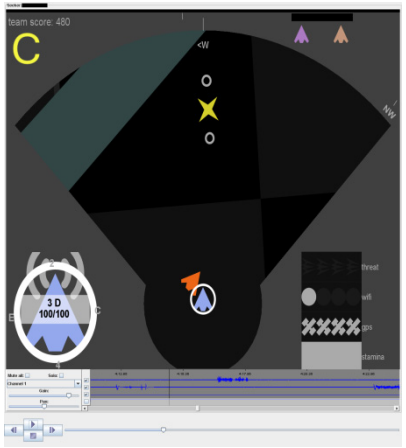

Figure 3. C requests that B help him collect the goal.

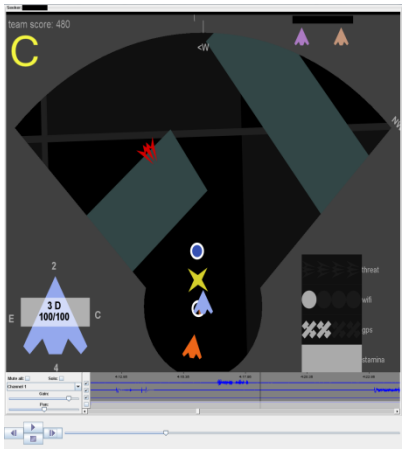

Figure 4. C and B collect the 2 player goal together.

creation of an audio mix that facilitates discovery. For example, when two players are carrying on a conversation, the researcher can slide one player's audio to the left and move the other to the right. Thus, spatial separation of the audio enables the researcher to distinguish the two audio streams easily.

Coordinated Viewpoint Visualization

We present a coordinated visualization of the team's game experiences. This is a recreation based on the game log of what each player saw while playing the game (**Figure 3**, **Figure 4**). Each player's visualization is a different view into the same game state. Together these coordinated views present the researcher with the vantage that was experienced by each participant. For the coordinator's view, the visualization is interactive, allowing the researcher to pan and zoom the global view of the game. For each seeker's view, the researcher sees exactly what was displayed to the player. The code that visualizes the log is the same as that used for the game. Due to limited screen space these views must be scaled. In order to preserve content, this is done so that that a view of the original size is scaled to fit within the available space.

Extensibility

CLAPS uses the `ecologylab.xml` information binding framework to read in XML log files [3]. Due to its flexibility, is it possible to read in a wide range of log files, given a specification for how to bind the XML to Java classes (known as a *TranslationScope*) and code for rendering game states. The rendering code for log playback can be the same as that used originally in the application that produced the log, maximizing code re-use. Writing the sequence of game state indices into the audio file as a synch track is straightforward.

Consequently, we expect that CLAPS will be easily repurposed to support other user studies of collaborative work and/or play.

Discovering a Qualitative Data Event

We used CLAPS to analyze data from a user study of our game for teaching team coordination. We discovered instances of emergent team coordination among participants that would be impossible to see without the tool.

During their final session, members of Team 3 (T3) exhibit implicit coordination. T3 is playing in the experimental condition in which all players are separated, communicating using radio. Near the beginning of the game, all three of the seekers' avatars are co-located in the game world. Two of the seekers (A and C) discover a cooperative goal, but A is attacked and is unable to assist in collecting the goal (Figure 1).

The remaining player, C, notices that B is nearby, and makes the request: "B, want to get that two-man real quick?" (**Figure 3**). B does not respond audibly to the request, but instead walks to the goal. C joins him, and the two collect the goal successfully (**Figure 4**).

The discovery of this instance of implicit coordination helps validate the game design, but is difficult to detect without CLAPS. Both player communication and in-game action are essential to understanding and discovering the event. With audio only, the utterance asking about the goal appears to be an unanswered question. With the game log alone, the goal collection lacks communicative context. The synchronized communication and coordinated views of CLAPS enable discovery of the data analysis picture.

Conclusion and Future Work

Discovering informative qualitative events from user study data is a time-consuming and difficult process. Researchers must observe multimodal data streams in multiple applications from multiple participants to mentally construct a coherent picture of what participants saw, did, and communicated. We have described an application that combines data streams from different sources, synchronizes them, and presents them to the researcher through a unified interface of coordinated views. This log playback application led to the discovery of significant qualitative data in a team game user study.

While analyzing records of team coordination games, it is essential that different records (game play and audio communication) be reviewed in a coordinated manner, so that significant non-verbal portions of communication are not missed and so that context can be understood. Without a synchronized representation, context and implicit coordination between players is lost. An application that simultaneously presents all the records of the game is a necessity.

We are continuing development of CLAPS, as our research of the team game is ongoing. We plan to incorporate other features into our log playback application, such as the ability to author annotations of the logs so that researchers can mark significant events. Because the game software automatically indicates when game-significant events occur, such as when a seeker is attacked or when one or more seekers collect a goal, these events will be made browsable. The time preceding these events is often characterized by interactions that contain interesting data, which researchers need to see and understand in order to discover significant qualitative data [1].

We plan to expand the framework for other applications, including a mixed-initiative creativity support tool [4]. The benefits gained through CLAPS are desirable during the analysis of other user studies, in which participant utterances need to be synchronized with application log playback for in-context observation.

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